Potential of Lean Tool of Value Stream Mapping (VSM) in Manufacturing Industries

Muhammad Ali Khan
Assistant Professor & PhD Scholar,
Department of Industrial Engineering & Management,
Mehran University of Engineering & Technology, Jamshoro, 76062,
Sindh, Pakistan
muhammad.nagar@faculty.muet.edu.pk

Shakeel Ahmed Shaikh
Associate Professor & Co-director (Post Graduate Studies),
Department of Industrial Engineering & Management,
Mehran University of Engineering & Technology, Jamshoro, 76062,
Sindh, Pakistan
shakeel.shaikh@faculty.muet.edu.pk

Tahir Hussain Lakho & Usama Khursheed Mughal
Under Graduate Final Year Student,
Department of Industrial Engineering & Management,
Mehran University of Engineering & Technology, Jamshoro, 76062,
Sindh, Pakistan.
f16in08@student.muet.edu.pk, f16in29@student.muet.edu.pk

Abstract

This research paper presented the detailed and broader picture of one major lean tool i.e. Value Stream Mapping (VSM) in terms of its implementation in manufacturing industries. This narrative research is based on the review of previous studies. Literature review is summarized, discussed and presented in tables. Since, the waste has been the severe problem in industries due to its association with cost; thus it has been the focus of academicians and practitioners to study and implement such waste elimination philosophy. Since, lean manufacturing is an effective waste elimination technique and its tools have captured the immense attention of academicians and practitioners. Therefore, there is an extreme need to conduct such studies about the usefulness and drawbacks of the implementation of lean tools. In future, other lean tools can be discussed in depth to put clearer and broader picture and to draw more comprehensive conclusion. Moreover, existing studies lack to investigate the implementation in various sectors. Studies related to VSM are significantly important in development of lean knowledge due to individual sectors have major differences in their processes. In this regard, present review is conducted so as to put the open and broader picture of Value Stream Mapping (VSM) comprehensively.

Keywords:

Value Steam Mapping (VSM); lean manufacturing; lean thinking; lean management; lean tools.

1. Introduction

Currently around the globe, companies based on manufacturing require to keep their production level sustainable as per customer demand. When they appears any capacity related problem, instantly they look ahead to increment in number of shifts, increases overtimes and purchase new equipment or machines(NALLUSAMY et al., 2018). During manufacturing process, the machines plays a pivotal role to keep the production smooth in other case production can confront several inhibits(Nurprihatin et al., 2019). On the other hand, the focus should remain on harnessing better resources and surging in performance of the machines that already exists which could pursue in reducing bottlenecks, improvising performance of equipment, curb overall downtime, turn operator performance efficient and reduce setup time and other loses, hence enabling in any decision on the investment of purchase of new machines (NALLUSAMY et al., 2018). In order to stay competitive and confront market pressures, companies requires to bring efficiency and productivity. Since very long, several companies are utilizing lean manufacturing systems pursuing Toyota model to curb wastage in-process and expand their added value (Lugert et al., 2018). Lean manufacturing has resulted in recent time as a resilient substitute that, if adopted at balance level by various actor

through supply chain, deduce satisfactory results in making significant profits (Romero & Arce, 2017).Toyota in the 1940-50s developed it, since then, lean has proven to be one of the significant managerial paradigms in business environments as empirical and theoretical evidence has highlighted its efficiency to expand the organizations' competitiveness(Garza-Reyes et al., 2018). The commencement of lean manufacturing was developed to reduce down waste in the automobile sector, (De Steur et al., 2016) defined at as "a system that utilizes fewer inputs and creates the same out- puts while contributing more value to customers".

Rajput et. al. (2020) conducted the case study at the automobile assembling plant to improve the productivity. The authors applied the lean tools and techniques to identify the causes of low productivity and proposed the lean manufacturing practices for the expected productivity improvement at the automobile assembling plant. The authors have also compared the the pre and post productivity measures. Khan et. al. (2020) conducted the comprehensive review of lean manufacturing in Pakistan. The authors have identified the potential, benefits and applications of lean manufacturing in the various manufacturing sectors of Pakistan. The authors have mentioned the case studies to support the growing awareness and increasing scope of lean manufacturing in the major industrial sectors of Pakistan. Sahito et. al. (2020) conducted the case study at the pharmaceutical plant to Identify, analyses and elimination the Lean Manufacturing Wastes through Lean Manufacturing Practices. The authors have identified the lean manufacturing wastes in pharmaceutical plant by lean standards and then analysis is performed by using the statistical tools and techniques. The authors, then suggested the most suitable lean practices for eliminating/reducing the most significant wastes at the pharmaceutical plant and compared the pre and post scenario.

