Automation of VSM with a focus on customers and suppliers

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Abstract
Value Stream Management is a methodology for mapping and analyzing actual value streams as well as designing target ones. The end-to-end (E2E) consideration of a value stream from a company's perspective including the manufacturing process as value-adding transformation, the supplier as supply or source and the customer as demand or sink of the value stream reveals a holistic overview of the entire supply chain. This overview facilitates a structured elimination of wastes according to the principles of lean management. Value Stream Management is a widely applied and field-tested approach, whose fundamental principles are still valid, but facing challenges in the context of an increasing digitalized and volatile environment. Several recent publications refer to this disadvantage and provide approaches, to enhance or improve the methodology by the integration of data. Though, all of these reviewed studies are limited to investigation of the manufacturing process, whereby the customer and supplier perspectives are largely not considered in detail. Target of the paper at hand is the review of the key performance indicator (KPI) in terms of the domains of customer and supplier within the Value Stream Management framework, the identification of potential data sources in regard to business application systems and the design of a modular framework, enabling the automation of the Value Stream Mapping (VSM) in various process and system landscapes with special emphasis on the value stream's source and sink.

1. Introduction
Value Stream Management is based on the principles and methods of lean management. The approach is widely applied by different companies and supports a structured mapping, analyzing, designing and implementing measures for improving value streams. Following these activities, four phases are distinguished in the VSM framework. These are Value Stream Mapping (VSM) for capturing the value stream, Value Stream Analysis (VSA) for analyzing the value stream in terms of waste and inefficiencies, Value Stream Design (VSD) for designing an optimized target value stream, and Value Stream Planning (VSP) for planning and implementing improvement measures with the aim of approaching or achieving the target value stream through multiple iterations.

In this context, a value stream is defined as an end-to-end supply chain, described from a company's perspective. The essential core of the methodology is formed by the Value Stream Map, which is a graphical model, visualizing the manufacturing process, the related dependencies to suppliers as inputs and customers as outputs and the specific business process control referring to order handling with focus on production planning and scheduling. In the model all relevant material and information flows are taken into account. Customer as well as supplier can represent both, internal as well as external stakeholders. Based on the map, wastes in the process, e.g. waiting times and further non-value-adding activities according to the seven wastes of lean management (transportation, inventory, motion, waiting, over-processing, overproduction and defects) are identified and eliminated by designing a target value stream. [1], [2] Such a value stream map is schematically depicted in Figure 1 [3].

Based on a systematic literature review according to [4] covering the years 2021 to 2024 in the databases GoogleScholar and ResearchGate, the following findings are revealed. In volatile environments, Value Stream Management exhibits various weaknesses, the elimination of which is the subject of numerous studies, such as [5], [6], [7], [8]. Various approaches providing concepts for the utilization of digital technologies and techniques are discussed for this purpose, summed up in the next section.

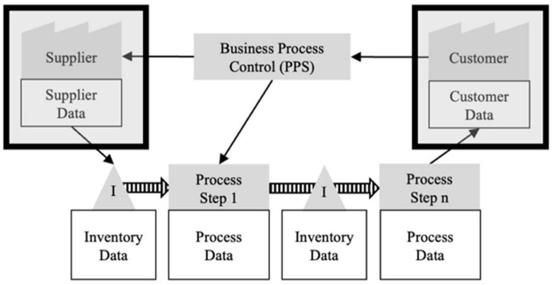

Figure 1: Supplier and Customer Information in the Context of a Value Stream Map

Companies face changing market conditions, leading to decreasing lot sizes, shorter innovation and product cycles, wider variety as well as increasing competition. Especially in dynamic environments, the procedure has several disadvantages, which are subject of recent research, as detailly investigated in [9], [10]. The future viability of Value Stream Management against the background of increasing digitization and digitalization as well as derived improvement potentials are investigated in several publications, e.g. [5], [6]. Different approaches are provided, aiming at the purposeful combination of the conventional Value Stream Management procedure and the application of data-based technologies to reduce the manual efforts and get more flexible. Beside the consideration of single technologies, e.g. RFID [13], [14], sensor networks [15], Industrial Internet of Things (IIoT) [16], Digital Shadows [17] and Digital Twins [7], cyber-physical systems (CPS) [18], [19] and industry 4.0 technologies in general [20], [21], universal frameworks, combining the application of a technology mix, e.g. [8], [22] are available. Furthermore, the utilization of data derived from business application systems as enterprise resource planning (ERP), warehouse management systems (WMS), manufacturing execution systems (MES), supply chain management systems (SCM) and similar ones is taken into account [23]. In differentiation to the conventional approach, the proposed procedures are named as dynamic Value Stream Management, smart Value Stream Management as well as VSM 4.0, considering the increased degree of digitalization [16], [21], [24].

