LOGISTIC ASSISTANCE SYSTEMS FOR DECISION SUPPORT IN COLLABORATIVE SUPPLY CHAIN PLANNING AND CONTROL

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ABSTRACT
Global market changes and new business strategies have changed logistic processes. Today complex supply chains contain numerous manufacturing levels with long transportation distances. Effective planning and control have to follow various objectives like cost reduction, flexibility and ecological target values. Several supply chain management (SCM) concepts have been developed to support these challenging collaborative planning processes. For a successful implementation they all require software support. As will be shown in this paper existing solutions cannot offer a sufficient collaborative focus on supply networks and at the same time features for supply chain planning. This paper introduces logistic assistance systems (LAS) for decision support in collaborative supply chain planning and control. Designed as lean software systems, LAS focus on specific process parts and integrate selected methods for data management, information processing and supply chain planning. First achievements with LAS at Volkswagen AG are now followed by two new promising projects.

Keywords: logistic assistance system, supply chain collaboration, supply chain simulation, decision support system

1. INTRODUCTION

A progressing globalisation is challenging logistics and companies that cooperate as partners in a supply chain. Purchase parts are sourced globally and new production facilities on different continents have to be supplied. This results in global multimodal supply chains with long transport times, increased handling, numerous customs checks and the involvement of multiple service providers for transportation. Due to large geographical distances, a high number of process steps and numerous involved actors, supply chains sustain extended lead times and reduced flexibility to respond to process changes like new demand situations. Demand variation induces either supply shortfalls or high inventory levels, both causing additional costs (Deiseroth, Weibels and Toth 2008). Nevertheless global sourcing and the relocation of production sites can only be efficient as long as the logistic costs do not exceed the expected savings through lower production costs.

In addition to the mentioned attributes of multimodal supply chains external risks like supplier insolvencies, transport damage or transport delays due to customs checks, strikes, bad weather conditions or accidents are also responsible for an increased complexity and difficulty of managing global supply networks. (Wyk and Baerwaldt 2005)

These internal and external characteristics conflict with logistic targets and important competitive factors like short service times and high delivery reliability. To reach high delivery reliability, avoid supply shortfalls, utilise the left flexibility and enable short service times in those complex supply networks, methods and processes for an effective joint planning and control are required. To gain benefits for all, supply chain partners have to act in collaborative decision processes. (Kuhn, Hellingrath and Hinrichs 2008)

Collaboration in supply chains focuses on joint planning, coordination and process integration between organisational departments, customers, suppliers and other partners like logistic service providers. In order to optimise an entire supply network and not just to create local and often competing optima the involved actors have to communicate and jointly make supply and demand decisions. This way they can reach sustainable benefits like cost reductions, increased reliability and responsiveness to market needs (McLaren, Head and Yuan 2002). As a result collaboration becomes a necessary requirement for a comprehensive and successful SCM.

To work together the different actors have to define and follow joint objectives, share proprietary data and process information, and trust each other. Often a lack of trust between the different actors avoids successful supply chain collaboration (Barratt 2004; Ireland and Bruce 2000). To face this problem it is necessary to involve all relevant actors along the supply chain for defining a collaborative process and show the benefits for all partners (e. g. Dudek and Stadtler 2004). To implement a manageable process information technology is an essential enabler for a collaborative relationship across the supply chain. (Mentzer, Foggin and Golicic 2000)

For logistics and SCM the developments towards complex global multimodal supply chains also result in a higher importance of ecological efficiency which has become a new logistic target (Meißner 2008; Fleischmann 2008; Souren 2000). Growing geographic distances and a rising number of manufacturing levels result in higher demands of transportation resources. A rising number of transports with truckload, sea freight an air cargo leads to higher greenhouse gas emissions. Recently these impacts have been a main topic in political, cultural, economical and especially ecological discussions. This growing importance is mainly driven by the increasing deterioration of the environment (Srivastava 2007). Defined thresholds for specific types of transportation vehicles and a certificate market for carbon dioxide emissions (CO_2 emissions) are just two results of those discussions. For this reason ecological key performance indicators (KPIs) like CO_2 emissions emerge as relevant objectives for decision processes in supply chain planning and control.

To support collaborative planning, control and decision processes in complex global multimodal supply networks considering economical and ecological logistic targets, network partners have to apply logistic concepts supported by IT systems. Those software applications have to provide all relevant information along the supply chain and present it to the responsible experts and planners. The setup of accountabilities in the network and the way information is processed can only be determined individually for each case, according to the requirements of the given process and respective logistic concept. This also applies to the selection of methods and IT technologies used in the software system. As will be shown later, existing software solutions cannot offer all features needed for an effective supply chain planning and control.

Logistic Assistance Systems (LAS) can provide those features. They are designed as lean software systems and focus on specific process parts and integrate selected methods for data management, information processing and supply chain planning. How these LAS can be used and designed in practice and which requirements they have to meet is a current research question. (Kuhn, Hellingrath and Hinrichs 2008)

This article contributes to this topic and starts with summarising and analysing requirements of balancing between logistic targets, typical planning situations in global multimodal supply networks and existing SCM concepts (section 2). In section 3 the focus is set on existing software approaches for SCM, showing that they can not fulfil all requirements of collaborative planning and control in global multimodal supply networks. In section 4 the concept of LAS is outlined, in section 5 a prototypical implementation of a LAS application is described. A conclusion and prospects are given in section 6.

