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To cite this version:

Maria Linnartz, Volker Stich. Software-Based Assistance System for Decision Support on Supply Chain Level. IFIP International Conference on Advances in Production Management Systems (APMS), Aug 2020, Novi Sad, Serbia. pp.209-216, 10.1007/978-3-030-57993-7_24 . hal-03630925

HAL Id: hal-03630925

https://inria.hal.science/hal-03630925v1

Submitted on 5 Apr 2022

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Software-based Assistance System for Decision Support on Supply Chain Level

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Abstract. In recent years, the complexity of the management of supply chains has increased significantly due to the growing individualization of products and dynamics of the market environment. To remain competitive, ensuring efficient and flexible processes and procedures along the entire supply chain are of particular importance for companies. Especially in the inter-company context, decisions must be made as quickly and correctly as possible. To enable good decision-making processes data must be processed and provided in a targeted manner. Currently, however, the necessary transparency is often lacking within the supply chains. In this article, a software-based assistance system for decision support on supply chain level is presented that aims to increase the transparency and efficiency of the decision-making process. A concept for decision support on supply chain level is presented. This paper focuses on the conceptual linkage of relevant decisions and data. Therefore, indicators are identified and linked with the relevant decisions. Moreover, a suitable way of visualizing the identified indicators for each decision in a user-friendly manner is defined. These results are then used to implement the software tool.

Keywords: Supply Chain Management, Decision Support, Software Tool.

1 Introduction

Many companies are facing an increasingly dynamic and volatile market environment. Various factors like increasing customer expectations, demand for individual products, shorter product life cycles and intensified cost pressure have led to an increase in complexity in managing supply chains. In this environment, efficient and flexible processes along the whole supply chain are necessary. At the same time, more and more data is generated along the supply chain. Utilizing this data holds the potential to increase transparency and improve processes and decisions. [1, 2, 3] Currently, however, the necessary transparency is often lacking within the supply chain. A reliable and up-to-date basis for decision-making is often not available. [4] The required data is often not available or not available in sufficient quality [2]. Companies need to be able to extract useful information from huge amounts of data and provide this information to decision-makers to stay successful [1].

To face these challenges, assistance systems for decision-makers in supply chain management and logistics are needed. Such systems can ensure a structured provision of required data and thereby increase the transparency. Therefore, assistance systems lead to faster decision making.

The aim of the software-based assistance system for decision support on supply chain level presented in this paper is to increase the transparency and efficiency of the decision-making processes on the strategic, tactical and operative level through a demand-oriented provision of data. The decision support is achieved through the analysis and linkage of data in indicators and the visualization of these indicators within a software-based assistance tool.

2 State of the Art

There is a wide variety of existing approaches used for decision support in different tasks within supply chain management. To provide decision support assistance systems need to be based on a sufficient database, process and utilize data and contain comprehensive technical solutions [2, 5]. To achieve the above-mentioned goal, the assistant system should address concrete decisions in the area of sourcing and delivering, contain a data model, provide the relevant evaluated data through a user interface and be implemented in a software tool.

A general framework for decision support along the whole product life cycle is the **Internet of Production** (see **Fig. 1**) which was introduced at the Aachen Machine Tool Colloquium in 2017.

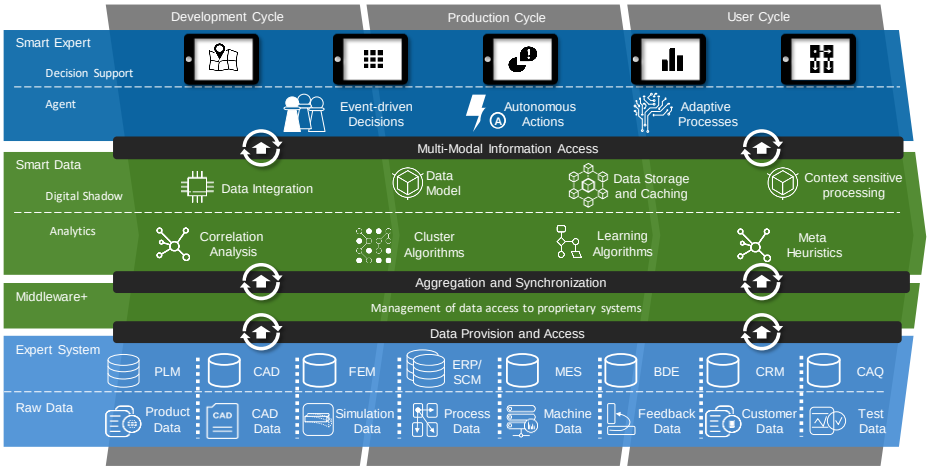

Fig. 1. Infrastructure of the Internet of Production [6]