Furthermore, findings reveal, all reviewed studies are limited to the manufacturing process, covering production- as well as logistics-related activities. An explicit consideration of the two domains of supplier and customer is missing, as visualized by the grey boxes in Figure 1. The supplier is the essential input of the manufacturing process and represents the supply, also mentioned as source of the production with input materials, e.g. raw materials, which are transformed into the final product or finished good during the manufacturing process. According to the lean principles, a production should follow the pull principle and is controlled by the actual demand, also mentioned as sink of the supply chain. For this reason, the output of the value stream is dependent from the customer's requirement. Even, if the demand for final products fluctuates, also the output of a levelled production is related to the demand per period to avoid resource-binding inventory, defined as waste in accordance with the lean management principles. In summary, the recent research focus lies on considering the manufacturing process within the framework of Value Stream Management, with suppliers and customers being treated as given parameters, lacking an explicit investigation. This leads to the central research question:

How can business data be utilized to automate the mapping procedure concerning the domains of supplier as the source and customer as the sink of the supply chain in the value stream map?

The aim of this paper is to examine this research question and to propose a possible solution approach. The methodology outlined in the following section forms the basis for this.

2. Applied Methodology

The applied methodology is divided into four steps and follows the procedure model, visualized in Figure 2.

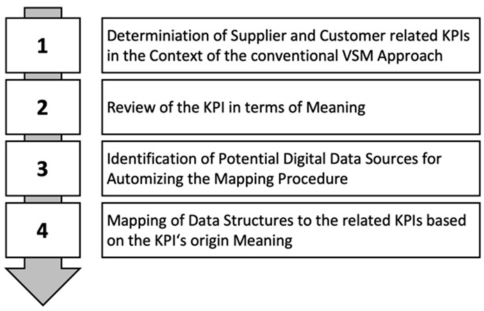

Figure 2: Applied Procedure

In the first step, the conventional Value Stream Management approach is reviewed with focus on the two domains of supplier and customer. Aim of the first step is the general determination of all supplier- and customer-related information, contained in the Value Stream Map. In the second step, the findings are structured and analyzed in terms of meaning, utilization and significance of the determined KPIs. Based on the refined and demarcated indicators, potential digital data sources, e.g. business application systems like ERP, enabling an automized derivation of the required information content from business application systems, are identified in the third step. The concrete business objects, e.g. customer order, purchase order and similar ones are deduced from the related digital data sources. Finally, the data structures of the business objects are mapped to the KPIs. In cases, a direct mapping of KPI and data structure is not feasible, calculation rules are redefined under the consideration of the KPI's origin meaning. In the fourth step a modular mapping framework is proposed, providing different ways of deriving the supplier and customer KPIs from available business information. By the modularity of the framework various company-specific process and systems landscapes are considered, which makes it universal in use.

The validation of the proposed approach is conducted on the basis of an SAP S4/HANA test environment, which covers the functions of common ERP systems and is provided by Magdeburg-Stendal University of Applied Sciences, Germany. Therefore, all figures depicting the graphical user interface are based on the testing environment, with the relevant data fields labeled.

2.1. Investigation of Customers in the Context of Value Stream Management

The customer is defined as demand of the value stream and highly impacts the manufacturing process and its efficiency. In accordance to Lean Management the manufacturing process should be controlled by the pull-principle. This means, the production is not based on forecasts, plannings and expected quantities, but only on actual customer demands. By this management principle, costs due to stock management, required for the materials, made to stock, as well as production lead times can be reduced. The value stream related indicators are mentioned according to [1], [2] in the following listing:

Customer (group)
A specific key customer or a selection of customers, grouped by the same conditions, e.g. ordering similar products, which can be grouped by a product family, defines the sink of the supply chain and impacts the required output of the manufacturing process according to the pull-principle of Lean Management.

