Value Stream Mapping for Natural Gas Supply Chain: Literature Review

Davor Dujak, Josip Mesaric, Dario Sebalj

***Abstract*—**Aim of this research is to provide extensive overview of research achievements regarding use of value stream mapping in natural gas supply chain analysis and optimization activities, and to provide guidelines for more effective value stream mapping use. Indicative preliminary literature review has been done by analyzing and comparing relevant scientific papers from Web of Science Core Collection and Scopus scientific databases dealing with value stream mapping use in natural gas supply chain activities. Results indicate only 9 research papers that use value stream mapping in natural gas supply chain activities, but all of them point to significant benefits of this method in company and supply chain surroundings. This fact justifies a need for considerable new research contribution to this field. Also, mostly used method in analysed researches of value stream mapping application in natural gas supply chain activities is case study method.

***Keywords*—**Value stream mapping, natural gas, supply chain, optimization.

I. Introduction

VALUE stream improvements are main goal of contemporary companies regarding their supply chain operations and activities. Therefore, lean concept gain huge popularity due to their value stream continuous improvement orientation based on process waste identification and elimination. In doing so, one of most important lean tools is Value Stream Mapping. According to [1], supply chain mapping (in line with use of metrics, ICT and different lean methods) has become crucial tool for most supply chain practitioners and method of mapping has been widely used in literature as well.

On the other hand, due to growing importance of natural gas as third most important fuel today [2], and the fastest growing component of world primary energy consumption [3], possibilities of natural gas supply chain improvements through extensive use of Value Stream Mapping have been recognized.

This paper starts from two research questions:

RQ1: How developed is the scientific research field of Value Stream Mapping use in natural gas supply chain activities?

RQ2: Is there a research gap for significant improvement in the field of Value Stream Mapping use in natural gas supply chain activities?

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RQ3: Which research method is mostly used in research papers regarding Value Stream Mapping use in natural gas supply chain activities?

To find answers to these research questions, paper uses preliminary literature review analysis scientific method. By answering research question, paper will try to deliver its goal – to provide extensive overview of researches of value stream mapping technique in natural gas supply chain analysis with optimization goals. Additionally, paper aims to provide suggestions for more effective value stream mapping use.

After introduction, paper continues with importance and principles of supply chain mapping with special emphasize on value stream mapping. Methodology (third chapter) and research results (fourth chapter) are presented in next. Paper ends with conclusion (fifth chapter) and future research suggestions.

II. Value Stream Mapping

A. Value stream map as a supply chain map

Commonly used type of activity-based supply chain maps is created by Value Stream Mapping (VSM) technique and is called Value Stream Maps. VSM is considered to be the central lean tool for analyzing product and information flow in a quest for waste identification and elimination, as well as for suggesting and planning improvement changes. Although VSM is mostly used in manufacturing, it can be used in logistics and supply chain management, and many service activities as well.

VSM originated from Toyota Production System, as it is inevitably connected with lean in manufacturing. Lean's way of improving process efficiency is by eliminating waste (non-value adding activities) or, according to Rother and Shook [4], the goal is to get one process to make only what the next process needs and when it needs it. Object of VSM is value stream which is defined as "all actions (both value-added and non-value added) currently required to bring a product through the main flows essential to every product: (1) the production flow from raw material into the arms of customer, and (2) the design flow from concept to launch" [4]. Hill [5] defines VSM as "a visual tool that graphically identifies every process in a product's flow from "door-to-door," giving visibility to both the value-adding steps as well as the non-value-adding steps". Lambert et al [6] talk about VSM usually used within four walls of manufacturing plants, while Rother & Shook [4] highlighted that VSM is about understanding the whole flow of information and material, and not about the map, because map is just a tool.

VSM consists of following steps [4]: product family choosing, current state drawing, future-state drawing, and work plan & implementation.

Product family choosing is a zero-step, the assumption of successful mapping. If similar or related products are produced in the same production process (which is in this case subject to analysis by VSM technique), it is logical that the focus of attention is this whole group of process-related products that we can call the product family. It is important to focus on only one product family (or even sometimes on only one product) and their value stream, and to do this from the end side of the value stream.

B. Current-state map

The mapping itself in VSM starts with current-state drawing with aim of building current-state value stream map. The best way to understand current process and to start its drawing is to walk through the facility where the value stream or process is taking place and draw it in parallel. The map should present all parts of process from goods entrance into facility all the way to its exit and loading for shipment to customers.

Drawing current-state map is a process that needs several repetition to correctly draw true situation regarding different process aspects. At the end, the final map could be developed with the use of specialized software for VSM.

While there are different approaches to its mapping, Locher [7] recommends following steps for current-state map completion:

1. Identify current customer needs.
2. Identify the main processes (in order).
3. Select process metrics (or data attributes).
4. Perform value stream walk-through and fill in data boxes.
5. Establish how each process prioritizes work.
6. Calculate value stream summary metrics such as lead time, process time, first-pass yield, cost, and other measures that the mapping team deems important.

