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MULTI-LEVEL INFORMATION VALUE STREAM MAPPING

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Abstract: *Digitalization and automation of the production according to Industry 4.0 opens new opportunities for companies to develop more efficient value chains. In the context of mass customization, it is promising to examine more closely the complete internal value chain of companies, from the first customer contact to the delivery of the finished product, prior to provide digital configurations for customized products. A critical aspect for internal inefficiencies and complication of an aspired automation are the interfaces of departments due to inconsistent and non-uniform information transfer.*
This article presents a versatile approach to visualize the internal information flow at inter-departmental level as well as at intra-departmental level. The described multi-level information value stream mapping method perfectly suits as prerequisite for a digitalization or automation of internal information flows. As framework for the time capturing and visualization, ISO 22468 is used, and an industrial use case exemplifies the research findings.

Key Words: ***Value Stream Mapping, Complete Internal Information Flow, Multi-Level, Digitalization, Automation, Visualization, Mass Customization***

1. INTRODUCTION

The fundamental concepts in the field of lean management are mainly connected to the introduction of the Toyota Production System (TPS) [1], later known as Lean Production Systems (LPS), with a primary goal to reduce operating costs through eliminating all non-value adding entities (waste/ muda) from the value chain of a company. In LPS, the customer-centric aspects such as best quality, short lead-time, and lower costs are key focus areas, which can be achieved through a set of tools and methods (e.g. JIT, jidoka, …) that aim to minimize the operating costs by reducing waste in production processes [2]. Value stream mapping is one of the more common lean methods [3], which is used to develop the current state visualization of product and information flows within organizations and represents one step of the overall value stream management (VSM) procedure [4].

VSM is an effective, easy to use tool to collect, evaluate, and continuously improve product and information flows within companies in a common and standardized manner [5]. The fundamental VSM concept has been developed by Rother & Shook [6], and over the years, a large variety of different VSM approaches were generated, leading to misunderstandings and conflicts within supply networks [7]. A holistic methodology for the assessment and subsequent optimization was needed to communicate in a standardized way throughout complex supply chains [8]. ISO 22468 provides the necessary guidelines for the application of VSM with regard to the collection, evaluation and continuous improvement of value stream relevant data, applicable in material-, energy- or data-related processes [4].

Industry 4.0 (I4.0) is considered to be the 4th industrial revolution, with as one common, technical definition [9]: "*Industry 4.0 is defined* as *digitization of the manufacturing sector, with embedded sensors in virtually all product components and manufacturing equipment, ubiquitous cyber-physical systems (CPS), and analysis of all relevant data*." The increasing use of Information and Communication Technology (ICT) in the manufacturing sector, mainly in reference with I4.0, brings new opportunities like the digitalization and automation of processes or information flows. These new I4.0 requirements can be challenging for companies, mainly if over time different IT storing systems have been used. The result are wasteful actions which hinder a proper and digitized production [10].

The multi-level information VSM introduced in this article opens new possibilities to analyze and assess the internal information flow in an end-to-end perspective prior to a pursued digitalization or automation. For the case company this was important for an anticipated replacement of a manual configuration with an online configuration, mainly in regard of mass customization (MC). MC is defined as an organization's ability to provide customized products and services which fulfil each customer's idiosyncratic needs without significant compromises in cost, delivery and quality [11]. The classic VSM is used as a framework and extended to visualize the different departments throughout the internal value chain, the used software, the respective process- and idle time as well as the information flow and information order throughout the complete processing sequences. The visualization can be performed at different levels, meaning at an inter- (between more than one department) and at an intra-departmental level (within one department).

The following sections of this article are structured as follow: First, a literature review concerning extended VSM methods to capture the internal information flow more in detail is done. Secondly, the methodology of the multi-level information flow VSM is elaborated before its application is shown by a use case study. Lastly, a conclusion to sum up the work is provided.

2. LITERATURE REVIEW

Countless articles exist on the application of conventional VSM (material and information flow), which is widely used in the industry to assess value added and non-value added activities in operations [1], [3], [5], [7], [8], [10], [12]–[15]. An extensive review of different VSM applications can be found in [16]. The aim of this section is to extend the literature review of [16] by examining the efforts conducted to extend conventional VSM to capture the internal information flow and to briefly explain the procedure of ISO 22468.

Thomas Meudt et al. [10] proposed an upgraded value stream mapping method for companies with an existing Lean Production (LP)-System that need orientation on how to react to the new challenges raised through I4.0. This new approach allows companies to systematically understand opportunities offered by digitalization and I4.0 to develop their lean production approach to the next level. In a conventional VSM, a material flow is always connected to an information flow (e.g. to schedule production, to evaluate performance information) and used to depict the information flow between the production processes and the IT-systems. Here, the focus lies on improving the lead time of a product and not on depicting Information Logistical Waste (ILW will be used in the following). Information Logistics (IL) are understood as the planning, management, realization and control of the totality of information flow as well as the storage and processing of this information. Especially, information flows of decision making are considered for IL. ILW is divided into three groups: data generation and transfer, data processing and storage, and data utilization. In this approach, the objective is to analyze and visualize a current state of value streams in terms of material and especially for information flows by depicting ILWs. The method is divided into six sequential steps. The first step is the conduction of a classical value stream map to get a general understanding of the value stream. The second step is to list all the storage media, used for recoding of data points and KPIs. The third step is to connect data points, KPIs and all further locally collected data of production and logistic processes with its storage media through vertical lines and junctions. The fourth step serves to determine the usage of data, so to check the purpose of collecting data points/ KPIs. In the fifth step, the types of ILW for all processes and logistics elements are collected. The last and sixth step is to rate potentials and spheres of activity.