Product / product family (output of the value stream)
The indicator product / product family is defined as the final product or material of the value stream.

Customer takt time
The customer takt time is the most important indicator to evaluate the effectivity of the value stream. The customer takt time [time/pcs.] is an indicator, which correlates with the reciprocal of the production rate from a sales point of view. The cycles time of each activity must be less than or equal to the customer tact to satisfy the demand with the given capacities. To calculate this key indicator, the following indicators are necessitated according to [1], [2], [23]:

- Factory days (according to factory calendar) in a specific period
- Daily working time
- Required quantity (annual sales volume) per period

Delivery time
The delivery time is affected by the logistical processing in the area of shipping and – if it is not stock material – the lead time of the manufacturing processing.

Delivery reliability
The delivery reliability is a performance indicator referring to the ability to consistently deliver products according to the agreed-upon specifications, schedules, and terms. It indicates the reliability or consistency of fulfilling delivery commitments without delays or errors.

Potential Data Sources
In general, the key indicators are directly connected to the domain of sales, but partially depend on the characteristics of the manufacturing process, e.g. available working time. As in the context of the supplier dimension, the ERP system is the central enterprise system, containing most of the required information. Additional data sources are customer relationship management (CRM) systems and sales platforms or order management systems (OMS) for information regarding customer, product as well as demand. But also supply chain management (SCM) systems are suitable data sources for determining (historical and future) sales volumes.

Mapping of Data Structures to KPIs
Products or product families define the value stream that is being examined more closely. This allows the demand causer, such as customer orders and consequently the underlying customers, to be identified.

The customer takt time is defined as the available time, in which an amount of one piece must be produced to match the customer demand. Therefore, its calculated as ratio of capacity's

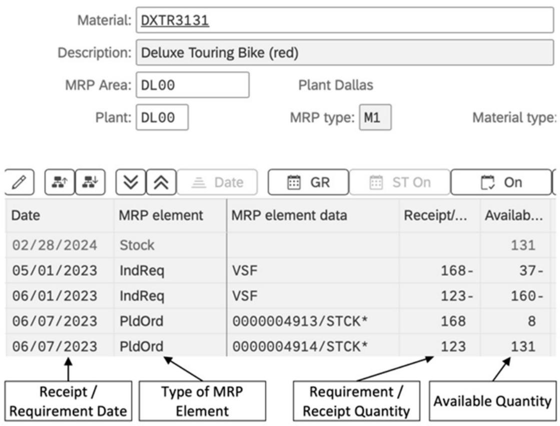

Figure 3: Determination of Sales Volume based on the Stock/Requirements List for one final Product

availability [time] per period and the customer demand [pcs.] per period. In the context of ERP systems, various MRP elements are differentiated, such as customer order, independent requirement, planned order, production order and further ones. The term MRP refers to the ERP-internal planning functionalities based on material requirements planning (MRP I) and manufacturing resource planning (MRP II). The selection of the relevant MRP-elements and the sum of all quantities in a specific period leads to the required quantity. For instance, a material-plant-specific stock/requirement list is shown in Figure 3, combining receipts and requirements including the related quantity and the date in one overview.
By the indicators daily working time and factory days, the average capacity availability is calculated, which is in addition to the annual sales volume