Lean manufacturing entails an enhanced range of methods and tools that intended to result in fundamental results, on the contrary, to find out the inefficiencies, wastes, non-valued added stages in a single, defined process of thorough process of product development Value stream mapping (VSM) method is used PDP) (Tyagi et al., 2014). To make process efficient Value Stream Mapping (VSM) is used. The purpose to develop it is to comprehend non-value-added and value-added activities from both material flow and information in value stream(Shou et al., 2017).

In the present research paper, literature review of above mentioned lean tool of Value Stream Mapping (VSM) has been conducted in the context of different industries.

2. Research gap

Since, lean is waste elimination technique and its tools have captured the immense attention of businessmen and the academicians. It has been reported that studies lack which examine the VSM implementation in various sectors. Such studies are significant and need of the hour for the development of lean knowledge because individual sectors have fundamental variance in their construction, production or service processes (Shou et al., 2017). In this regard, present review was conducted so as to put the open and broader picture of Value Stream Mapping (VSM) comprehensively.

3. Aim and objectives

This research aimed to present the applications of Value Stream Mapping (VSM) in the various industrial sectors along with their effectiveness, impacts and their useful outcomes after implementation.

- To discuss the applications of Value Stream Mapping (VSM) in various types of industries in detail
- To highlight the effectiveness of mentioned tools in industrial productivity

4. Research methodology

A narrative literature review was conducted to put the detailed and broader picture of lean tool of Value Stream Mapping (VSM) in terms of its implementation in industrial world. For the analysis of literature, narrative review is used and it enables an extensive understanding of problems and controversies associated with the use of technology and at the same time, it helps to take out the key success factors of adopting and using technologies (Frennert & Östlund, 2018) . By this method, researchers conduct analysis of debates and outcomes of already conducted research; moreover, it helps in figuring out the research gap and future implications (Ferrari, 2015). Present research paper, summarizes the data and evidences as collected from the previously conducted research on the implementation of specific lean tool of Value Stream Mapping (VSM).

4.1 Data Collection

This narrative research was based on the secondary data which was collected from the previously conducted empirical studies, case studies and literature reviews. Research papers on the implementation of mentioned lean tools were downloaded and then most suitable research papers mentioning Value Stream Mapping (VSM) were considered for the literature review. The data was extracted from those papers and was organized into the tables.

4.2 Data Analysis

Literature review was presented and summarized in the form of tables and graphs. For the data analysis of the collected data, MS excel was used for data organization in tables and plotting graphs.

5. Literature review

Literature review has been carried out on the lean tool of Value Stream Mapping (VSM). The literature review is produced under multiple headings and summary.

5.1 Value Stream Mapping

Value Stream Mapping (VSM) is a critical tool when it comes to implement the lean approach and it has spanned to many sectors in industry (Romero & Arce, 2017). VSM has become a popular method for lean thinking and implementation in recent years (Shou et al., 2017). Value stream mapping is a widely used and proven method that enables the mapping and analysis of process chains and helps to derive potentials for improvement (Meudt et al., 2017). VSM has been developed as a systematic theory which can be applied in various scenarios to identify waste and eliminate waste (Shou et al., 2017). The digitalization of production according to Industry 4.0 promises new opportunities to develop more efficient production lines. Particularly companies which digitally upgrade existing operations need to be introduced to a new approach (Meudt et al., 2017). As the next wave of productivity, Industry 4.0 aims to enhance the competitiveness and efficiency of manufacturers by bridging the gap between industrial manufacturing and information technology. Value stream mapping (VSM) is very common in the manufacturing industry to enhance transparency and support improvements within the production process (Lugert et al., 2018). Through digitalization, it provides the advantage of enabling the real-time/near-real-time monitoring of manufacturing. This digital information allows monitoring tools such as Value Stream Mapping (VSM) to help the decision makers efficiently capture the non-value-adding processes on the factory floor (Huang et al., 2019). Pen and paper-based value stream mapping (VSM) is the established tool for recording processes, identifying waste and deriving recommendations for action: however, today, its application in manufacturing industry requires a high level of effort and is challenging due to product and process complexity, as well as dynamics (Knoll et al., 2019). Furthermore, some of the researchers` work has been summarized as referred from different research publications.