2. REQUIREMENTS OF SCM TO INFORMATION TECHNOLOGY

This section is structured into three parts. First it will be shown that in today's corporations the main targets of logistics can only be balanced with effective usage of information technology (2.1). Then typical planning challenges in global supply chains are outlined (2.2) and major SCM concepts are presented, focussing on their requirements to IT support (2.3).

2.1. Balancing Logistic Targets

According to the mentioned logistic focus to supply a demand with the right product and the right quantity and type, at the right time, in the right place with the right costs LAS focus on all parts of the order process of an enterprise (Kuhn, Hellingrath and Hinrichs 2008; Plowman 1964). The logistic targets in this context can be divided into economic, performance and ecologic objectives (Fleischmann 2008). The economic objectives aim for targets like high machine and transport unit utilisation and a low capital commitment. The performance objectives aim for targets like high supply flexibility, high adherence to delivery dates and high service standards (Kuhn, Hellingrath and Hinrichs 2008). As shown before recent socio-political and industrial ambitions are the reason for a rising number of 'green logistics' concepts which aim for ecologic values like reducing carbon dioxide emissions or resource consumptions (Meißner 2008; Souren 2000).

Nickel and Vogel state that an effective IT system is needed to position an enterprise in between its conflicting logistic objectives (Nickel and Vogel 2006). Deiseroth, Weibels and Toth show that for an optimal decision process current and future process data is needed which can only be offered by an IT based software system integrating methods for forecasting, e. g. simulation (Deiseroth, Weibels and Toth 2008). Kuhn, Hellingrath and Hinrichs point out that a balance between those concurring objectives can only be reached, when decision processes in global multimodal supply chain planning and control are either partly or totally supported by LAS (Kuhn, Hellingrath and Hinrichs 2008).

2.2. Planning Situations in Global SCM

Typical planning situations in global multimodal supply networks arise from short conditions like short-term fluctuating customer demands, short-term order changes or supply shortfalls.

Fluctuating customer demand results in unsteady demand for parts that are purchased from suppliers. With every additional manufacturing level uncertainty for demand planning rises. Global multimodal supply networks often have multiple manufacturing levels which lead to extended lead times, great geographic distances and difficult planning situations at the last level of supply chains. Extended lead times also mean extended times for customer orders and a reduced flexibility to respond to fluctuations. This results in long-term planning periods for all levels of the supply chain. Information about the customer demands has to be shared over all levels as fast as possible to reach the best possible planning situation. If information is not running fast or only by the reaction of one manufacturing level to the next by showing the current demand, the 'bull-whip' effect occurs. That means that demand variation rises along the supply chain and with it inventory levels rise or drop and cause a high capital commitment or supply shortfalls (Fransoo and Wouters 2000). A collaborative planning based on information transparency in a supply network can avoid these impacts.

Short-term order changes by end customers have large impact on a supply network. This especially applies for products with a great variability. Here, order changes can result in an unchanged production volume on the one side, but in short-term changes for the demand of production parts on the other side. For some parts demand turns out to be much higher and for others a lot lower. To manage these order changes businesses can provide higher safety stock levels for the affected product parts, reduce supply chain lead times and try to reach high supply chain flexibility. As has been shown global multimodal supply networks are characterised by external lead times and reduced flexibility. Since high safety stock levels conflict with economic logistic targets businesses try to use the remaining supply chain flexibility to answer capable-to-promise (CTP) requests. With those the question if a certain demand of a product or product part is available at a certain time can be answered. In contrast to available-to-promise (ATP) requests not only the bills of materials, local production capacities and inventory levels are considered (Zhao and Ball 2005) but also supplier production capacities and their inventory levels. This way information about local and supplier production capacities, transport times and inventory levels of all levels of the supply chain including all parts in transit can be used for an effective collaborative planning to reach delivery reliability and answer CTP requests. In coordination and synchronisation processes supported by calculations all possibilities and scenarios to avoid supply shortfalls can be considered.

Supply shortfalls can result from low demand forecasting accuracy, quality problems, transport damage, loss, incorrect data about inventory levels, or external effects. For early identification of upcoming supply shortfalls forecasts on production demand, inventory levels, supplier production capacities and transport times are needed. Using this information an early identification of supply shortfalls can be reached by applying calculations and defined thresholds. This enhanced collaborative planning depends on consistent and up-to-date supply network information. If a supply shortfall cannot be avoided by an improved planning process with integrated methods for answering CTP requests, business partners still can initiate activities like additional transports, extra working shifts or using additional machines. For an effective planning of all of these activities it is necessary to exactly know how many additional product parts can reach the location of demand in which time and for which expenses. With sufficient relevant information about the supply network different scenarios can be calculated or forecasted.