Timo Busert et al. [13] developed a six-staged procedure to ensure sufficient information quality (IQ) for an efficient production planning and control (PPC), mainly in regard of the increasing information availability provided by I4.0. Many companies increased their internal flexibility and accelerated their operational processes by applying LP principles, like reduction of waste, a continuous improvement of processes, and a change in production control towards demand-oriented production. One problem here is, that LP was invented in the 1950s and did not need to consider possibilities of modern ICT. For this reason, man LP principles have been exhausted in terms of their efficiency for the control of operational processes. For the controlling of operational processes nowadays, LP and I4.0 can reinforce each other. The six-staged procedure aims to present a conceptual framework based on the value stream mapping method to systematically analyze operational processes, to develop concepts, and to harmonize the necessary information flows to control operational processes. The first step consists of a classical value stream analysis, to get a general understanding of the value stream to identify improvement potentials, similar to the first step of [10]. The second step is the concept development, where a concept must be developed how to attain the identified production control Kaizen. The third step is the modelling of information flows, where the data acquisition, transmission and the information processing is modelled. The fourth step is the harmonization of IQ, by determining information quality dimensions for existing information flows and deriving requirements of the IQ dimensions. The fifth step is detailed planning and implementation, by selecting information acquisition and transmission tools, defining storage media and interfaces of IT-systems and a concept roll out. The last and sixth step is the evaluation of the effectiveness of the concept by evaluating the achievements of the defined targets and identifying further improvement potentials.

Nauman Bin Ali et al. [14] propose to combine value stream analysis with FLOW, which is a methodology that systematically captures and visualizes channels for information flow and allows the identification of sub-optimal communication paths. The simple notation, ability to identify and visualize both documented and undocumented channels of information, make FLOW a practical and relevant complement for use in conjunction with VSM. The idea of this combined FLOW-assisted VSM is to first conduct a typical artifact flow analysis and secondly an information flow analysis done by the FLOW approach to overcome the limitations of existing VSM methods and notations. Through a case study its success was proven in systematically uncovering issues, characterizing their solutions and indicating their practical usefulness for waste removal with a focus on information flow related issues. The FLOW-assisted VSM aims to improve the large-scale software product development process, mainly with the ability to capture complex information flows and identify improvements opportunities during the development. The combination of FLOW and VSM is an interesting approach to compensate the weaknesses of both methods and thus be able to conduct a profound information flow analysis.

Dagmar Piotr Tomanek et al. [17] developed an innovative evaluation scale to classify information flow following the added value. The collected data was visualized by using the Value Added Heat Map, which is a visualization tool that indicates the level value creation concerning production relevant factors. The information flow is classified by the authors in six value added levels from zero to five. The effort that is needed for the information exchange serves as scale for the categorization. The higher the effort, the lower the value added level and vice versa. The first categorization (level 0) is ‘No Added Value’ and means that the exchange of information is insufficient, incorrect or unnecessary with maximal effort. The second categorization (level 1 – level 4) is ‘Limited Added Value’ and means a written (level 1), verbal or visual (level 2), not real-time electronical (level 3) or real time electronical exchange of information (level 4). The third and last categorization (level 5) is ‘Maximum Added Value’ and means a digital exchange of real-time information with minimal effort. This method shows a possibility to visualize losses of time through deficient or defective information.

Further VSM applications which focus on the information flow can be found in [18]–[22].

The different applications of VSM have been summarized and standardized in the ISO 22468 [4], which is the first international standard for value stream management and has been published in march 2020. ISO 22468 provides guidelines for the application of VSM with regard to the collection, evaluation and continuous improvement of value stream relevant data. A standard for VSM was necessary due to the large variety of different VSM approaches since the 1990s. Mainly, communication and collaboration issues appeared during the application of VSM in practice due to different value stream visualizations and associated calculation procedures. These challenges mainly occur at the interfaces of departments, corporate groups or entire supply chains. The standardized VSM method ensures a unified collection, visualization and calculation of value streams within companies, corporations and along supply chains. The basic VSM procedure is divided into three main phases:

- Value Stream Analysis
- Value Stream Design
- Value Stream Planning.

Every main phase is divided into three fundamental steps and collectively they cover the PDCA-cycle. Beside a common procedure, the following common characteristics are defined within ISO 22468: symbols and terminology, parameters, calculation procedures and data boxes.

