A Standardized Value Stream Management Method for Supply Chain Networks

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Abstract
In a globalized market environment, almost all companies operate in complex supply chain networks. A high degree of product diversification in combination with rapidly changing customer needs require cross-enterprise supply chain collaboration, which causes communication problems. A way to cope with this complexity is to optimize both internal as well as external processes in a holistic manner and to define standards for interaction, collaboration and communication procedures. An established method for process analysis and optimization is Value Stream Management (VSM). Despite a variety of promising VSM approaches, there is a lack of a standardized VSM method, especially with regard to complex supply chain networks. Thus, a review of methods for process visualization and their suitability for different process types shall be discussed. A common VSM method with integrated features according to the specific needs of the applying organization will help to optimize the value creation in cross-enterprise supply chains.

Keywords
Lean Manufacturing, Value Stream Management, Supply Chain Networks

1 INTRODUCTION

Due to rapidly changing market conditions in a globalized environment, numerous companies strive for international competitiveness, e.g. by shifting operations to emerging markets [1]. One goal of these globally operating companies is to achieve integrated product and information flows based on robust IT infrastructures, which enable efficient collaboration and communication procedures between suppliers and customers. However, cross-enterprise supply chain networks in combination with a heterogeneous and inconsistent VSM landscape lead to waste like repetitive work, e.g. during auditing processes. Thus, a standardized and comprehensive VSM method will enhance the analysis of complex supply chain networks.

According to Aitken, a supply chain is defined as "a network of connected and interdependent organizations mutually and co-operatively working together to control, manage and improve the flow of materials and information from suppliers to end users" [2]. The described cooperation of different companies in supply chain networks requires standardized collaboration and communication procedures, which are investigated thoroughly in the following sections.

This paper is structured as follows: firstly, a general literature review on existing collaboration and communication procedures in supply chain networks is presented. Secondly, selected methods for network and process analysis are discussed, followed by the description of a developed multilevel VSM approach and an associated data acquisition method. Finally, this paper concludes with a critical review of the novel approach and further steps of research in this field.

2 COLLABORATION AND COMMUNICATION IN SUPPLY CHAIN NETWORKS

Cross-company collaboration and communication are essential aspects of complex supply chain networks. In order to better understand the basic principles of supply chain collaboration based on communication procedures in globalized supply chain networks, recent scientific publications in these fields have been investigated.

2.1 Supply Chain Networks

Farahani et.al. [3] present a review on competitive Supply Chain Network Design (SCND) and develop a framework to model those supply chain patterns. SCND describes the structure of supply chains, their cost and performance, e.g. by analyzing the number, size and location of facilities in a supply chain. Based on these analyses, tactical and operational decisions could be taken.

Closed-loop supply chains (CLSCs) have in addition to the forward-oriented chain a reverse chain for recycling purposes. Özceylan et.al. [4] investigate the modeling and optimization with regard to closed-loop supply chain network design and disassembly line balancing. The authors present a nonlinear mixed integer programming formulation for solving strategical and tactical decisions in supply chains.

Another publication in the field of SCND in combination with CLSCs by Devika et.al. [5] deals with the design of a sustainable CLSC network based on a triple bottom line approach incorporating economic, environmental and social impacts. In order to consider further environmental aspects like greenhouse gas emissions, Urata et.al. [6], Comas Martí et.al. [7], Sparks and Badurdeen [8] as well as

Eskandarpour et.al. [9] present their approaches to model and balance economic and environmental aspects of global supply chain networks. With the help of different mathematical formulations, e.g. mixed integer programming (MIP) problems, the market correlations are modeled while considering environmental aspects, such as CO_2 emissions within globalized supply chains.

Schuh et.al. [10] develop a concept for the management and the design of production networks. In consideration of the structural complexity as a key parameter of global networks, the authors present an approach for the analysis and optimization of production networks.

Furthermore, Matt et.al. [11], adapt the value stream optimization approach to collaborative company networks in the construction industry. The authors describe a methodology to design an integrated and customized value stream map, which is tested in a collaborative project of applied research.

The described approaches focus mainly on the analysis and optimization of specific supply chain structures or associated process types. However, a common VSM method suited for supply chain networks is not provided. With regard to a wider range of process types, a holistic and standardized VSM approach needs to be developed.