Khan, Shaikh & Marri (2020) conducted the detailed systematic review of lean manufacturing practices in the pharmaceutical industries and highlighted the feasible applications of Value Stream Mapping (VSM) to pharma industry. The authors mentioned the substantial benefits of applying the specific lean practices in the selected segments of the pharma industry.

Steur et al., 2016 conducted a systematic review which was used to show the potential of Value Stream Mapping (VSM) not only to identify and reduce food losses and wastes, but also as a way to establish links with nutrient retention in supply chains. The review compiled literature from 24 studies that applied VSM in the agri-food industry. Primary production, processing, storage, food service and/or consumption were identified as susceptible hotspots for losses and wastes. Results further revealed discarding and nutrient loss, most especially at the processing level, as the main forms of loss/waste in food, which were adapted to four out of seven lean manufacturing wastes (i.e. defect, unnecessary inventory, overproduction and inappropriate processing). This paper presents the state of the art of applying lean manufacturing practices in the agri-food industry by identifying lead time as the most applicable performance indicator. VSM was also found to be compatible with other lean tools such as Just-In-Time and 5S which are continuous improvement strategies, as well as simulation modelling that enhances adoption (De Steur et al., 2016).

Romero and Arce, 2017 conducted the present work to make it possible to realize of the great evolution of the available research work regarding VSM. We confirmed how it has spanned too many regions over the world, and how it helps to reduce every type of waste that lean manufacturing approach encompasses. Although the implementation of VSM in the manufacturing sector is still growing, its potential has been clearly illustrated.

Regardless of the inadequate use found in some works, VSM has shown to improve the visibility of the value stream and the performance of manufacturers. This study promotes the importance of sharing valuable ideas about the potential positive results that this technique offers, by adapting it to different environments and thus, carry out better research, especially in the cases where its performance does not appear to be good enough. Additionally, this review offers innovative insights for future scientific research in fields different from manufacturing environments(Romero & Arce, 2017).

Khan (2018) conducted the preliminary study on lean manufacturing practices in textile manufacturing industry. The author mentioned that he used the Gemba, Waste Relations Matrix, Cause & effect analysis, ranking and statistical techniques to identify and analyse the wastes of lean manufacturing. The seven deadly wastes of lean manufacturing are investigated and defect is identified as the most significant waste in the textile manufacturing industry. The author also suggested most relevant lean practices to eliminate /reduce the most significant defect waste of lean manufacturing which include Value Strean Mapping (VSM) as well.

Shou et al., 2017 aimed to determine the-state-of-the-art development of VSM in five sectors, including manufacturing, health care, construction, product development and service sectors. A total of 131 journal articles are reviewed and analyzed from the period of 1999–12/2016. The analysis covers the complete implementation cycle of VSM, including metrics for current state map, improvement techniques for future state map, benefits and achievements of VSM application, and critical success factors for VSM implementation. Cross-sector comparisons and investigations are conducted to understand the differences of VSM implementations in various sectors to facilitate VSM development and increase the number of successful VSM implementation. The results suggest that understanding value and waste in a diverse value stream environment and ensuring the suitability and usability of traditional lean metrics/techniques within the different flow settings are central to the VSM development. VSM has been developed as a systematic theory which can be applied in various scenarios to identify waste and eliminate waste. However, the specific settings in the scenarios may affect the applicability and the effectiveness of the VSM implementation. The review indicates that previous VSM implementations can be classified into five business domains, including manufacturing, health care, construction, product development and service. Each domain has its unique metrics to analyze the CSM and relevant lean tools to achieve an improved FSM. One specific limitation of this study is related to the sampling method. Specific and predefined search criteria were established to include only peer-reviewed publications, although other types of publications may also contribute to the development of VSM theory and implementation. The overall review suggests that there are a number of issues related to the use of VSM which may require immediate attention. First, researchers need to address the issue of reference points used in measuring value and waste. The design of applying VSM theory to boost lean thinking application in empirical cases has been the most discussed idea in the literature. A number of lists of value and waste interpretation have been proposed, however, there is no single generally accepted list of unified value-adding and non-value adding time/activities in the specific context. So, how do the current performance evaluation can be conducted if the concept is not properly defined? Understanding what is meant by value and waste and its point of determination in a diverse value stream environment is central to developing solutions for their reduction. Second, rather than simply focusing on the employment of lean metrics/techniques for identifying and eliminating wastes in processes, it is suggested that there should be a drive towards a conceptual focus to validate the suitability and usability of lean metrics/techniques within the different flow settings. As already indicated, contributions from the value streams and flows analysis in explaining the large differences of lean metrics/techniques employment, peculiarities of value streams and flows in production processes have been recognized as key impediments of the selection and application of lean metrics/techniques. In other words, actions in VSM should focus on what types of lean metrics/techniques should be employed, as well as how the recommended lean solutions should be implemented exactly with the consideration of the production value streams and flows characteristics (Shou et al., 2017).