It covers the different phases of the product life cycle (development, production and use). The basis for analysis and decision support is raw data from different business application systems like Enterprise Resource Planning (ERP) systems. Raw data is processed using algorithms and business analytics to create smart data which contains a

high information content. This information is then used to provide decision support for the decision-maker through assistance systems. [6] In the framework of the research project Cluster of Excellence “Internet of Production” several decision support apps within the different cycles are developed. So far, it does not contain a specific assistance system for decision support on supply chain level.

According to a systematic literature review by TENIWUT AND HASYIM [7], decision support systems in the context of supply chain management often focus on specific tasks like determining delivery routes or choosing a supplier.

IVANOV [8] presents an adaptive framework for aligning (re)planning decisions on supply chain strategy, design, tactics, and operations. While this framework identifies specific decisions and relevant data, it does not provide a data model or advise on the data provision for the decision-maker. BISWAS AND NARAHARI [9] present generic supply chain objects to model a variety of supply chains. MUKKADES ET AL. [10] identify information categories for a demand-oriented provision of data on supply chain level. SCHUH AND BLUM [11] develop a data structure for order processing as a basis for data analytics. These works offer data structures to model supply chains but they do not link these data to specific decisions. Moreover, they do not focus on the design of the user interface for data provision.

Existing software tools and business application software for different tasks along the order processing process contain user interfaces for decision support but often focus on a few specific decisions. As an example, anyLogistix uses optimization and simulation results to support decisions in the area of location and capacity planning, procurement and transport guidelines and order consolidation. Moreover, the tool uses key indicators to measure the quality and effects of the decisions. [12] However, the tool does not cover all relevant decisions. SAP APO (Advanced Planning and Optimization) as an example for business application software in supply chain management contains different modules amongst others for demand or network planning. Moreover, it includes a Supply Chain Cockpit that offers an overview of the entire supply chain as well as a view of all products, resources, locations, production process models and transport relationships. [13] Even though SAP APO enables decision support, it is system-oriented and requires high implementation effort.

Existing conceptual contributions only cover some of the derived requirements. The approaches focus either on concrete decisions or on general data models. The provision of the relevant evaluated data through a user interface and implementation in a software tool is mostly missing. Existing software tools provide user interfaces but usually focus on individual and specialized tasks. Moreover, these systems are often not efficiently linked with each other.

Thus, a software tool that offers a comprehensive picture of the status of the sourcing and delivering processes on supply chain level by linking data from different sources is currently missing. To increase transparency on supply chain level, such a system should cover decisions on strategic, tactical and operative level and ensure the demand-oriented provision of data for decision-makers in a software tool.

3 Software-based Assistance System

The software-based assistance system presented in this paper systematically links data from different sources to generate information that supports the decision-maker in sourcing and delivering decisions on different decision levels. It has been developed as part of the research project Cluster of Excellence “Internet of Production” and thus uses the above-described framework of the Internet of Production which ensures systematic linkage and processing of data and user-friendly decision support.

The concept comprises five modules (see Fig. 2). To utilize the increasing amount of data to support decisions, a systematic linkage of decisions and data (Module 3) and a demand-oriented provision of evaluated data (Module 4) is needed. This is achieved through a systematic comparison of information needs and offers. Identifying relevant decisions (Module 1) and the development of a data model (Module 2) serve as the basis for modules 3 and 4. Module 1 uses a process reference model to identify relevant decisions. Module 2 applies a standardized notation to ensure a structured and formal data model. Module 5 combines the developed content of modules 1 to 4 and implements them within a software tool. This ensures the applicability of the results. The paper focuses on the linkage of decisions and data, the demand-oriented provision and the implemented software tool.