The described planning situations show that in every case specific consistent and up-to-date information from all relevant business partners are needed. They were described as single planning situations but in practice they can occur in the same processes at the same time and this way can have interdependencies. For all described planning situations information transparency about the current process status and methods for calculations and planning are required. The information and results have to be presented to the decision makers and experts.

For an effective planning in SCM various concepts and methods have been developed and published in literature as will be shown below.

2.3. Concepts and Methods for SCM

Since its appearance business logistics has developed from principles about efficient supply into a very comprehensive approach. SCM and subordinate concepts have emerged, addressing all levels from strategy to operations, as illustrated in figure 1 (Baumgarten 2008).

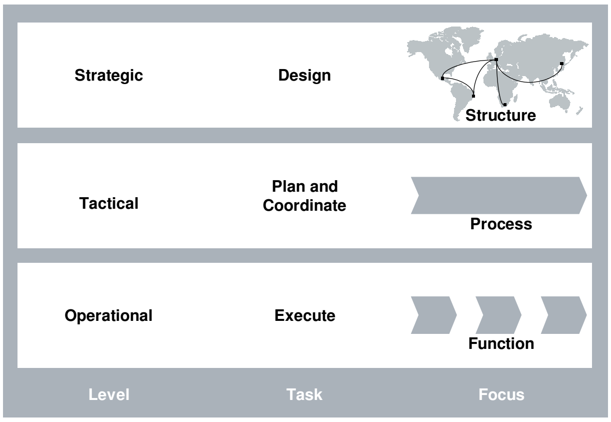

Figure 1: Scope of SCM (Baumgarten 2008)

Focusing on the customer and synchronising supply and demand, market needs should be met flexibly while stock levels are reduced (Kuhn and Hellingrath 2002). Among other things SCM includes the coordination and collaboration of the supply chain partners (CSCMP 2009). For a successful implementation of these concepts information and communication technology is essential.

One comprehensive approach which addresses the strategic, tactical and operational level is called collaborative planning, forecasting and replenishment (CPFR), a concept that identifies certain supply chain processes as being collaborative tasks, which means that they should be planned together by the supply chain partners. Having relevant information available is a precondition for effective collaboration, therefore a CPFR implementation should be supported by information technology. This can either be realised by one single CPFR application with centralised data management or through individual applications which can communicate via standardised interfaces like XML or EDI. (VICS 2004)

Visibility over the current state of the supply chain is an essential requirement for planning tasks on the tactical and operational level. The concept of supply chain monitoring (SCMo) supports supply chain partners by exchanging information about inventory and demand. This transparency should prevent stock-out and oversupply situations and optimise allocation in case of a bottleneck. For establishing visibility SCMo applications need data from the companies' back-end systems. (Odette 2003)

Access to relevant information is a very important precondition for collaborative demand and capacity planning (DCP) as well. Aligning the partners' production capacities with demand, DCP aims to avoid both capacity shortfalls and under-utilisation of capacities. A DCP process regularly checks if capacity is in line with demand, therefore DCP applications need data from the partners' back-end systems as well. (Odette 2004)

On the operational level the concept of supply chain event management (SCEM) aims to support the execution of agreed plans by automatically identifying unacceptable deviations and suggesting alternative solutions. A SCEM system should offer five basic functionalities: Monitoring, alerting, simulate, exception handling and measure. Monitoring and alerting are the core functions that a SCEM application has to offer. Therefore it needs status information from enterprise resource planning (ERP) and tracking systems, which then are processed and visualised. The other functionalities can be provided by other tools or components. (Hegmanns, Hellingrath and Toth 2008)

All concepts mentioned above have in common that reliable information about the supply chain is needed. It has to be collected, processed and presented by IT systems to support collaborative decision processes. Depending on individual requirements of specific planning situations in different supply chains, some elements of SCM concepts, like the ones mentioned above, are needed. In the following, existing software solutions are analysed to what extend they can support decision-making in collaborative supply chain planning.

3. EXISTING SOFTWARE SOLUTIONS FOR SCM DECISION SUPPORT

As previously shown an effective supply chain planning and control can only be done in collaborative decision processes and all mentioned concepts need software support that fulfils a number of assumptions. To support numerous business partners in a supply network with relevant and consistent data for collaborative planning and control, information about the current process like inventory levels, supplier capacities and production demand, have to be provided. Thus information asymmetries can be avoided. As shown above global and multimodal supply chains are often very complex and underlie fast and dynamic changes. Those characteristics determine that adequate software applications for decision support in SCM have to be very flexible to give sufficient possibility to readjust them to a changed process of the supply network. In addition to that smaller process changes (e. g. altered part numbers due to validities) should be integrated automatically by processing data from preceding operational systems. Further categories for the evaluation of supply chain decision support systems are: user interface capabilities; desired analytical tools like optimisation and simulation; methods for information presentation like reports, dashboards and tables; hardware and software requirements; compatibility for integration with existing systems (Simchi-Levi, Kaminsky and Simchi-Levi 2000).