2.2 Supply Chain Collaboration

In order to get deeper insights in supply chain networks, an investigation of general collaboration procedures within supply chains is advantageous.

According to Shephard [12], the term collaboration refers to a "cooperative relationship built on developing synergies within and across company boundaries that help all supply chain partners". The author analyzes the collaborative demand and supply planning between supply chain partners. Benefits of collaboration are presented as well as guidelines for the right choice of supply chain partners. Moreover, different levels of collaboration, such as limited, partial and full collaboration are explained.

To facilitate supply chain collaboration, Schubel et.al. [13] ask for uniform reference models and common definitions of basic terminology in production and logistics. Therefore, the authors analyze reference models in five different fields: Computer Integrated Manufacturing (CIM), Production Planning and Control (PPC), Digital Factory, Supply Chain Management (SCM) as well as in production, logistics and factory planning in general.

Cao and Zhang [14] give a broad overview of collaboration within supply chains. In addition, the importance of IT resources and inter-organizational systems (IOS) is stressed. Different levels of collaboration and their impact on sharing of crucial data among supply chain partners are addressed.

These general approaches of cross-enterprise collaboration in supply chains need to be extended and integrated with regard to the development of a standardized VSM method.

2.3 Communication standards for supply chain networks

In the past decades, different standards for intra- and inter-company communication have been developed. Communication standards that guarantee a secure and efficient Electronic Data Interchange (EDI) are for example "EDIFACT", "GAEB" in the construction sector, "ebXML" in the business sector, "Fortras" in the transport sector or "openTRANS" in the trade sector. In addition, there are other communication standards like "RosettaNet", "Universal Description, Discovery and Integration" (UDDI) or "Web service description language" (WSDL). Most of those standards are based on the "Extensible Markup Language" (XML). In the work of Cecere [15], EDI is described as a workhorse of the value chain. The publication presents deeper insights with regard to the application of EDI in extended supply chains with a special focus on processes for Business-To-Business (B2B) connectivity. The study reveals that an efficient use of EDI leads to meaningful business results, e.g. shorter shipment cycles or a better order fulfilment.

To ensure an efficient collaboration within global supply chain networks, communication standards and procedures have to be followed. These common communication procedures will enhance integrated information flows across company borders and need to be considered while analyzing complex supply chain networks.

3 EXISTING METHODS FOR SUPPLY CHAIN NETWORK AND PROCESS MODELING

The following chapter describes existing methods for supply chain network analysis as well as for process modeling and visualization. Furthermore, the applicability of these methods for cross-enterprise supply chain networks is evaluated.

3.1 Supply Chain Network analysis techniques

One of the first approaches for supply chain network analysis has been developed by Gereffi and Fernandez-Stark [16]. According to them, the following four dimensions of global value chain analysis can be distinguished:

- input-output structure
- geographic scope
- governance
- institutional context

From a governance perspective, Gereffi et.al. [17] have introduced a typology of five different governance patterns, from strong hierarchical structures with a high degree of power asymmetry and explicit coordination to market based structures with a low degree of power asymmetry and explicit coordination.

Ferrarini [18] introduces a method to map global networks with regard to production and trade. To perform the mathematical analysis of the data set, the author defines a "Network Trade Index" (NTI) as a weighted index for the supply of countries. By means of a force-directed algorithm, the global network can be solved and analyzed.

The concept of netchains is introduced by Lazzarini et.al. [19]. Netchain analysis comprises supply chain and network analyses. The study of netchains is the first step to optimize inter-organizational collaboration by analyzing interdependencies between different stakeholders of a supply chain.

The development and application of an “Inter-Country Input-Output” (ICIO) model is described in the OECD report on global value chain mapping [20]. The ICIO model is able to analyze trade and production of countries based on international input-output tables.

The four presented methods for network analysis are all suited for global supply chain analysis and optimization. Nevertheless, the described approaches are based on country level and do not provide a value stream analysis from a company perspective.

3.2 Process modeling and visualization

3.2.1 SCOR model

The Supply Chain Operations Reference model (SCOR) developed by the Supply Chain Council, is the leading reference model for internal and cross-enterprise business processes. The process description is divided into several levels. On the first level, the processes are categorized according to the following structure:

- Plan
- Source
- Make
- Deliver
- Return
- Enable

Besides these categorization and modeling efforts, the SCOR model provides a comprehensive overview on Key Performance Indicators (KPIs), which are suited for the assessment of the supply chain.