Huang et al., 2019 presented a cyber-physical multi-agent system. The system can interoperate with other existing MES systems. The characteristics of modularity and decentralization make the system less complex and more flexible in the application. The real time and virtual characteristics of the system make transparent the conditions of material, workforce, and machine. These features innovatively display a material's dynamic value steam and DVSM for machine and worker, which can provide valuable information for the decision maker and makes progress towards a digital lean manufacturing system through the adoption of CPS-Heijunka and an E-Kanban system. In the future, on the basis of this CPS system, all the resources on the manufacturing shop floor will be virtualized. Furthermore, the relations among key parts of the manufacturing value stream will be established in cyber space; this will enhance the ability to adapt to variation, which makes it possible for the customer to participate in manufacturing via the cyber network(Huang et al., 2019).

Khan, Khatri & Marri (2020) conducted the descriptive analysis of lean manufacturing practices in textile industry. The authors mentioned the most notable global research of lean practices in textile sector and then performed the comprehensive descriptive analysis by considering the major factors. The autors have identified the major lean practices including Gemba and Value stream Mapping (VSM) in the textile sector generally and its sub secors specifically.

Jia et al., 2017 improved energy efficiency, extensive studies have focused on the cutting parameters 10 optimization in the machining process. Actually, non-cutting activities (NCA) occur frequently during 11 machining and this is a promising way to save energy through optimizing NCA without changing the 12 cutting parameters. However, it is difficult for the existing methods to accurately determine and reduce the 13 energy wastes (EW) in NCA. To fill this gap, a novel Therblig-embedded Value Stream Mapping (TVSM) 14 method is proposed to improve the energy transparency and clearly show and reduce the EW in NCA. The 15 Future-State-Map (FSM) of TVSM can be built by minimizing non-cutting activities and Therbligs. By 16 implementing the FSM, time and energy efficiencies can be improved without decreasing the machining 17 quality, which is consistent with the goal of lean energy machining. The method is validated by a 18 machining case study, the results show that the total energy is reduced by 7.65%, and the time efficiency of 19 the value-added activities is improved by 8.12% , and the energy efficiency of value-added activities and 20 Therbligs are raised by 4.95% and 1.58%, respectively (Jia et al., 2017).

Lugert et al., 2018 evaluated the current status of the method from the user's point of view and addresses its future sustainability in the context of the ongoing digitalization. An empirical survey with 170 participants from different branches was conducted. The web-based questionnaire covers the topics Lean Management, respectively, VSM, Industry 4.0, the integration of both approaches as well as a possible need for action to modify the VSM. Results are analyzed in a quantitative way. Benefits and shortcomings of VSM are already confirmed by previous publications. The serious challenge is the lack of flexibility of the method. In general users appreciate a combination of Lean methods and solutions of Industry 4.0. Moreover 92 percent of the participating experts request further development of the VSM using digitalization to compensate weaknesses (Lugert et al., 2018).