In the past a great number of decision support systems focusing logistics and SCM concepts have been developed and vary from flexible mainframe systems, over isolated PC tools and client/server processes to high-performance and extensible enterprise decision-support applications (Simchi-Levi, Kaminsky and Simchi-Levi 2000).

In the following business intelligence (BI) technology for information analysis and processing and three major types of relevant existing software solutions for decision support in SCM will be analysed: advanced planning and scheduling (APS) systems; supply chain simulation (SCS) systems and SCMo systems as one example for a solution that focuses on a specific SCM concept. BI systems focus on consolidation, preparation and analysis of information for decision support of experts and executives. APS systems are optimisation-based modular extensions of ERP systems that focus on planning in SCM. SCS systems enable enterprises for strategic planning by using simulation studies and scenarios. As follows all concepts integrate some excellent methods for decision support, information processing and advanced planning but cannot fulfil the specific assumptions for the collaborative management and planning of high dynamic and complex supply networks.

3.1. BI Systems

The first concepts of BI systems have been developed in the 1960s, starting with management information systems and were used for decision support for executives. With progresses in IT development and growing areas of applications further concepts followed (e. g. decision support systems and executive information systems). Today they are all known as management information systems and usually integrate graphical user interfaces, functions of exception reporting and various standard interfaces to operational standard software systems. Today they support executives and experts in decision processes (Chamoni and Gluchowski 2006). Typical exception reporting functions are visual effects (e. g. markings or traffic lights for exceeding specific thresholds), instant messages (e. g. by e-mail, pop-up window or short message service) and drill-up and -down for the aggregation and detailing of data (Zwerenz 2006). Systems with integrated concepts like data warehousing, online analytical processing (OLAP) and data mining are called BI systems. A data warehouse is a central and consistent database which obtains comprehensive data from other operational databases. It is used for data integration and analysis (Navrade 2008; Chamoni and Gluchowski 2006). Systems that integrate OLAP are usually based on multi-dimensional data storage and enable complex analytical and ad hoc queries with rapid execution times (Kemper, Mehanna and Unger 2006). Data mining makes it possible to identify unknown data structures and performances by data analysis (Chamoni and Gluchowski 2006; Gluchowski, Gabriel and Dittmar 2006). The additional integration of pivot tables gives users the possibility to manually analyse table data by creating cross tables or by automated sorting, counting or totalling (Zwerenz 2006).

Today BI systems are standard software systems which usually will be customised for the implementation in single enterprises of all business sectors. Since they usually do not integrate methods for forecasting and collaboration the solutions are not set up for planning and control in global supply networks integrating multiple network partners. Since they do not focus on planning they also lack the functionality to integrate expert knowledge and master data for a model-based representation of the supply network.

3.2. APS Systems

The first ERP systems were released in the 1990s (Al-Mashari 2002). Today they integrate almost all operational core functions of any type of enterprise (e. g. accounting or material planning). As modular based and customised standard software systems they support and contain inter-departmental processes and functions (Betge 2006). Usually ERP systems integrate a single and central database that contains the data of all software modules. APS systems are additional modules of ERP systems for forecasting and supply chain planning and were published in the mid 1990's for the first time. Typically APS systems cover the areas demand planning, supply planning and manufacturing and scheduling (Simchi-Levi, Kaminsky and Simchi-Levi 2000). Usually they are based on optimisation procedures or industry-sector-specific planning methods based on mathematical algorithms (Stadtler 2004).

The successful integration of an ERP system with an additional APS module requires complex process analysis and adjustments and high expenses for license fees and customising. The customising can only be done within the limited flexibility of the ERP system structure. In addition to that ERP systems with APS modules often have high hardware requirements especially for servers and fast connections for data transfers, both causing further expenses. Especially an inter-organisational linking-up and collaboration are main challenges to APS systems (Betge 2006). Betge shows that a production stage planning for the whole or parts of the order to delivery process with the integration of multiple network partners cannot be supported by APS systems sufficiently (Betge 2006). The needed inter-organisational supply chain integration for supply chain planning and control cannot be accomplished with APS systems.

3.3. SCS Systems

For strategic decision support enterprises often use SCS systems. With modelling the entire or just specific parts of the supply network and processing simulation studies they can reach valuable support for strategic decisions. Usually SCS systems are used prior to the execution of a plan or in irregular intervals to verify a given or planned situation. This way various benefits can be reached: Understanding of supply chain processes and characteristics; capturing system dynamics (using probability distributions gives the possibility to model events and analyse the impact of those) and testing alternatives with simulation scenarios (Chang and Makatsoris 2001). For daily operative use network partners would need a simulation-based real-time system to monitor the network status and make decisions. Therefore an organisation needs to offer a number of capabilities: interfaces to legacy databases to obtain information; hardware and software for short-time simulation runs; interfaces to operative systems to assign tasks and receive feedback (Chang and Makatsoris 2001). Available SCS systems and technologies can offer the flexibility to automatically integrate smaller process changes by using data from operative systems.