To sum up, this literature review has shown that many different approaches have been developed to analyze the information flow more closely by means of the VSM method. It has been identified that most research studies neglect the visualization and analysis of the complete internal information flow on different levels and that no attempt was made in developing a prerequisite for an envisaged digitization or automation The multi-level VSM approach described below will focus on solving this problem statement.

3. METHODOLOGY

In this section, the methodology of the multi-level information VSM is described more in detail. First, the intended field of application is stated secondly, the basic procedure with its different steps is clarified.

Conventional VSM is a useful technique applied to identify opportunities for kaizen efforts (continuous improvement) to eliminate waste in a system. The benefit lies in being able to visually present the state of performance of a production line or any other studied system. To preserve its value as a useful and easy-to-use tool, these features must be maintained during the extension towards the multi-level information VSM.

The objective of this method is to examine the entire internal information flow from product enquiry through the customer to product dispatch to the customer as simple and clear as possible. A major difference between the conventional and this multi-level information VSM is that instead of the supplier symbol (left upper part), the customer symbol is illustrated twice (left and right upper part). This is necessary, since this method only focuses on the information flow between the company and the customer, and not on the information flow between the company and its suppliers of raw material.

The visualization can be done at different levels and can be used as prerequisite for a later digitalization and automation of internal information flows. Its main aim is to detect and localize inefficiencies and ILW [10] throughout the complete internal value chain.

3.1. Field of application

The multi-level information VSM method is universally applicable but provides the most significant added value for companies with a high density of complex information exchange. This means that the internal information flow goes through different departments, who are using different software and are always adding new additional information to the system. This is often the case for companies, which work with a lot of individual orders (order-related individual production) and do not process standardized procedures (series production). In the complex environment of individual production, different individual tasks need to be performed by different departments and thus ILW often arises unconsciously since every department is mainly focused on its own tasks. If, a company went through a rapid growth and steady expansion of its company size and product portfolio, its IT-system probably went through the same expansion. This normally results in a high number of different operating systems (difficult to pass on information internally which leads to information entanglement) instead of one common IT-system with interacting sub-systems. The result is a complication of the internal communication due to different software within each department.

For companies with a high density of complex information exchange which are using many different operating systems, it is difficult to adapt to the needs of I4.0 and keep up with the required digitalization and automation. The multi-level information VSM should be applied in the previous described field of application to support these companies with a method to easily visualize and understand their complex internal information flow and be used as prerequisite for a later digitalization and automation of internal information flow processing. The different levels allow an in-depth analysis of critical areas. Additionally, it can be used to detect ILW throughout the internal information flow.

3.2. Procedure

In the following, the basic procedure of the multi-level information flow is described. The procedure is divided into the following five steps (figure 1) and is inspired by the PDCA-cycle [23].

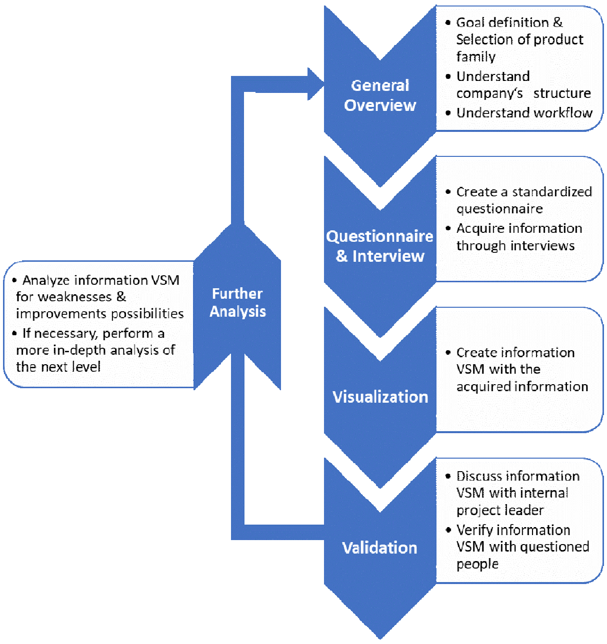

Fig. 1. *Basic procedure of multi-level information VSM*

To start with, it is important to get a general understanding of the company's structure with its different departments and work tasks. After this, a structured and standardized questionnaire should be established (Plan), which serves as help to acquire the information during the interviews. The next step is to visualize the internal information flow throughout the different departments with the respective software with a value stream map (Do). The fourth step is discussing the value stream map with the internal project leader and later verifying it for accuracy with all the questioned people (Check). The last step is a more in-depth analysis of the next level, so an intra-departmental analysis (Act).

In the following, the different steps of the procedure are described more in detail.

3.2.1 General Overview

Before starting with the actual work, it is important to define the goal of the project and to choose a specific product family. The goal can either be to simply detect ILWs or to visualize the complete information flow before starting with a digitalization or automation of the internal information flow. In the second case, the multi-level VSM analysis is a prerequisite for a later digitalization or automation. After this, it is important to get a general overview of the company under investigation and understand the structure and functioning of the company. The internal jargon should also be understood to avoid misunderstandings. In both points an internal contact person who has a profound knowledge of the company and its processes is a great help. In the following, this person will be referred as 'internal project leader'. Later, a chronological presentation of all the departments that are part of the workflow for the selected product family needs to be listed together with the internal project leader which is the framework for the level 1 map.