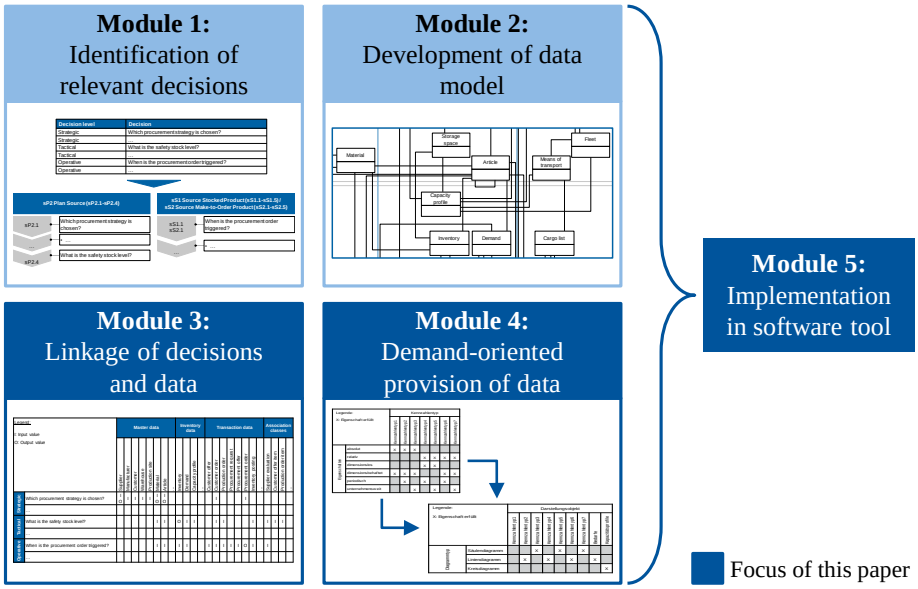

Fig. 2. Concept for decision support at supply chain level

A detailed description of the results of the first modules can be found in [14] and thus will only be summarized shortly. The **identification of relevant decision** is based on planning, sourcing and delivering processes described in the SCOR model [15]. Strategic sourcing decisions concern the definition of the procurement strategy and long-term

planning of the required articles and stock. In the tactical decisions, the material program is detailed, whereby, among other things, the required quantities are specified. The operational decisions concern specific procurement orders. Strategic delivery decisions include determining the distribution strategy, the distribution channels and the distribution concept. Within the tactical decisions, carriers are selected and the capacities of the vehicle fleet are determined. Decisions on concrete transport orders and route planning are made within the operational decisions. The result of the second module is a UML-based **data model** containing the data which is needed in order to provide decision support. It consists of data classes, attributes and links between different data classes.

To **link decisions and data** an impact matrix is developed to analyze which data classes are needed for which decisions. This impact matrix is iteratively developed further. On one side, the influence matrix serves as a basis for identifying relevant indicators for decision support and, on the other side, existing literature-based indicators enable the revision of the influence matrix. Thus relevant indicators in the context of sourcing and delivering are identified using a literature analysis. These indicators are then linked to different decisions. Indicators condense information and enable statements about quantifiable facts in the past or future [16]. To cover the different decision levels absolute and relative indicators, as well as financial and non-financial indicators, are used. While relative indicators represent a ratio of two variables, absolute indicators are absolute values that summarize data. Moreover, indicators can be evaluated by company-wide or periodically comparisons. Absolute indicators are mostly non-financial indicators that will be used for decisions on strategic level. Moreover, the absolute indicators can be used to analyze the development over defined time horizons and are thus used for periodical comparisons. Examples for absolute indicators for the sourcing area are number of suppliers, number of procurement orders and number of procurement order items. For decisions in the area of delivering examples for absolute indicators are the number of distribution points, the number of means of transport and the number of customer orders. Relative indicators serve as decision support on all decision levels. Moreover, they comprise several financial indicators. Examples for indicators in the area of sourcing are stock turnover capability, stock range and costs per stock movement. Examples for indicators that are relevant for delivering processes are means of transport utilization rate, delivery service level and average transport distance. The indicators are calculated using the data model.

To ensure a **demand-oriented provision of data**, a suitable way of visualizing the indicators to support the decision-maker is defined. Characteristics for sufficient data visualization are a target group-specific and context-related presentation in an easily understandable, quickly comprehensible and precise form [17]. For the visualization of the indicators, different diagram types are used in the context of this work (bar chart, line chart and network diagram). The application of each diagram depends on the indicator type, the unit of the indicator and the type of indicator comparison. For each decision, the indicators that support the decision and a suitable way of visualization are identified. Moreover, the time horizons for the calculation of the indicators are determined.