3.2.2 Value Stream Mapping

Value Stream Mapping is a key concept and one of the initial steps of Value Stream Management (VSM) to capture relevant process steps and corresponding value stream data. As main literature in the field of VSM, the work of Rother and Shook [21] has to be considered, since it is the first systematic approach to describe and optimize value streams. The resulting VSM method is a concept for the structured modeling and optimization of product and information flows.

Based on the existing approaches in the field of VSM, Womack and Jones [22] develop an extended VSM method by expanding the perspective from a single company to supply chain optimization. By means of this extension, there is the possibility to map product and information flows across company borders.

3.2.3 Further methods for process modeling and visualization

Besides the process modeling techniques described above, there are further methods for process modeling and visualization. The approach “Architecture of Integrated Information Systems” (ARIS) developed by Scheer [23], helps to map processes and associated data flows on company level. Other means for process modeling are for example swimlane diagrams or the “ICAM Definition for Function Modeling” (IDEF0). Several of these methods are based on flow charts, which have their origins in the formulation of “Flow Process Charts” (FPC) by Gilbreth. In addition, there are different approaches to deal with the complexity of value streams in terms of components. Supporting approaches for visualizing multiple value streams in supply chain networks are for example the Critical Path Method (CPM), Value Network Mapping (VNM) or graph theory in general.

The application of the described methods is often well defined within a company, but needs to be extended and standardized for a common modeling and visualization of all types of external processes.

4 MULTILEVEL VSM METHOD FOR SUPPLY CHAIN NETWORKS

In the following chapter, a new VSM method for the analysis and optimization of supply chain networks on company level is presented. Beyond existing approaches of extended VSM, this new method incorporates data acquisition and value stream visualization techniques for differing applications.

4.1 Extended VSM approach for various process types

Complex supply chain networks require well-defined analysis methods to facilitate and optimize cross-enterprise collaboration procedures. In practice, there is often no common understanding of those procedures, especially across company borders. This leads to communication problems, repetitive work and consequently to waste due to a differing use of these techniques. Therefore, the existing methods for process and network analysis have to be extended and standardized.

In contrast to the described value chain analysis approaches on country level, the following VSM method has been specially developed for a multilevel assessment of complex supply chain networks on company level. The structure of this multilevel VSM method has been designed in conformity with previous VSM approaches, e.g. [21][22]. Depending on the focus of the supply chain analysis, different value stream perspectives are provided (s. Figure 1).

The four different levels of detail are defined as:

- macro level: multiple companies or plants
- meso level: sub-network with transport links
- micro level: single company or plant
- nano level: single process

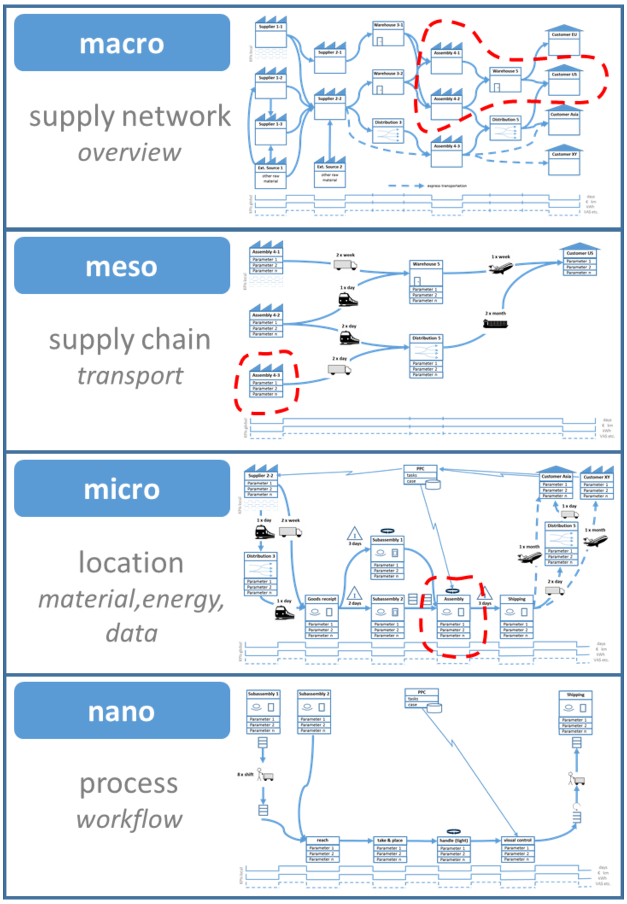

Figure 1 - Multilevel VSM method

On the macro level, a quick overview of the entire supply chain network can be achieved. The subsequent meso level provides further information with regard to transport modes linking the different supply chain partners. On the micro level, an intra-company view of a value stream is shown with product and information flows. This level corresponds to the usual VSM perspective of a specific location or plant. The underlying nano level is suited for a detailed process analysis and a subsequent workflow optimization.