The internal level breakdown as well as the difference between inter- and intra-departmental analysis is described hereinafter. The first level (level 1) is the basis for all the following levels and is an inter-departmental (between more than one department) analysis of a company. At this level the different departments (e.g. sales, scheduling, production engineering, manufacturing, etc.), which are part of the work process for a specific product family are mapped and analyzed in a chronological order. The second level (level 2), is a breakdown of level 1 and thus is a more in-depth analysis of a specific department. This department specific analysis is referred to as intra-departmental (within one department) analysis of the different work processes (e.g. entering sales quote, retrieving customer information, etc.) within one specific department. The third level (level 3) is a breakdown of level 2 and thus is a more in-depth analysis of a specific work process within one department. Meaning, how does a worker perform a specific work task and how does the worker gather the necessary information. This breakdown results in a pyramid-shaped figure (see figure 2), with on top the company under investigation at the second plane the different departments (level 1), at the third plane the individual processes of a specific department (level 2) and at the bottom plane the individual sub-processes of a specific process (level 3). These levels are similar to the level breakdown into macro-, meso-, micro- and nano level [16] within the conventional VSM.

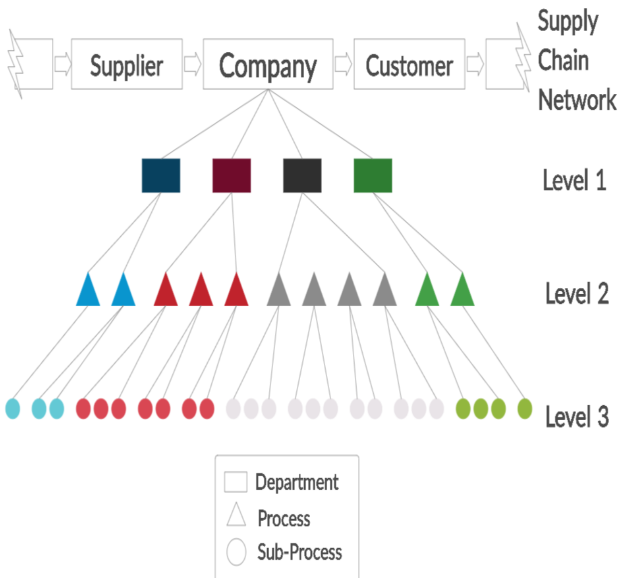

Fig. 2. *Level breakdown of multi-level information VSM*

It is not necessary to further breakdown every department into a level 2 or level 3 analysis. The extent to which the filtered level should be broken down depends on the respective company and its respective goals. This way, the methodology can be adapted to the needs and go into as much detail as desired. Normally, it is only necessary to further analyze critical departments with a long process time, to detect weaknesses and bottlenecks of internal information flows.

3.2.2 Questionnaire & Interview

A level-specific questionnaire is compiled, which makes it possible to document the information flow and the corresponding IT-systems. It's important that the questionnaire is based on a few constructive questions in order to not create an overabundance of unnecessary information that is difficult to sort. The input and output information flow as well as the processing time and software information form a solid basis for the level 1 questionnaire. An example of a level 1 questionnaire is shown in table 1. The level 2 questionnaire would relate to the main steps of the departments and the information flows generated. However, it is advisable to approach level 2 only after completing the diagram for level 1.

Table 1. *Questionnaire Example – Level 1*

Level 1	**Department**	
	# Operators	
	# Software	
	Responsible Person (SME)	
	Product Identification	
	Primary Input (From/ What)	
	Secondary Input (From/ What)	
	Output (To/ What)	
	Processing Time	

With the help of the internal project leader, one person per department should be selected who can provide the necessary knowledge to answer the questionnaire. This person should work in this department for a long time and be aware of the respective work steps. In this case, the person is referred to as Subject Matter Expert (SME). During the interview the SMEs of the different departments should provide necessary information to fill out the questionnaire and if needed they need to gather further information. The questionnaire only serves as a guide for the consultant to help focusing on the most important aspects. During the interviews with the different SMEs, it is important to coordinate/ match the information from the different respondent. Therefore, in the example questionnaire input and output is mentioned. This means that the information from department A concerning their output should be matching with the information from department B concerning their input. After the interviews with all the SMEs are finished, the received information should be analyzed together with the internal project leader and if inconsistencies are detected, a second round of interviews may be necessary.