Since SCS systems usually do not provide graphical user interfaces with comprehensive methods for information and presentation simulation results of those dynamic systems usually have to be integrated into secondary systems to be analysed and presented for decision support. The same applies for the execution of decision results which is usually done in additional operative systems. Missing concepts for collecting, evaluating and presenting data, SCS systems also lack functionalities to provide information transparency to experts and decision makers.

3.4. SCMo Systems

As mentioned above SCMo is a collaborative multi-level SCM concept that needs software support for processing information between network partners (Odette 2003). These software applications are known as SCMo systems. Their basic function is the exchange of production demands and inventory levels between business partners in supply networks to reach information transparency and avoid time lags in information flow. This data will be processed by comparison between present and future production demands and inventory levels. Depending on the results of the comparison and defined thresholds, automatic alerts (e. g. by sending a message or traffic lights on a dashboard view) will inform experts if inventory levels are out of range. By cumulating the inventory levels over the whole supply chain and considering the demands of the last business partner in a supply chain demand solutions for the 1^{st} to n^{th} tier can be calculated (Odette 2003). With this advanced functionality the bull-whip effect can be avoided and a smooth and secure supply chain with low inventory levels is supported. For SCMo applications interoperability, scalability and technical robustness are the main technical requirements. Full interoperability can be reached when every business partner in a supply network can choose one application, depending on their specific needs. Standard interfaces can provide the flexibility for information exchange between different systems (Odette 2003). Recent developments in SCMo applications integrate Supply Chain KPI and assortment of graphical tools (e. g. predefined charts, cockpits or dashboards) for information presentation (Bäck and Gössler 2006). Typical KPIs that can be found in SCMo applications are forecasting accuracy and range of material (Hegmanns, Hellingrath and Toth 2008).

SCMo systems provide all functionalities for monitoring the current process status of a supply chain or network but they miss methods for forecasting and planning like optimisation and simulation.

3.5. Insufficient Existing Software Solutions

As shown above the analysed system technologies and methods cannot integrate the entire functionality of providing information transparency for supply chain control, forecasting for supply chain planning and executing for decision processing. The high complexity and fast dynamics of supply networks, the process specific supply chain structures and the integration of global network partners for collaboration require lean and affordable software systems that can offer comprehensive and process specific software functionality. The potential methods of BI technology, APS systems, SCS systems and SCMo systems should be chosen and applied as required in given process. Considering the mentioned planning situation an optimal software solution has to combine parts of the described IT concepts: The data collection and evaluation can be supported by methods of BI systems, an optimal information presentation for supply chains can be provided by concepts of SCMo systems and for forecasting and planning methods of APS or SCS systems can be used.

4. LOGISTIC ASSISTANCE SYSTEMS AS A NEW SCM SOFTWARE STANDARD

This section introduces LAS as a paradigm for the development of flexible, lean and specified software systems that can be applied to all parts of the order process of a manufacturing business and have a special focus on decision support in supply chain planning and control (Kuhn, Hellingrath and Hinrichs 2008). Focusing on global multimodal supply chains they can give multiple benefits to all involved network partners.

Subsection 4.1 presents the basic idea of LAS, illustrates the main characteristics and functions and shows which concepts and methods can be used for supply chain planning and control and ends with a concept definition. After that, the different possible areas of application are described (4.2) and potentials and limits of LAS are shown (4.3).

4.1. LAS as Specified Software Solutions

The basic idea of LAS is to design specified software solutions for given planning situations in global multimodal supply chains which integrate and present all relevant information for decision support. The concept focuses on enhanced collaboration, consistent information over the whole supply chain, transparency about the current process status, planning functionality and fast system development and implementation.

Taking a closer look LAS integrate the following main characteristics and functions: information transparency, information processing, decision support, collaborative planning, process orientation and software flexibility.

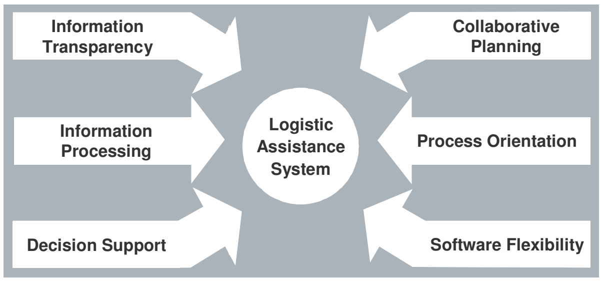

Figure 2: Characteristics and functions of LAS

'Information transparency' in LAS means that all relevant information about a planning task can be provided to decision makers and experts. On the one hand the software system reveals the current process status including information like inventory levels, production demands, positions of transport units or supplier production capacities and on the other hand planning information about forecasted future developments.

By 'information processing' data from experts and various back-end systems of all relevant and integrated network partners can be consolidated, evaluated and presented in the software system. The evaluation of the consolidated information can be processed by calculations and defined thresholds, rules for data developments and other data exceptions. The presentation of the consolidated and evaluated data to decision makers and experts can be done by using various forms of illustration like tables, text or diagrams.