Particularly in cross-enterprise applications, a broad usability of the developed approach is essential. To achieve a common and holistic VSM method, different parameters for various process types have to be defined (s. Figure 2). Beyond a default setting for all process types, flexible adjustments can be made depending on the specific supply chain.

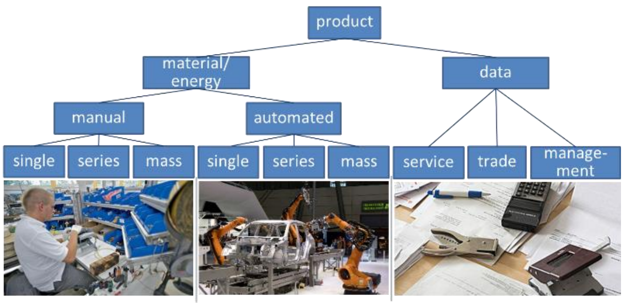

Figure 2 - Process types according to [24]

The downstream-oriented product flow can be separated in material, energy and data-driven processes. The material or energy related processes can be further distinguished according to the production type (manual vs. automated) and production volume (single, series or mass production). The data-driven process types are either service, trade or management processes.

4.2 Data acquisition in supply chain networks

In consideration of the existing power structures in supply chains, which are primarily dominated by Original Equipment Manufacturers (OEMs), a new approach for a more efficient supply chain collaboration and communication is presented in the following. One major objective of this data acquisition approach is to determine the contribution of an individual actor with regard to the entire value stream. The data acquisition method is divided into six major steps (s. Figure 3).

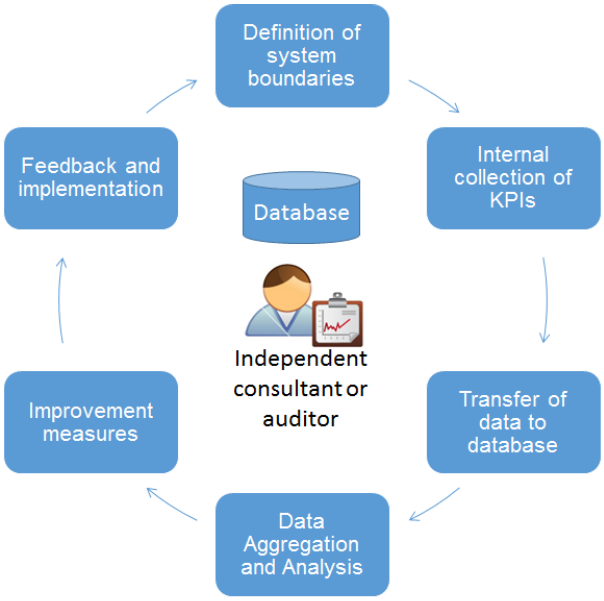

Figure 3 - Six step method to enhance supply chain collaboration and communication

First, distinct system boundaries for the subsequent data acquisition and analysis have to be defined. The decision of drawing extended or narrow system boundaries is very subjective. As a general rule, all those supply chain sections, which have a significant impact on the final product, should be considered. In practice, this might lead to very complex structures due to a huge number of suppliers. A way to cope with this complexity is to concentrate first on key suppliers and if required extend the analysis to further suppliers. During the second phase, company specific data, such as KPIs or other process data, are collected. This could be done separately by dedicated contact persons in each company or by an external specialist. As the company-specific pieces of information are often highly confidential, working with value stream data should be in the ideal case a task for an independent consultant or auditor. Having collected all relevant parameters, the data may be transferred to a central database. While reporting or integrating this process-related data in a central system, it is essential to maintain confidentiality related to other companies in the supply chain network. Then, the company-specific data can be aggregated to value stream data and analyzed on supply chain level. Different results of this value stream investigation can be expected in contrast to a pure intra-company analysis and optimization. Based on the value stream analysis phase, different measures for the improvement of the current value stream will be defined. In the last step, the supply chain actors inside the system boundaries get feedback on their contribution to the entire value stream. In addition, information with regard to the value stream analysis and optimization phase can be disseminated within the supply chain network.