3.2.3 Visualization

With the information gained from the interviews it is possible to create the level 1 information value stream map, which is based on the ISO 22468 guidelines [4]. The level 1 information value stream map is divided into four main parts:

- Departments
- Software
- Information flow & - order
- Timeline

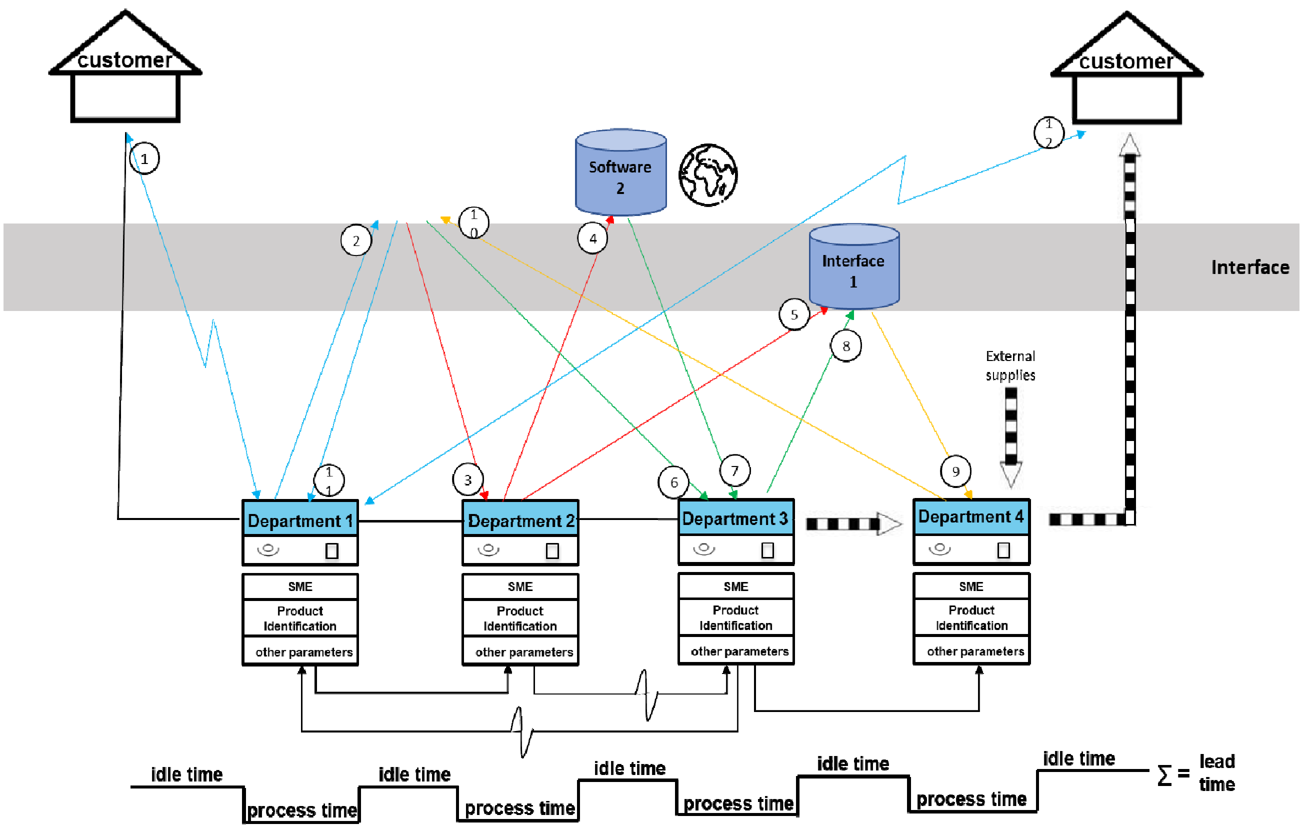

Fig. 3. *Typical multi-level infomration VSM – Level 1*

Figure 3 illustrates the four parts in a typical multi-level information VSM and serves as visualization example. To start with, the different departments are listed in a chronological order and gives a certain structure. Additionally, on the upper left and upper right side, the customer symbol is placed. In the conventional VSM, a supplier symbol is placed on the upper left side. This is not necessary, since the multi-level information flow analyses the information flow from a customer perspective (inquiry and acceptance). Beneath the respective departments, a data box with the information from the questionnaire is added to summarize the gathered information. The second step is to list the different software with its respective interfaces (marked in grey) above the departments. They replace the production planning and control symbol from the conventional VSM. The third step is to visualize the different information flows with its respective order. The information flow is either going from a department to a software (output = department; input = software) or the other way around, from a software to a specific department (output = software; input = department). This is depending on the fact that either a department is uploading or downloading a certain information to or from a software. Each information flow (one specific information) is depicted as an arrow indicating the direction of the information. Every information which is transferred between two departments without any intermediate software, is depicted as direct arrows underneath the departments. The last step is to add the timeline, with the respective process-, idle- and total lead time. The process time is the amount of time which a department needs to fulfill its work task. Additionally, the processing time can be added in the data box to indicate how long the individual work tasks took, so the actively processed time. The idle time is the time which passes between department A finishes its work task and department B starts processing with the following work task and the lead time is the sum of the all process- and idle times. Table 2 summarizes the used symbols.