Knoll et al., 2019 developed a methodology to apply process mining (PM) to internal logistics for a mixed-model assembly line. The methodology combines multidimensional process mining (MDPM) techniques with proven principles of lean production and VSM. Firstly, internal logistics is modelled using existing event data by automatically mapping physical logistics activities (e.g. transport, store). Secondly, to enable PM, the event data is transformed into enriched event logs. Thirdly, the MDPM approach contains (1) a discovery analysis, (2) a performance analysis and (3) a conformance analysis including a reference process classification for each individual part and process. Finally, a waste analysis and strategy for practitioners is designed to identify and prioritise wasteful parts and processes. The methodology has been applied and evaluated in a case study at a German automotive manufacturer. In the case study, we analysed 7500 parts and 15 reference processes. An analysis for each individual part and process has not been available yet. We could both identify part-specific root causes (e.g. a long lead time) and process-specific root causes (e.g. a low trace fitness). The main contribution of this paper is to provide an MDPM methodology for practitioners to enable a continuous recording, evaluation and waste analysis of each individual part and process within internal logistics. VSM is the most suitable and most frequently used tool to analyze logistics processes. In industry, VSM shows limitations due to high manual effort and its lack of support to when handling product and process complexity and time-dependent dynamics. To overcome these challenges, PM can utilize the event data from internal logistics (Knoll et al., 2019).

Carvalho et al., 2019 compared the well-known value stream mapping (VSM) with a recent tool named waste identification diagram (WID), regarding the capacity of information representation and easiness of interpretation. The work begins with a brief literature review comparing the main tools for representation of production units, with special emphasis on VSM and WID, in terms of ability to identify several types of waste. Then, the authors developed the VSM and the WID of a specific production unit and after that several groups composed by students of Industrial Engineering (IE) and/or professionals from industry were asked to analyze/interpret only one of these diagrams. Finally, a questionnaire with closed and open questions was applied to the groups to evaluate the analyzed tool. In general, the results revealed that WID is more effective than VSM and participants recognized that most of the WID elements are relevant. Specifically, a measure coined overall effectiveness was applied (based on the response time and percentage of correct interpretations), indicating a clear advantage of WID (22 per cent of correct interpretations per minute) compared to VSM (9 per cent of correct interpretations per minute). The main drawback pointed to the WID is the lack of representation of the information flow (Dinis-Carvalho et al., 2019).

Reyes et al., 2018 Research into the application of Value Stream Mapping (VSM) as a tool to enhance the environmental sustainability performance of operations has been confined to a handful of studies only. Research on this green lean research stream is therefore limited, especially when compared to the vast amount of scholarly research focused on the 'traditional' VSM tool. To complement and support the narrow body of knowledge on the application of VSM as tools to improve environmental performance and enhance the effectiveness of its application, this paper proposes an approach, based on the Deming's Plan-Do-Check- Act (PDCA) improvement cycle, to systematically implement and conduct Environmental-VSM (E-VSM) studies. The implementation of the proposed method is reported through an action research-based case study conducted in a helical rolling process of one of the mining consumables business units of an international diversified mining and materials multinational company. The results of the case study indicate that the proposed PDCA-based approach to E-VSM can be an effective alternative to improve the green performance of operations. Besides the proposal of this approach, it's testing, and expanding the body of knowledge in the green lean field, the paper also contributes by providing a guiding reference for operations managers who may want to make the operations of their organizations more sustainable and environmentally friendly. Finally, this paper also intends to contribute by inspiring researchers and practitioners to broaden the study of the under-researched field which explores the application of VSM for environmental sustainability enhancement (Garza-Reyes et al., 2018).

Tyagi, S., et al., 2014 focused to exploit lean thinking concepts in order to manage, improve and develop the product faster while improving or at least maintaining the level of performance and quality. Lean thinking concepts encompass a board range of tools and methods intended to produce bottom line results however, value stream mapping (VSM) method is used to explore the wastes, inefficiencies, non-valued added steps in a single, definable process out of complete product development process (PDP). This single step is highly complex and occurs once while the PDP lasts for 3-5 years. A case study of gas turbine product has been discussed to illustrate and justify the use of proposed framework. In order to achieve this, the following have been performed: First of all a current state map is developed using the Gemba walk. Furthermore, Subject Matter Experts (SMEs) brainstormed to explore the wastes and their root causes found during the Gemba walk and current state mapping. A future state map is also developed with removing all the wastes/inefficiencies. Besides numerous intangible benefits, it is expected that the VSM framework will help the development teams to reduce the PD lead-time by 50% (Tyagi et al., 2014).Driving aggressiveness is the outcome driving anger and driving impatience (Kalwar, Khan, et al., 2020; Khaskheli et al., 2018). Queue is the common occurrence in our daily life (Kalwar et al., 2018; Kalwar, Mari, et al., 2020; Khaskheli et al., 2020). Summary of the literature review regarding value stream mapping is presented in the table 1 presented below.