All these necessary steps for data acquisition and analysis are in line with the management method Plan-Do-Check-Act (PDCA). Thus, for a steady improvement of the entire value stream, this procedure needs to be repeated continuously.

There are several benefits for the contributing supply chain partners. From an OEM perspective, the new data acquisition approach could be used as additional supplier evaluation tool that increases the efficiency of audits. Furthermore, this six-step method facilitates the data management of the entire supply chain network, from the supply of raw material to the delivery of the final product. Another benefit is the improved inter-company collaboration based on a central database and associated IT solutions.

The benefits for the supplying companies have to be seen in view to their customers. In OEM dominated supply chain networks, suppliers show a strong adherence to supply chain standards and requirements, as a stronger relationship to the OEM or the final customer ensures production and sales. In most supply chains, there are strong dependencies of supplying companies with regard to OEM's. Due to the dissemination of results, suppliers and other supply chain actors get sensitized to their contribution to the final product.

4.3 Mapping of cross-enterprise value streams

In addition to the described data acquisition and analysis procedure, the mapping of value streams in supply chain networks has to be standardized. With the help of a consistent catalogue of symbols and a common terminology, different supply chain partners get a common understanding of the value stream and are able to exchange knowledge and short-term modifications more efficiently.

Especially for specific VSM applications, there is no consistent use of symbols or calculation procedures. Parallel or repetitive processes (see Figure 4) serve as challenging examples.

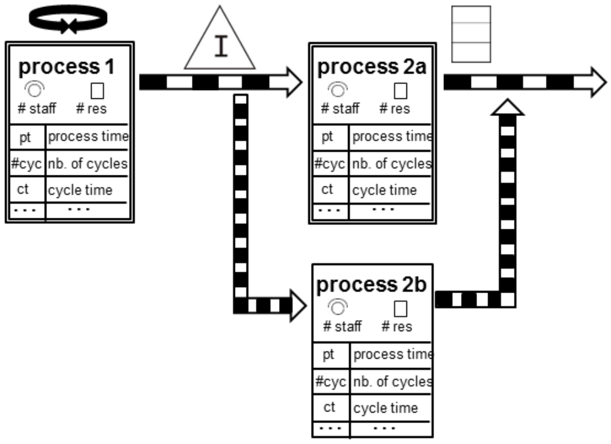

Figure 4 - Repetitive and parallel processes

Problems occur while aggregating cost or quality parameters, e.g. the determination of an overall scrap rate.

The aforementioned approaches of multilevel value stream analysis and supply chain data acquisition are key concepts, which contribute to a standardized VSM method. In connection with this holistic VSM approach, integrated IT solutions will help to facilitate the collaboration in supply chain networks.

5 PROOF OF CONCEPT

5.1 Applicability and validation of the developed approach

The multilevel VSM approach has been tested successfully on nano and micro level for intra-company applications [25].

In addition, the developed VSM approach will be tested on meso and macro level in various industry sectors to ensure its general applicability. A validation in real industry and business environments will proof the suitability of the VSM method, especially with regard to cross-enterprise applications.

5.2 Risks and limitations

Regarding the presented VSM approach and associated data acquisition technique, some limitations have to be considered. The multi-sectoral VSM approach is limited to the analysis of companies, plants or processes in contrast to the described supply chain network models on country level. From a company perspective, a potential risk might be the lack of willingness to share crucial data with supply chain partners. Therefore, the gathering and analysis of data shall be a task of an independent and external consultant or auditor under a non-disclosure agreement.

6 CONCLUSION AND OUTLOOK

This paper provided a review of existing methods for the analysis and optimization of supply chain networks. To analyze collaboration and communication procedures in supply chains, a multilevel VSM approach and an associated method for data acquisition have been developed. These concepts are suitable for various process types.

Further steps are the validation of the VSM approach in real industrial or business environments followed by a proposal for standardization. This standardized VSM method shall be suited for a holistic analysis and optimization while facilitating collaboration and communication in complex supply chain networks.

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