Here is important to highlight that all starts with customer wishes and needs, and understanding in what way process should add value for the customer. Usually, customer requirements are set in a box symbol located in the upper right corner on a map. Starting with the customer is in accordance with lean principles - all enhancements should have a purpose to increase customer value and to eliminate or decrease non-adding value activities.

Value stream map should consists of three main parts: information flow (upper part of the map), material flow (bottom half of the map), and timeline (bottom, under material flow).

It should be started with material flow drawing, and it should be done in the processing steps order (even it is different than in physical layout), and starting from the left side of the map [4]. Material flows are drawn with process boxes that symbolise connected group of processes in which material is flowing. Under each process box stays data box with process description – usually data for most important lean process metrics of this process. Some of the frequently used process metrics are [4]: cycle time, throughput, changeover time, uptime, EPE (every part every…), lead time, number of operators, number of product variations, pack size, working time. Between boxes, authors should draw inventory symbol - this way they will represent both its location and quantity on this location in process. This location means that here material flow is stopping. Symbols of a transport vehicle in VSM could represent external material flows with suppliers and/or customers.

In the upper half of the map is drawn information flow starting from customer to production control from where information goes to supplier and to different process steps. Most important information are those about orders and forecasts. Straight arrows are used for paper information flow whereas lightning-like wiggle arrow are used for electronically exchanged information like through Electronic Data Interchange - EDI or Internet) [4] and it is important to recognize the difference between these two types of information flow.

Bottom part of value stream map is reserved for a timeline. The role of timeline is to illustrate if this activity is value-adding or non-value adding activity and to show duration of activities occurring during value stream. Indicating nature and duration of activity, timeline results in a line that forms a "castle wall" which ends with overall non-value adding activity's time (production lead time) and with the total of the value-adding activity's time (processing time). This way effectiveness of a process could be tracked in a very simple way.

There are different versions of VSM symbols [9], but it is important to use same symbols for same material or information flow parts in the whole value stream map to avoid confusion. VSM symbols are usually divided into: process symbols, material symbols, information symbols, general symbols, and symbols for extended VSM.

C. Future state map

After current-state map is done and analysed, future-state map should be drawn based on implementation of lean principles in current process and with aim of visualization of it and providing most important clear guidelines for its value stream improvements. There are different approaches or methodologies for creating future-state map [4], [7], and [8], but it is always important to start from customer requirements. Therefore takt time has to be calculated [8]:

$$\text{Takt time} = \frac{\text{Effective working time per time period}}{\text{Customer requirement during time period}} \quad (1)$$

If customer requirements during a certain period are customer demand per period (e.g., per one shift) than it is logical to conclude that takt time means "how often you should produce one product based on the rate of sales, to meet customer requirements" [4].

The goal of newly optimized process should be to be faster and shorter, with less inventories, and better overall performance. AS VSM is primarily lean tool, improvements are going to be based on implementation of continuous flow, pull system, searching for waste and its elimination or reduction options. Most popular solutions in future-state maps are workcells for integrating more activities into one location, concept of Kanban pull system, levelling the production to avoid batching or kaizen burst process improvements. In doing so, holistic approach on the level of whole process must be used and therefore VSM builders usually include different guidelines in future-state map on what needs to be done for suggested solution to be properly

implemented, ensuring adequate results. Sometimes for these implementations kaizen burst or kaizen event needs to be performed ensuring rapid improvements in this activity.

Sometimes, VSM ensures not only a map of future-state, but also more detailed written usually based on the results of one or more kaizen bursts, and with stated required implementation resources.

Finally, it has be said that VSM process improvements are continuous activity, and when one future-state map becomes current process, there is always a chance for new process improvements and new round of VSM activities.

III. METHODOLOGY

For the purpose of preliminary literature review analysis of using value stream mapping in scientific publication dealing with natural gas supply chain, a basic search of Web of Science Core Collection (WoS CC) and Scopus databases was conducted. WoS CC and Scopus were chosen as they are probably most relevant and worldwide used scientific databases of academic publications. Keywords used for searching were: „value stream mapping“ and „natural gas“ and “natural gas supply chain”. Search was conducted by relevance. In WoS CC, they were searched within the topic of publications indexed in Science Citation Index Expanded (SCI-Expanded), Social Science Citation Index (SCI), Conference Proceedings Citation Index (CPCI) and Emerging Sources Citation Index (ESCI). During search there was no limitation regarding publication date. And according to above criteria, search resulted in 7 papers in WoS CC and 7 papers in Scopus.

Next step was excluding of duplicates (paper that are indexed both in WoSCC and Scopus database) and full content analysis of remaining paper. Finally, only 9 papers remained for analysis that truly argue about different uses of VSM connected with natural gas industry and its supply chain. Analyzed papers are presented in Table 1.