Table 1: Summary of the papers from value stream mapping

Author	Industry	Findings/Outcome	Limitations / Implications
Steur et al., 2016	Food Industry	This paper presents the state of the art of applying lean manufacturing practices in the agri-food industry by identifying lead time as the most applicable performance indicator. VSM was also found to be compatible with other lean tools such as Just-In-Time and 5S which are continuous improvement strategies, as well as simulation modelling that enhances adoption	Increasing production of food industry should not only be the focus during the implementation of VSM but minimization of nutrition wastage should be considered along. This review therefore offers innovative insights for future scientific research and policy practice to extend the application knowledge of VSM as an unexplored and complementary approach, with potential to sustainably enhance both food and nutrition security
Romero and Arce, 2017	Manufacturing Industry	This study promotes the importance of sharing valuable ideas about the potential positive results that this technique offers, by adapting it to different environments and thus, carry out better research, especially in the cases where its performance does not appear to be good enough. Additionally, this review offers innovative insights for future scientific research in fields different from manufacturing environments	This study is helpful to extend the knowledge about the application of VSM as an unexplored tool in some branches of industry and a complementary approach, capable to enhance the outcomes of many areas besides manufacturing. Further reviews could help to understand how VSM could be developed in diverse sectors, offering a view of the possibility to improve performance indicators.
Shou et al., 2017	VSM in various sectors	The results suggest that understanding value and waste in a diverse value stream environment and ensuring the suitability and usability of traditional lean metrics/techniques within the different flow settings are central to the VSM development. VSM has been developed as a systematic theory which can be applied in various scenarios to identify waste and eliminate waste.	Many of the proposed lean tools/techniques need further validation to confirm transferability to accommodate the distinguished characteristics of a sector.
Huang et	SMEs	The system can interoperate with other existing MES	This research focuses on DVSM, CPS and E-Kanban

al., 2019		systems. The characteristics of modularity and decentralization make the system less complex and more flexible in the application. The real time and virtual characteristics of the system make transparent the conditions of material, workforce, and machine. These features innovatively display a material's dynamic value steam and DVSM for machine and worker, which can provide valuable information for the decision maker and makes progress towards a digital lean manufacturing system through the adoption of CPS-Heijunka and an E-Kanban system.	which are the unique combinations for the implementation in SMEs. These combinations can be applied in the other SMEs and LSIs as well to get the in depth analysis of their relationship.
Jia et al., 2017	Manufacturing Industry	Total energy was reduced by 7.65%, and the time efficiency of 19 the value-added activities wereimproved by 8.12% and the energy efficiency of value-added activities and 20 therbligs are raised by 4.95% and 1.58%, respectively.	This paper was mainly focused on evaluating the non-cutting activities and Therbligs, and reducing their energy demand. Optimization of cutting parameters, of course, is another important way for energy saving. In future work, better improvement results can be achieved by combining 4 the method proposed in this paper with the optimization of cutting parameters
Lugert et al., 2018	Manufacturing industry	Benefits and shortcomings of VSM are already confirmed by previous publications. The serious challenge is the lack of flexibility of the method. In general users appreciate a combination of Lean methods and solutions of Industry 4.0. Moreover 92 percent of the participating experts request further development of the VSM using digitalization to compensate weaknesses	The findings are based only on Lean expert's opinion. Over 95 percent of the participants are from Europe however most of them are from Germany. Although the results are adequate an international expansion of the survey would be advisable in order to distinguish local differences and similarities. In future work researchers need to further develop VSM to overcome the identified gaps.
Knoll et al., 2019	Manufacturing industry	The main contribution of this paper is to provide an MDPM methodology for practitioners to enable a continuous recording, evaluation and waste analysis of each individual part and process within internal logistics. VSM is the most suitable and most frequently used tool to analyze logistics processes.	In industry, VSM shows limitations due to high manual effort and its lack of support to when handling product and process complexity and time-dependent dynamics.
Carvalho et al., 2019	Manufacturing Industry	In general, the results revealed that WID is more effective than VSM and participants recognized that most of the WID elements are relevant. Specifically, a measure coined overall effectiveness was applied (based on the response time and percentage of correct interpretations), indicating a clear advantage of WID (22 per cent of correct interpretations per minute) compared to VSM (9 per cent of correct interpretations per minute). The main drawback pointed to the WID is the lack of representation of the information flow	A case study at a German automotive manufacturer has outlined the feasibility and the advantages of the approach. As this paper has been an initial attempt to support VSM using PM, further research is required. Firstly, the internal logistics model can be extended with additional information. This affects both the logistics activities (e.g. costs or transport distance) and the parts (e.g. price and size). Secondly, the waste analysis must be detailed. This requires the development of additional metrics, other waste types and the analysis strategy. For example time-based methods such as sliding windows could be used to identify concept drifts. Thirdly, different PM algorithms and parameters needs to be evalu- ated. Fourthly, the approach should be adapted to other processes, such as VSM in manufacturing. While this list is not completed, it outlines potential steps for future research
Reyes et al., 2018	Manufacturing Industry	The results of the case study indicate that the proposed PDCA-based approach to E-VSM can be an effective alternative to improve the green performance of operations. Besides the proposal of this approach, it's testing, and expanding the body of knowledge in the green lean field, the paper also contributes by providing a guiding reference for operations managers who may want to make the operations of their organizations more sustainable and environmentally friendly.	Different industrial contexts should be considered, with special focus in more complex product routes, as the production unit selected for this study was a single route in a sequential (line type) production flow. Another important recommendation involves the selection of practitioners with more experience in lean implementation – probably some lean consultants should be included as their opinions could be more effective while identifying the true potential of WID. Further research can focus on validating this approach in other companies not only to improve manufacturing operations but also other type of operations such as logistics and transport, healthcare, services, among others
Tyagi, S., et al., 2014	Manufacturing	Besides numerous intangible benefits, it is expected that the VSM framework will help the development teams to reduce the PD lead-time by 50%	Implementation of other innovative methodologies such as Critical Chain Project Management is clearly a matter of future research.