'Decision support' in LAS means that depending on the given process and the integrated functionality the software system can support single or all parts of the human decision process from the decision preparation over option selection to decision execution and control (Kuhn, Hellingrath and Hinrichs 2008). In the decision preparation for identifying a solution LAS help to reveal all needed information for a correct alternative selection. After choosing an alternative the user or expert is able to directly execute the decision in LAS. The last part the decision control can enable the user to control the chosen decision execution and its impact on the subsequent process (Blutner, Cramer and Krause 2007; Toth and Wagenitz 2009).

To support 'collaborative planning' LAS combine data from all relevant network partners. This way information about all considered levels of the supply network can be used for information processing and decision support. Supporting the planning process, manual changes in data can be tracked and documented by users. In addition to that it is possible to integrate individual user views by an implemented role-based user management. This way proprietary information can be revealed to selected user groups, network partners or organisational departments. To support an enhanced communication process for collaborative planning workflows and message systems can be applied.

'Process orientation' follows the basic idea of developing lean and specified software systems that provide all needed information and functionality for a given planning situation. That means that only relevant functionality and information are selected and integrated in the software system. In addition to that user views can be designed according to the focused process. This way, users reach a valuable decision support for a given planning situation, transparency about the interdependencies in the supply network and the possible impacts of planning scenarios and executed decisions.

'Software flexibility' in LAS means on the one hand that the software system is flexible to be adjusted to process changes in dynamic supply networks and on the other hand that it is possible to integrate data from various back-end system by using standard interfaces and selected IT methods for information processing and collaborative planning. In addition to that a fast system development and implementation at affordable expenses is followed.

Based on the specific requirements of a given process and the involved users and experts, an optimal selection of IT methods and concepts has to be found for a reliable and optimal integration of LAS. Usually it is necessary to consolidate data from various back-end systems and data bases for data analysis and information transparency. As shown above BI systems offer reliable methods for this use: data warehouse, OLAP, data mining and exception reporting. For forecasting and planning APS systems offer optimisation procedures and specific planning methods based on mathematical algorithms. In addition to that or as an alternative it is possible to use dynamic SCS systems for supply chain planning and forecasting. Under consideration of the assumptions of the selected methods of the shown IT concepts it is possible to combine them in a lean LAS specified to the given process. Since it will be used by multiple organisational departments and/or network partners an additional central user management system combined with a web-based graphical user interface can reduce the administrational efforts. At the same time it enables for the integration of role based and specified user windows and data access. The presentation of the data can be done with text, tables, diagrams or KPIs supported with methods of exception reporting, pivot tables and drill-up and drill-down functionalities. Dashboard views are another way for presentation like they are often used in SCMo systems. With an integrated message system (e. g. news, e-mail, SMS or pop-up window) an optimal communication between all experts and users can be supported. If there are standardised processes with successive tasks and decisions for different experts it is also an option to integrate them as semi-automatic workflows that will be processed in a previously defined and standardised order.

As an example considering the planning situation of short-term order changes described in section 2.2 a LAS can provide all needed functions for planning and control: To reveal the current process status of the supply network data from various back-end systems of all relevant network partners can be integrated in a database (e. g. data warehouse). For the given planning situation information about supplier production capacities, inventory levels of all levels of the supply chain and the current production demand are most important. In addition master data about the supply chain can be integrated and continuously updated from different IT systems or expert knowledge. Especially the supply chain structure including transit times and the bills of materials are important for planning calculations. To show a current and consistent process status to all involved network partners and organisational departments a graphical user interface (e. g. web-based browser views) can give an overview. Using technology for forecasting and planning (e. g. SCS systems) information about the current process status the production demands, bills of materials, inventory levels over the whole supply chain including parts in transit and transit times can be processed to identify future process developments. By using safety stock levels or defined thresholds the current system status can be evaluated by calculations if stock levels are too high or too low. An effective interpretation of the evaluated information can be achieved by using some of the described presentation concepts (e. g. diagrams or dashboards) and exception reporting methods. ATP or CTP requests for short-term order changes can be answered by manually changing production demand data and run simulation scenarios. If supplier capacities or inventory levels are too low the evaluation of the data can help to identify bottlenecks and present it to decision makers.

It is a great potential of LAS that they can offer the possibility of integrating large amounts of data and complex procedures which overtop the cognitive skills of humans (Blutner, Cramer and Krause 2007). LAS can integrate data, information and expert knowledge from various back-end systems, complex process structures, individually selected algorithms and methods for data processing and forecasting. Nevertheless they support processes in supply networks that are too complex and have too many intern and extern influences for total automatic and autonomous software based processing. At least the final option selection still has to be left to the involved experts. To them the LAS can provide all relevant information for an effective decision process.

After all, LAS can be defined as lean, flexible and specified software systems for decision support in supply chain planning and control and their central functions are collecting, evaluating and presenting all relevant information about the current process status and providing planning support. Depending on the specific area of application they integrate information about certain process steps and relations, about up-to-date data and analysis from preceding operational systems, mathematical methods and algorithms and concepts for forecasting and planning.

4.2. Area of Application

One way of classifying the area of application for LAS focuses on the type of decision process, if it regards operational control or tactical and strategic planning. The other one concentrates on the involved organisational units of the order process.