TABLE I
RESEARCH PAPERS UNDER FINAL EVALUATION

Paper	Topic	Publication
Gunduz & Fahmi Naser, 2017 [11]	Cost savings calculation for pipeline construction using VSM	*Sustainability*
Mok et al., 2010 [10]	VSM and simulation as a lean tool in natural gas pipes installation	*Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors*
Pereira et al., 2018 [17]	Energy VSM for energy management and reduction in industry processes	*Journal of Lean Systems*
Rachman, A., & Ratnayake, 2016 [15]	Use of VMI in risk management processes in oil and gas industry	*2016 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*
Ratnayake & Chaudry, 2015 [14]	Use of VMI in oil and gas valves requisition	*2015 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*
Schillig et al., 2016 [16]	Analyzing energy input with EVSM	*IFIP International Conference on Advances in Production Management Systems*
Tyagi et al., 2015 [12]	VSM for reducing lead time for developing gas turbine	*International Journal of Production Economics*
Vasconcelos Ferreira Lobo et al., 2018 [18]	Evaluation of VSM applicability in oil and gas processes	*International Journal of Lean Six Sigma*
Wenchi et al., 2015 [13]	VSM for turnaround maintance in oil and gas industry	*31st Annual ARCOM Conference*

IV. RESEARCH RESULTS

Analysis of selected research papers has shown variety of possible applications of VSM in natural gas industry and supply chain activities. First mentioning of VSM use connected to natural gas industry was in 2010 by Mok et al. [10]. In their research authors have presented combined use of VSM and simulation as integrated lean approach to eliminating waste and improving productivity. After developing current and future-state maps with VSM, they also developed simulation model for current natural gas operations, as well as simulation for improved suggestion of these operations. Their results indicate strength of VSM for work productivity improvement, even in natural gas operations. Gunduz & Fahmi Naser [11] proved cost effectiveness side of VSM technique by calculating 20,8 % cost reduction in future state versus current state of underground pipeline construction project. Additionally, authors argue how VSM is actually sustainable measurement tool. Furthermore, VSM has proved its effectiveness in shortening lead time for new product development. According to Tyagi et al. [12], product development of new gas turbine has been analysed with VSM method. As a result, future-state map introduced improved process that reduced gas turbine development lead time by 50 %, and provided many other intangible benefits. Wenchi et al. [13] find VSM especially applicable in oil and gas industry for improvements in turnaround maintance projects – both for identifying wastes as well as guiding improvements. Through case study method, research has proven 26,2 % reduction of lead time, and 67,5 % reduction of cycle time, while highlighting certain challenges and limitations of VSM use in turnaround maintance projects in oil and gas industry [13]. Ratnayake & Chaudry [14] have researched use of VSM for valves requisition in oil and gas industry. Their conclusion is that VSM ensures solution to process standardization (which was biggest problem in this process) by implementing lean principles, and their future-state insures 91,4 % increase in process cycle efficiency. Paper by Rachman & Ratnayake from 2016 [15] presents possibilities of lean principles application in risk management in oil and gas industry. Using case study method, authors implement VSM technique for identifying wastes and ensuring recommendations for Risk Based Inspection process improvements, and in their research VSM insured improvement of process cycle efficiency from

38,6 % to 53,1 %. Additionally, if we consider industrial consumption of natural gas as part of natural gas supply chain, two more interesting studies can be mentioned. Schillig et al. [16] and Perreira et al. [17] in their papers talks about Energy Value Stream Mapping (EVSM) as a beneficial way of how the VSM can be extended to an Energy Value-Stream Mapping method which allows dividing the energy input of the production process in value-adding and non value-adding activities, and to continue in quest for process improvements – in this case through reducing energy (sometimes natural gas) consumption and shortening overall lead time [16]. Furthermore, [17] highlight that EVSM is mostly implemented in electronics sector, and its limitation to only static representation and only one product analysis.

Finally, Vasconcelos Ferreira Lobo et al. [18] research on applicability of value stream mapping (VSM) tool in processes of the oil and gas chain indicates even lower number of studies in literature on VSM applicability and lack of specific framework that has been used by the oil and gas chain companies for VSM implementation.

V. CONCLUSION

Most contemporary industries and supply chain seeks for optimization of their operations by using lean principles, and Value Stream Mapping is usually inevitable lean tool in doing so. Although natural gas industry and supply chain was not using lean tools to a considerable extent, this study presented certain examples of successful use of VSM technique in natural gas industry. There is extremely low number of researches that use VSM mapping in natural gas supply chain activities (only 9 in WoS CC and Scopus scientific databases), but all of them presents significant benefits in real company and supply chain surroundings. Therefore it can be concluded that there is significant lack in this field and there is justified need for new researches and scientific contributions. Mostly used method in analysed researches of VSM application in natural gas supply chain activities is case study method.

As an indicative preliminary research, this paper has certain limitations like use of only two scientific databases and limited number of papers taken into consideration. In further researches authors plan to contribute to research field employing case study method and checking of efficiency of VSM technique in one specific process in natural gas supply chain. However, paper could serve as a good starting point for researchers who would like to use value stream mapping method in their papers dealing with natural gas supply chain activities.

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