Table 2. *Summary of used symbols* [4]

Symbols			
Category	**Symbol**	**Term**	**Additional information**
process		process	indicates for level 1 the respective department and for level 2 and 3 a certain process
process		customer/ supplier process	differentiation: end customer (symbol customer process) vs. customer/plant (symbol external sources) if supplier also customer, use customer symbol
process		operator	number of operators responible for the tasks of a department position in value stream diagram: within process symbol
process		resource	define resources for every process type in this case software the number of different software used position in value stream diagram: within process symbol
process	parameter 1 parameter 2 parameter 3 parameter n	data box	(pre-)selection of process parameters, cf. data per process type position in value stream diagram: within process symbol
product flow		PUSH product flow	product flow controlled by upstream processes in this case it is an indication that an actual product is forwarded
information flow		information up- or download	colored arrow indicates an information exchange (up- or download) between a department and a software. Every department has its own color.
information flow	1	# information flow	respective order of the information flow
information flow		manual information flow	e.g. list, label, document only applies for direct information exchange between departments or between a company and its customer
information flow		electronic information flow	e.g. telephone/fax, mail, EDI only applies for direct information exchange between departments or between a company and its customer
software	Software x	software	different software used by the departments
software		globe symbol	indicates that a certain software is used by departments from different locations

3.2.4 Validation

After finishing the value stream map, it is important to discuss it with the internal project leader to see if all the needed information were taken or if some are still missing. To make sure that no misunderstandings or false assumptions have been done, it is important to verify the value stream map for accuracy with all the SMEs. If necessary, adjustments must be conducted before the visualization of level 1 is finished. It is important to make sure that the requirements set for the level 1 information flow visualization have been met and that no inconsistencies are present.

3.2.5 Further analysis

The last step of the first cycle is to analyze the value stream map more in detail to detect waste (ILW), to identify improvements possibilities and to see if a further breakdown is necessary. This should first be done separately from the internal project leader (to not influence each other) and later during a workshop together with the internal project leader. If problems are detected or if the available information is not clear enough to decide, a further breakdown should be considered in order to analyze a certain department more in detail.

For a further breakdown, the same basic procedure, which is adapted to the needs of a level 2 or 3 analysis should be applied.

4. APPLICATION CASE STUDY

To validate the proposed model, a pilot case study was conducted with a local supplier of manufacturing solutions (hereinafter named case company), which is globally active and has locations all over the world. With employees working in different countries and even on different continents, a lean information flow and a well-structured communication is important. Most of the case company's products are tailored to the needs of the customer (build-to-order products), what makes mass production impossible and requires a vast amount of information handling. Nevertheless, the analyzed product family *Tronto* (fictive name) is suitable for a partial standardization and automation because only a few parameters (e.g. number of drilling operations) change based on customer requirements.

The aim of the project was to replace the time-consuming manual configuration via phone and mail of the analyzed product family *Tronto* by an online configurator. In terms of MC, the task can be summarized as aim to provide customized products without taking significant compromises in cost, delivery and quality. Additionally, the internal information flow for the same product family should be automized in a way that the actual production could start faster. This means an automatic handling of tasks which take place before the actual production like the verification of the solvency of the customer or the technical drawings of a product. In a lot of cases, the information handling is responsible for a major amount of time of the overall lead time and thus should not be neglected. Prior to the automation, it was important to get a clear understanding of the different tasks within the individual departments.

The multi-level information VSM perfectly suits this problem statement, since it allows an exact analysis of the internal information flow at different levels and thus enables the possibility to localize all tasks which could be automatized as well as ILWs. The rest of this section is structured equally than the methodology.

After having a clear goal definition in mind and selected a product family, the first step is to get a general overview of the case company under investigation and thus understand the case company's structure and understand the workflow of the product family. The internal project leader was of great help to accomplish this first step. As already mentioned before, the product family *Tronto* was chosen and its overall workflow through the different departments was mapped.

The second step is to create a questionnaire and perform interviews to gather the needed information for the later visualization. The questionnaire for level 1 was the same as shown in table 1. After having established the questionnaire, the next task was to perform the interviews with the respective SMEs. The interviews were performed together with the internal project leader in the same chronological order as the different departments were mapped at the previous step. Following this sequence, it was easier to recognize inconsistencies between the different departments. At this point, it is important, as already mentioned in paragraph 3.2.2, that the output information from a department is corresponding with the input from the subsequent department. Most of the interviews took less than an hour. To get a better idea of the performed work, it was helpful to first let the SMEs explain their work briefly before starting with the actual interview.

The third step is to visualize the acquired information in an information VSM as shown in figure 4. In total, nine departments which are using seven different software are involved in the handling of one production order for the product *Tronto*. The respective departments are Sales, Project Engineering, Finance, Scheduling, Production Engineering, Production Control, Process Planner, Production (Manufacturing and Assembly) and Shipment. The used software are CRM (customer-relationship-management), ERP 1 (enterprise-resource-planning), Design Tube, ERP 2, Autorelease Tube, Teamcenter and Assembly Board. Figure 4 clearly shows that a lot of different tasks are performed by the departments, for which they need many different software. An exact explication of the different up- and downloads of information from the departments to the software, the same as the different process- and idle times should not be elucidated here, since this is not the scope of this article. It is only important to see, that the information exchange for only one product can easily increase to many exchanges, which normally do not follow a strict roadmap but are the result of a growing company. Unfortunately, this is a normal situation for companies who expanded a lot during the last years and needed to acquire many different software for different tasks. If the inter-departmental communication is lacking, a structured and unanimous use of software throughout different departments is not the case and ends up in a lot of ILWs. The multi-level information VSM helps to depict and analyze this vast amount of information flow.