LAS can be used for decision processes with varying scope. They can regard multiple stages of the supply network and their impact can be different concerning time, geographic range, monetary influences and process changes. Within the operative logistic control especially tasks like active order planning, transport monitoring and container management can be found (Blutner, Cramer and Krause 2007). In transport monitoring LAS provide the possibility to consider ecologic objectives like carbon dioxide emissions. The tactical logistic planning regards operations and decision processes of the sales planning, the production planning, the transport planning and the purchase planning. The strategic logistic planning includes the design of supply networks, location planning and the design of stock and production sites (Kuhn and Hellingrath 2002).

The areas of application of LAS concerning the different organisational units are various. For the mentioned tasks of the strategic planning specified software systems can support in the logistic planning department. In the material control department an efficient and collaborative material control can be reached by providing information transparency over the whole supply network with history, current and future data. Using forecasted (e. g. by simulation) planning data for multiple stages of the supply network the department for demand and capacity management is able to reduce supply shortfalls by increasing supplier capacities with short or long term arrangements. By integrating simulation technology it is also possible to analyse the inventory levels of the whole supply chain for alternative production programs to achieve flexibility in the order process. With data preparation, aggregation, analysis and the integration of KPIs for supply chain planning and control the supply chain controlling reaches transparency over the current process and its history or future development. The KPIs can consider all mentioned logistic targets and focus on economic, performance and ecologic objectives.

4.3. Potentials and Limits

After all it can be determined that LAS offer great potentials for providing experts with relevant information and specified functionality for decision processing in global multimodal supply chain planning and control.

A high transparency of the stages of the supply network can help to identify future supply shortfalls or too high inventory levels. Both can help to avoid logistic costs due to production stops, additional transports or working shifts. Deviations to defined thresholds and other events can be noticed early and enable for quick response. Forecasts for inventory levels and multiple stages of the supply network and a collaborative planning may avoid the bull-whip effect and help to regulate safety stock levels concerning production flexibility and capital lockup. By the integration of transport routes and current information on transport unit positions (e. g. by satellite technology for trucks or ships) timetables can be checked and adjusted. A shared consistent and comprehensive data base (e. g. data warehouse) supports an effective collaborative planning. In using LAS it is possible to enhance decision and communication quality for collaborative decision processes. In addition to that experts and users may reach learning effects because they cognise their decisions impact on the supply chain.

To achieve these great potentials there are some challenges that have to be managed. Similar to all collaborative concepts a common future process and business targets have to be defined with all involved partners of the supply network. Responsibilities have to be assigned and unequal advantages have to be agreed on or balanced out. The main necessary requirement is that no involved business partner will reach advantages that come out as disadvantages for another one (Hegmanns, Hellingrath and Toth 2008). The implementation of collaborative processes means for all involved network partners that they have to trust each other and share data and process information. Often this means that proprietary data has to be shared as well. As mentioned before there are solutions in literature how to synchronise plans (e. g. Dudek and Stadtler 2004).

Since global multimodal supply chains integrate network partners from different countries this also means that they integrate different cultures which have varying communication processes, different technology standards with different computing performances and interfaces and different standards for data management (e. g. manual or automatic data collection). This results in a great challenge for continuously and automatically collecting all relevant, current and correct data from various back-end systems. IT-standards for interfaces like EDI or XML enormously help to solve those problems.

The LAS has to be constructed as a lean and flexible software system with acceptable computational performance requirements. This way it is possible to run the system in countries with low technology standards and adjust it to their local standards. Especially by using web-based technology it is possible to keep computational performance requirements and administration efforts low. In addition to that system flexibility is needed to be able to adjust the software system to process changes in the dynamic supply network immediately. The way of constructing a system only with the relevant and selected functions keeps the system development process short and affordable.

5. LAS FOR COLLABORATIVE SUPPLY CHAIN PLANNING IN THE AUTOMOTIVE INDUSTRY (VOLKSWAGEN AG)

The benefits from using LAS will now be shown on three examples from the automotive industry. Major original equipment manufacturers (OEM) produce at worldwide locations to enter growing markets and to utilise lower production costs. For cost reasons supplier parts are used in different vehicle models. Most suppliers are located in the countries of the established OEM sites. Due to a lack of local suppliers OEM production sites in growing markets have to be supplied over long distances. This is organised as multimodal transports with container vessels for main carriage. Using logistics service providers for consolidation scale effects can be realised. A typical global supply chain is shown in figure 3.

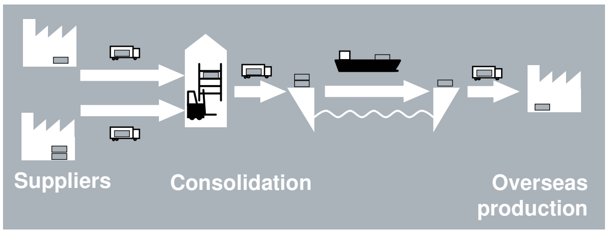

Figure 3: Supply chain in the automotive industry

Since 2006 Volkswagen AG corporate IT, Volkswagen Commercial Vehicles and Fraunhofer Institute for Material Flow and Logistics (IML) have been developing and testing LAS in the field of global SCM. A framework is used that can be easily customised to create individual LAS for specific applications. The supply network is represented by an object-relational database with predefined objects, classes and inheritance for the order-to-delivery process (OTD). Supply chain models can be created and filled with data via an XML interface.