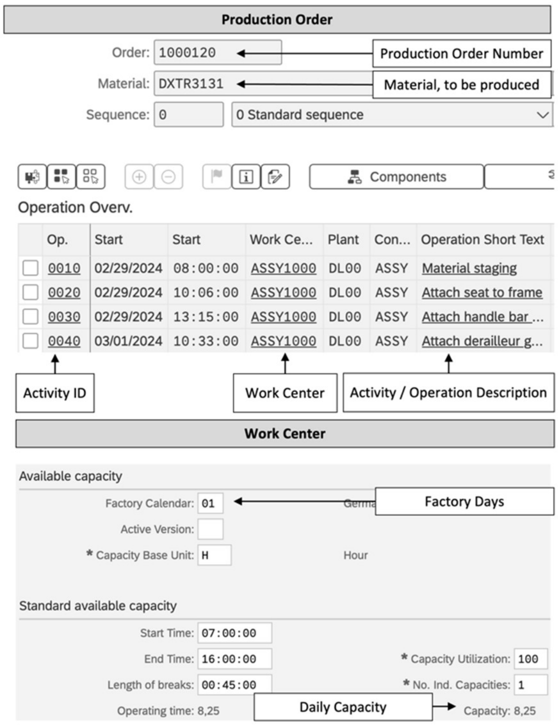

Figure 4: Determination of Availability based on Production Order and Work Center Parameters

required for calculating the customer takt time. These indicators are work center specific. The relevant work centers for producing the final product are determined by the material-related routing (master data object) and the concrete production order (transactional data object), as shown in Figure 4.
If all resources underly the same shift schedule and are not utilized by further production processes, the available capacity of the work center (production resources) is calculated by the related master data as product of factory days and daily working time. If the work centers' capacities are based on different shifts, but the same working days, the customer takt time can be calculated on a daily basis. Regarding work centers, which are part of further value streams or the full capacity is shared for the production of different products a proportional split of the capacity is necessary. Are more detailed consideration of capacities can be found in [23].

The actual delivery time is based on the stock level for unrestricted use. Customer orders are supplied from stock as long as stock is available. The information regarding the stock levels is available in ERP-systems, as shown in Figure 5, but also warehouse management system (WMS), directly connected to the ERP-system.

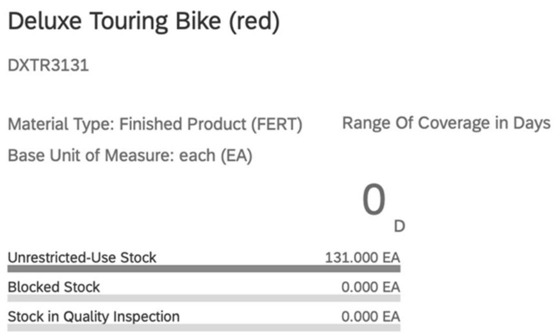

Figure 5: Product-related Stock Level

If no stock is available, the missing product must be externally ordered (in case of procurement type F) or internally produced (in case of procurement type E). Based on the MRP run, a backward scheduling is applied to determine the start of production of the final product based on the requirement date. If the calculated start date is in the past, a forward scheduling is applied. For procured material the replenishment time is explicitly maintained. From a sales' perspective handling times for packaging and shipping are available. On the basis of this data, the delivery time for stock material is calculated as sum of all handling activities in the area of shipping. For non-stock material the delivery time is extended by the replenishment time or production lead time as well as the times for logistical handling, e.g. inbound processing.

The delivery reliability is a performance indicator, derived from the planned delivery dates and the actual delivery dates. Therefore, the determination of this indicator is formula-based and requires historical data.

In addition to the mentioned business application systems, superior systems like DW and BI potentially provides the required information.

2.2. Investigation of Suppliers in the Context of Value Stream Management

The supplier in the Value Stream Map represents the source of the supply chain and ensures the supply of the manufacturing process. The value stream related indicators are mentioned according to [1], [2] in the following listing:

Supplier's name
The supplier´s name the identifier for the supplier, which provides the required components or raw materials to the company.

Materials (input components of the value stream)
The material or components are the input factors for the value stream.

Lead time for replenishment
The lead time for replenishment is the duration between two deliveries, e.g. controlled by delivery schedules, or in case of individual shipments the time between ordering and goods receipt.

Error rate/quantity reliability/delivery reliability
The reliability of the supplier is expressed by the three indicators, referring to volume (quality and quantity) as well as time.

Whereas the first three indicators are related to general master data information in the context of procurement, the last three ones are defined as relative indicators, describing the supplier's performance/reliability by relative indicators, which are calculated from the ratio of past-orientated transactional data and a reference value. The error rate (good, waste, repair) and quantity reliability (deviations as under- and over-delivery) relates to volume and the delivery reliability (punctual delivery) to time.

Due to the high complexity of the bill of material (BOM) structure of several products in practice, it is not economically feasible, to cover all materials by the conventional approach. Therefore, the investigation is limited to the most important or critical one(s).