4 Presentation of the Software Tool

To provide decision support, user-friendly and context-dependent information visualization and interaction formats are of particular importance [18]. Thus, the above-described results are implemented in a software tool to ensure the practical use of the developed results. In doing so various software components are utilized. The most important components are a scripting language (Python), a web framework (Django) and a relational database management system (PostgreSQL).

The foundation for the implementation of the developed concept in a software-based solution is a relational database. This database is derived from the above-described data model. The database integrates data from different data sources like ERP systems and Supplier Relationship Management systems.

The software tool consists of various screens. **Fig. 3** shows the welcome screen and a detailed screen for operative sourcing decisions of the software tool.

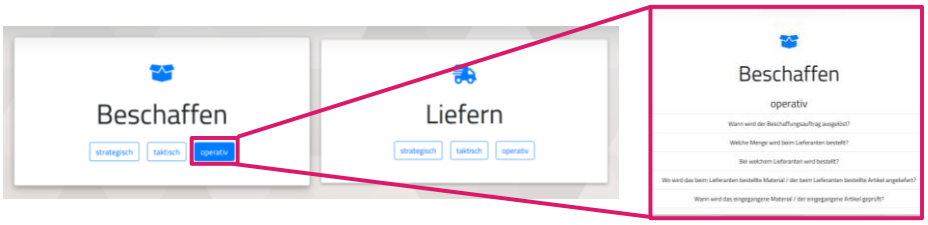

Fig. 3. Structure of the software tool

The welcome screen of the software tool summarizes the main decision areas (sourcing and delivering) and the decision levels (strategic, tactical, operative). Choosing one of the decision levels for sourcing or delivering leads to the list of decisions that are covered within the tool. For each listed decision the tool then contains detailed screens that summarize the necessary information to support the decision-maker. These screens comprise visualized indicators that have been identified in Module 3 and Module 4.

The operative decision from which supplier a material should be ordered serves as an example of the visualization (see **Fig. 4**). This decision is strongly influenced by supplier evaluations. For the five best-rated possible suppliers their service level, the response time and the delay rate are visualized. Moreover, the average price and the average procurement time for these suppliers are compared.

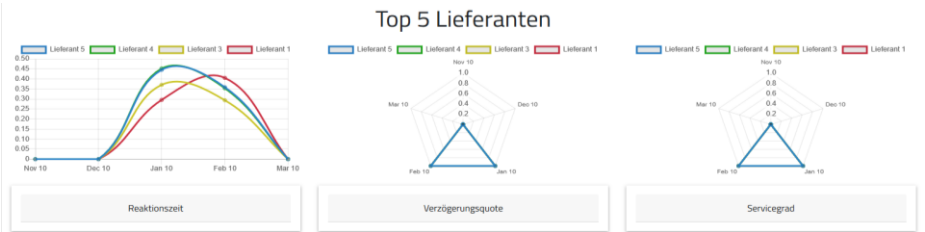

Fig. 4. Screen for operative sourcing decision “Which supplier is ordered from?”

5 Summary and Need for Further Research

To increase the transparency and efficiency of decision-making processes in the area of sourcing and delivering a software-based assistance system is developed. The decision support is reached through the visualization of data and indicators. Relevant decisions on strategic, tactical and operative level and a data model serve as the basis. The paper focused on the linkage of decisions and data through indicators and the definition of a suitable way of visualizing the selected indicators in the context of specific decisions. Moreover, it is demonstrated how these results are implemented in a software tool.

The concept systematically links data from different sources to provide a comprehensive overview of relevant sourcing and delivering decisions. The software tool ensures the demand-oriented provision of evaluated data and practical feasibility. In doing so, the presented concept and software tool bridge the described research gap.

The tool will be validated using real company data and conducting expert interviews with different user groups. In the developed software tool the different decisions are currently dealt with separately. Further research is thus needed to link the decisions. In doing so, interdependencies between the decisions need to be analyzed. These results can then be integrated into the software tool for instance through overview dashboards or push messages for the user. Another additional functionality for the software tool is the integration of analytical methods to gain even more information from existing data.

Acknowledgments: Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy – EXC-2023 Internet of Production – 390621612.

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