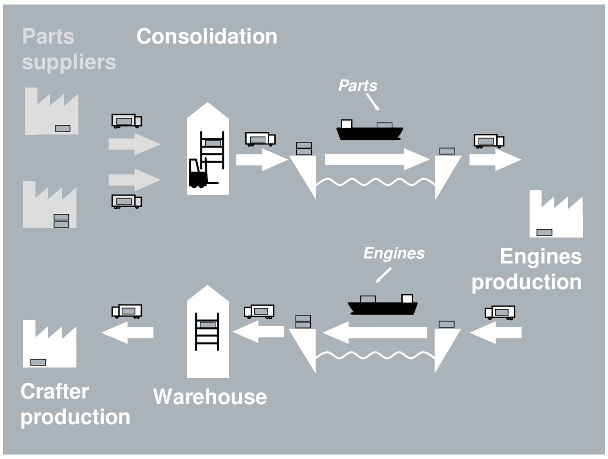

Figure 4: Crafter engines and parts supply chain

A first prototype was created to gain more flexibility in a challenging supply process: Parts built into the engines of the Volkswagen Crafter are delivered from Europe to South Africa, where the engines are produced. These engines are then shipped to Germany where the Crafter is built. Shipping alone takes several weeks. Since the safety stock has to be low it does not cover the entire time span between call-off and delivery. Production orders are released late in the process, so that call-offs are based on forecasted quantities. Varying customer demand can only be met as long as there is enough stock in the pipeline, consisting of safety stock and other stock, which has been built up due to batch sizes or earlier varying demand. For utilising this stock and gaining more flexibility, there has to be full visibility over demand, lead times, inventory levels and their interaction. Figure 4 shows a simplified illustration of the supply chain.

The LAS prototype is being used for controlling this supply chain of engine parts and assembled engines since 2007. It is based on a client-server-architecture, providing access to all relevant information on inventory and demand, which are extracted from different data sources and kept in a central supply chain database. The data also includes information about the shipping parts and engines and their estimated arrival. Having this data available is a precondition for answering capable-to-promise requests. For this functionality the OTD-NET simulation engine has been integrated into the LAS. OTD-NET has been developed by Fraunhofer IML and Volkswagen for simulations of the OTD process and has been used for numerous studies. Considering dynamic parameters, future inventory levels can be forecasted on each client. The results are presented in customised views (figure 5); a potential running out of stock is shown using traffic light colours. Flexibility is gained and emergency transports by airfreight can be avoided. (Deiseroth, Weibels and Toth 2008; Wagenitz 2007)

Figure 5: Planning view of the “Crafter Tool”

Recent projects extend these features adapting it to new requirements. In the automotive industry in-house logistics service providers centrally supply production sites in new markets with parts. Serving several customers within the cooperation, these divisions have to avoid shortage situations while demand is varying and delivery time is long. A new web-based application replaces the clients, offering features and views for significantly higher data volume. An integrated user management regulates the access to information and provides data security. Input data is extracted from different data warehouses and operative systems. Creating visibility over all integrated supply chains and simulating future scenarios can stabilise planning and reduce cost for additional transports. A prototype is currently developed by Fraunhofer IML and Volkswagen AG.

A third project deals with the control of supply chains from different logistics service providers to a production plant in South America. Besides the features already mentioned above it is planned to consider production capacities from suppliers as further input data. In a future step real customer orders, calculation of dependent demand requirements and cross-checking with inventory levels and supplier capacities will be integrated into a simulation model. In addition CO_2 emissions of transports will be calculated. They will be displayed historically, for current and for future transports and cover the standard process as well as additional future transports like airfreight. The prototype of the LAS is expected to be released in the fourth quarter of 2009.

6. CONCLUSION AND PROSPECTS

It has been shown that all mentioned SCM concepts need software systems that can be implemented for collaboration of multiple partners of a supply network. Existing software systems offer various concepts and methods for preparation, aggregation and analysis of data from multiple interfaces to support expert decision processes. They also provide forecasting functionalities for planning but they all cannot offer the flexibility to be immediately implemented to specific supply chain parts and for multiple network partners.

Existing software solutions cannot fulfil all requirements of collecting, evaluating, forecasting and presenting information for supply chain control and planning in global multimodal supply networks. With the integration of selected methods of these IT systems LAS can be developed as lean and specialised software systems that provide all relevant functionality and information for a given situation in supply chain planning and control. To realise the great potentials of LAS, they have to be specified and customised to the given process and involved experts and be implemented in a short time. Another assumption is the willingness of all involved network partners for collaboration. Both can only be reached with a preceding and common planning process. As shown above under consideration of these requirements of collaborative concepts first applications in industry show convincing results and follow-ups have been started already.

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