Potential Data Sources
All indicators are directly connected to the domain of supplier. Therefore, potential digital data sources are business application systems, covering the operational procurement process, e.g. ERP as central enterprise system, but also domain-specific systems like supplier relationship management (SRM) systems and procurement platforms. Quality-related figures in terms of supplier assessment are available in quality management (QM) systems, covering supplier management functions. Data warehouses (DW) in combination with analytic tools and process mining enables further options of the automation of gathering the specific supplier information. The determination of the mentioned indicators based on ERP-data is described in the following section.

Mapping of Data Structures to KPIs
The production order is the central data object of the manufacturing process and defines, inter alia, the material and quantity, to be produced, the way of production (routing/activity lists with resources), as mentioned in the former section, and the input components based on the bill of material (BOM). In accordance to the base quantity, the required components and related quantities are calculated by the system. Furthermore, the listing of materials in the component overview shows the material allocation to the activity/operation in the manufacturing process, ensuring, that the materials are supplied in the area of production at that time, the material is actually needed, as shown in Figure 6.

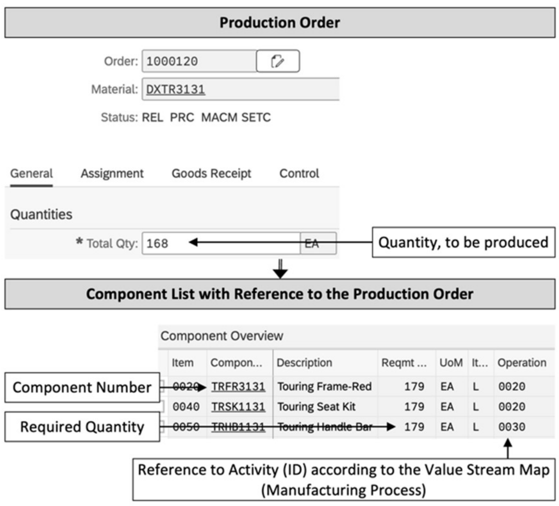

Figure 6: Determination of Input Materials of the Value Stream

By a drill-down to the plant-specific material master data, different views on the material are available, such as basic data, MRP, accounting, costing, storage location stock and further ones. In the area of MRP, the procurement type defines the material as in-house production (E) or external procurement (F) as shown in Figure 7.

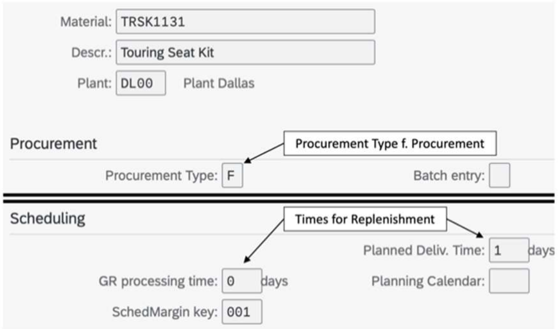

Figure 7: Determination of Source of Supply and Replenishment Time

For in-house production materials, the mentioned consideration enables the identification of interdependencies between the investigated value stream and adjacent ones, forming a system of value streams. The value stream, consuming a component corresponds with the role of a customer in regard to the value stream supplying the required component. This leads to interactions between these ones and rise the complexity to a level, the conventional methodology based on an analog model cannot manage.

Based on the externally procured material number, the available supplier or - in case of dual-/multiple-sourcing - suppliers can be derived. In SAP most of the information is contained in the purchasing info record, which is a source of information in regard to the procurement process, illustrated in Figure 8. Essential information, e.g. pricing and conditions and lead time can be directly derived and utilized for enriching the supplier information in the Value Stream Map. Furthermore, basic vendor evaluation reports are available and enable the rolling calculation of KPIs based on a specific period, e.g. one year. More detailed evaluations, which are not covered by the standard reports, can be processed by the targeted combination of data warehouses, business intelligence (BI) tools (business analytics) and process mining.

3. Results and Discussion

The paper at hand aims at the provision of a framework for automizing the mapping process of the conventional Value Stream Management procedure, limited to the consideration of the two domains of supplier and customer.