A detail view of the first two departments with its respective information flow is shown in figure 5. It should be clarified once again, that at level 1, only the main information flow is depicted. At the beginning, an electronic information exchange (phone or mail) takes place between the customer and the sales department, like the exchange of technical details, the purchase order, the sales quote and the quote information. The sales department uploads the quote information into the CRM software and receives the sales quote. The next department, the project engineering departments can download customer information from the CRM software and receives additional order information directly from the sales department via mail. Now, the project engineering department can create the product quantification within one of the two used ERP systems. For the further steps, other departments are interacting as well and should thus not be elaborated more in detail.

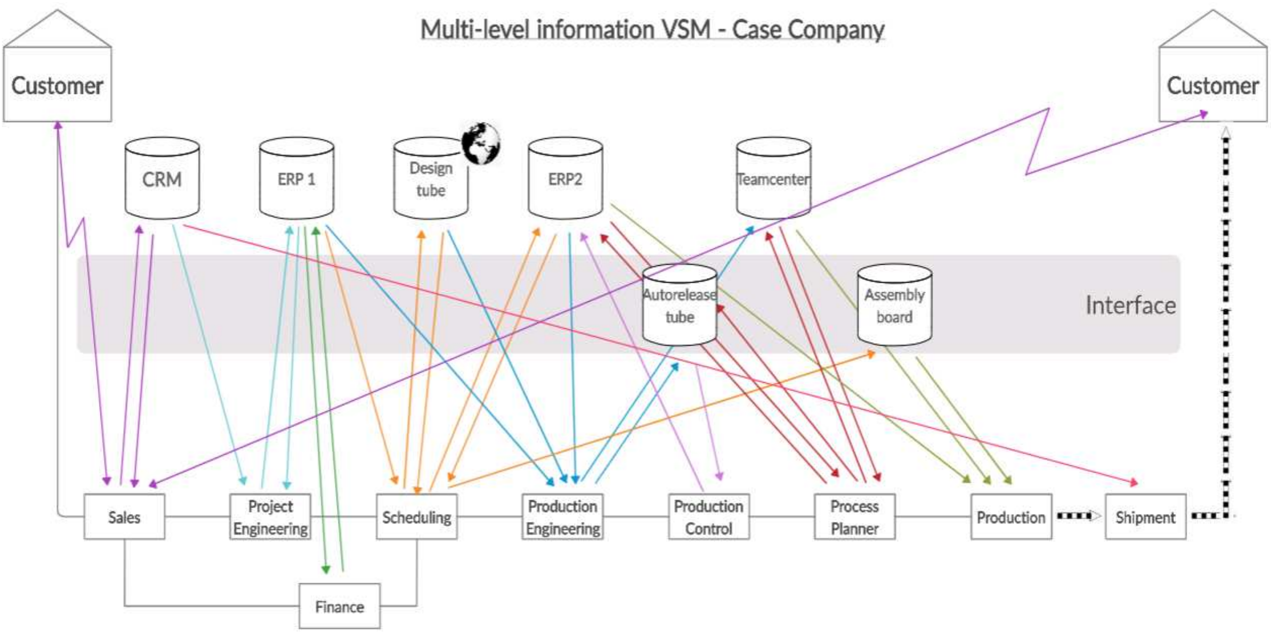

Fig. 4. M*ulti-level information VSM of case company – Level 1*

Within the sales department, one person is responsible for the tasks and is using two different software (depicted by the operator and resource symbol, see table 1 for further information). The second software is a specific software for the sales department and thus is not visualized at the level 1 but would be visualized at level 2. As already mentioned in 3.2.3, PI stands for project identification, PT for process time (total amount of time which a department needs to fulfill its work task) and PRT for the processing time (time of the individual work tasks). After having visualized all the needed captured information, the third step is finished, and it is now important to revise them.