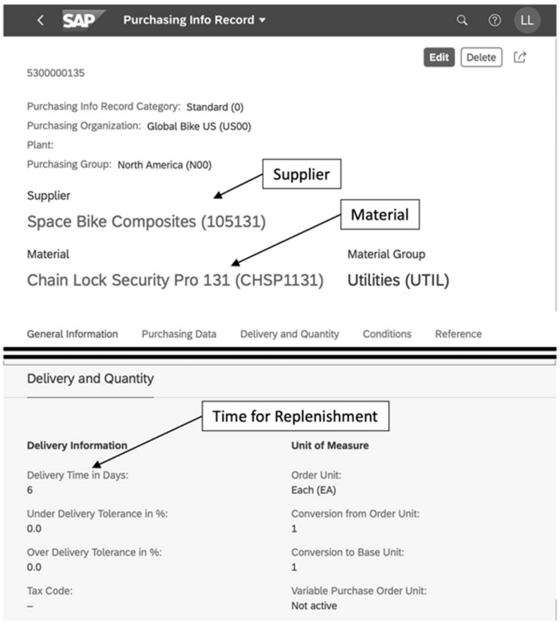

Figure 8: Determination of Supplier based on Purchasing Info Record

The starting point of this investigation is the determination of relevant supplier as well as customer indicators according to the conventional approach. The review of each indicator in terms of meaning and significance is the information baseline, for the identification of potential data sources. In the areas of the different data sources, e.g. ERP, WMS, MES and further ones, related data objects are determined to map the digital data to the appropriate Value Stream Management indicators.

The naming of data objects for the automated derivation of Value Stream Management indicators, as well as the identification of various data sources for these data objects, ensures modularity of the mapping framework. This supports universal usage in heterogeneous process and system landscapes. The fundamental feasibility is demonstrated through validation in an S/4HANA training environment, provided by the Magdeburg-Stendal University of Applied Sciences.

4. Limitations and Conclusion

Value Stream Management is still a valid and widely used approach to optimize value streams. As pointed out in various studies, the conventional procedure has some improvement potentials to ensure its economical application in highly dynamic environments. Recent studies provide approaches for the combination of the conventional methodology and modern information and communication technologies. The focus of this consideration is mainly limited to the manufacturing process. By the paper at hand an approach is discussed to enhance digitalization of

VSM by covering the two domains of supplier and customer.

As detailly described in the previous sections, the mapping Value Stream Management indicators in the domains of customers and suppliers in its origin meaning to data objects, hosted by different types of business application systems is generally feasible. Different data sources are discussed and included in the consideration.

The present study provides a solid foundation, yet it also exhibits limitations that offer potential for further investigation:

As emphasized, the validation of the mapping framework is restricted to the consideration of an S/4HANA training environment. In the next step, the validation is to be extended to other application systems.

The study at hand focuses on external suppliers. The topic of intra-company customer-supplier relationships, which lead to interactions between value streams, mentioned in section 2.2 under the term "system of value streams" and visualized in Figure 9; however, a more in-depth examination is lacking. The digital representation of value streams, as well as the application of simulation models, opens up options in this context that go beyond the possibilities of the conventional approach. In addition to the aforementioned customer-supplier-relationships, also the consideration of shared resources, utilized in more than one value stream, offer investigation potentials, taking into account the tendency towards more flexible production configurations.

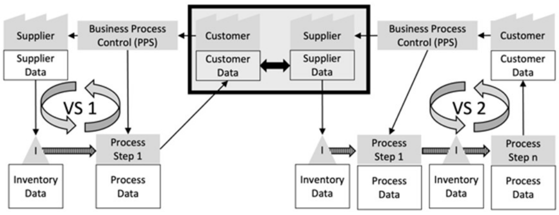

Figure 9: System of Value Streams

Value Stream Management 4.0 follows the approach to create a digital representation of a Value Stream Map as a data-based model, continuously enriched by operational data. Such a digital model opens new opportunities in regard to the utilization of techniques in the field of data sciences. But a detailed analysis of the concrete potentials in terms of VSM and the residual phases is missing and requires further investigations – not only in the domains of supplier and customer, but also in the domain of the manufacturing process.

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