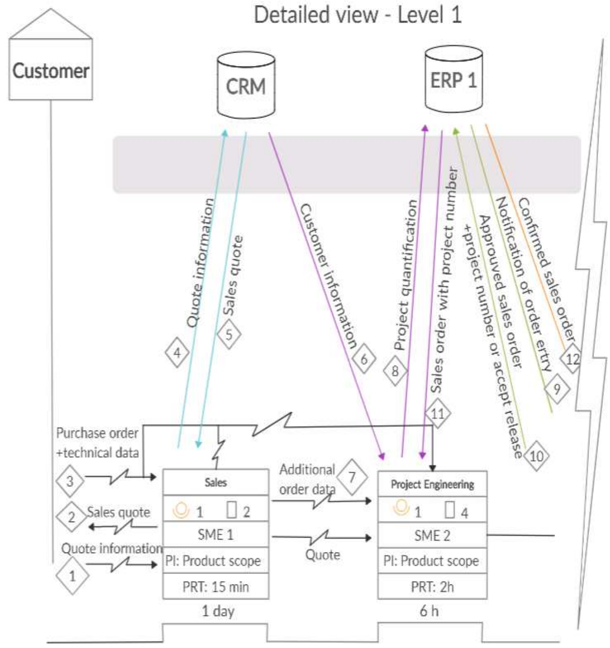

Fig. 5. *Detailed view – Level 1*

The fourth step is called correction and aims at verifying if the gathered information is correct and complete. To do so, first the established level 1 information VSM was discussed with the internal project leader. The aim of this discussion was on the one hand to verify if the gathered information is correct and on the other hand to see if some information were missing and thus another interview round had to be carried out. Additionally, the information VSM can be shown and discussed to the different SMEs, with two goals in mind. First, it helps to verify the gathered information once again and secondly it helps bring attention to the different SMEs to not only focus on their own department but to see the overall picture. It can be very useful for workers from different departments to see, recognize and understand the work tasks from other departments and thus improve the overall communication.

The fifth step is a further analysis with the aim to analyze the information VSM for weaknesses and improvement possibilities the same as to decide if further, more in-depth analysis is necessary or not. At this point it is important to consider the initial goal definition. If the aim was to depict ILWs, it is maybe enough to first focus on the level 1 analysis by trying to improve the inter-departmental information flow. ILWs can be classified into three different groups [10]: data generation and transfer, data processing and data storage and data utilization. Furthermore, the classical seven lean types of waste [24] can be analyzed. However, if the level 1 information VSM shows that the process time of one department is extraordinarily long, it could be useful to further breakdown this department with a level 2 analysis. On the other hand, if the goal was to use the multi-level VSM as prerequisite for a later digitalization or automation, like it was the case for the case company, it is important to determine if a level 1 analysis is enough or if certain departments need to be considered more in detail and thus a level 2 analysis is necessary. Depicting improvement potentials, the same as defining the automation tasks are out of the scope of this paper and are thus not considered more closely.

This was the last step of the first cycle and finishes the application case study. Before concluding, the benefits of using the multi-level information VSM should be summarized at the example of the application case study. For the case company, the multi-level VSM was very useful to depict its large amount of internal communication and information flow in an easy and structured way. By applying a level 1 analysis, it was possible to get an overall image of the internal usage of software and its involving information flow. This is helpful to show and highlight the importance of a structured and well-organized communication between the different departments within a globally active case company. Furthermore, it was possible to allocate weaknesses (long process time) to specific departments. A future level 2 analysis of certain departments will allow the company to highlight their information flow bottlenecks even more exact and thus be able to improve these bottlenecks or even completely avoid them during the aspired automation. Other companies can use this new method in a similar way.

5. CONCLUSION

With the multi-level VSM an easily understandable method was introduced to visualize and analyze the internal information flow of a company throughout different levels of application. Regarding the new challenges of I4.0, it gets more and more important for companies to clearly understand what an excessive use of different internal software means and how complicated it makes the internal data management.

Companies which aim to digitalize and automate their complete or partial internal information flow, aiming at MC, can use the multi-level VSM as a prerequisite. In this case is it important to gain a clear overview of the executed tasks of every department prior to change an internal IT-system. Since the typical timeline from the conventional VSM approach is kept, the multi-level VSM can be used as well to detect bottlenecks in the processing of the internal information flow. The timeline will point out irregularities, like long process- or idle time, and the multi-level approach allows to take a more detailed look into specific intra-departmental information processing.

The described case study proves the model's applicability as a prerequisite for a later standardized automation of the internal information processing. The aim of the case company was to replace the currently used manual configurator with an online configurator in order to fulfill the customers design requests without any negative impact in costs, delivery or quality of the products. Prior to do so, it was important to get a clear overview of the different tasks and information flows within the different departments. This task was successfully performed for the product *Tronto* with the multi-level information VSM.

This easy to use extension of the conventional VSM approach shows once again the broad applicability and practical utility of VSM in the industry. Further research needs to be done in including the information flow between the company and the supplier of raw material or parts as well. Currently, this method only focuses on analyzing the information flow between the company and the customer, however, to further improve the digitalization or automation, the information flow between the company and its suppliers need to be analyzed as well. Another possible improvement would be to simplify and clarify the design of the current method. For large information flows, it is difficult keep a clear overview over the individual information flows. The different colors as well as the numbering helps but could still be further improved. A last interesting future research could be to combine the multi-level information VSM with the later digitalization or automation. This way, the multi-level VSM would not only be used as prerequisite but could be used as guide for information flow digitalization and automation in the sense of I4.0

The case-study proved that this new multi-level information VSM is an easy to use method to visualize the internal information flow, to detect waste and bottlenecks within the information flow as well as prerequisite for a later digitalization or automation.

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Find more details about the project Di-Plast at https://www.nweurope.eu/projects/project-search/di-plast-digital-circular-economy-for-the-plastics-industry/

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