6. Discussion

Tiyagi S., et al., 2014 This research discusses the objective and associated problems with product development process for a case study unit of a Gas Turbine manufacturer. Drawing from the experiences and best practices of reviewed case study, the practical strategies are described to improve product development performance achieving lean goals such as improved quality, reduced waste and shortened PD lead-time.

Table 2. Comparison of existing and suggested scenario as per research (Source: (Tyagi et al., 2014))

Number	Criteria	Current State Value	Future State Value	Changes
1	Total number of steps	48	29	19
2	Number of value added steps	10	15	5
3	Percentage of value added steps	25%	52%	27%
4	Total time in system	620 days	210 days	410 days
5	Value added time	122.5 days	122.5 days	0
6	Percentage of value added time	21%	71%	50%
7	Total waiting time	272 days	30 days	242 days
8	Total number of hand-offs	87	23	64
9	Total number of iterations	17	8	9
10	Number of software involved	11	9	2

Specifically, Value Stream Mapping based method is used to develop the current state map in order to find the wastes in the process and action plan to eliminate all the wastes to reach the future (better) state. In order to develop the current state, a Gemba walk is done in order to find the most complex and lengthy lead-time process targeted for improvement. Consequently, a brain storming session is conducted to find out the root causes of wastes. The framework is still in the implementation phase, however, the expected benefits are summarized. All the proposed changes will result in the reduction of lead time for the design stage reducing thus the overall PD lead time by 50% (Tyagi et al., 2014).

7. Conclusion

Literature review was conducted of one of the major lean tool i.e. Value Stream Mapping (VSM) in the context of its application and implementation in various industrial sectors. Most of the manufacturing and automotive companies, some of SMEs, food and construction companies have implemented mentioned lean tool i.e. Value Stream Mapping (VSM). Due to the lack of awareness about the effectiveness and impact of lean tools, the companies are reluctant to adopt this approach. At the other hand, resistance from employees and top management are also the main hindrances in the way to this change. In this regard, one of the researcher have suggested that the employees must be taught for proper lean tools implementation from the bottom to the top in the execution of various tasks (S. Singh et al., 2020).

8. Acknowledgement

The authors are very thankful to their supervisors, colleagues and well wishers at the department of Industrial engineering & management and Mehran UET, Jamshoro, Sindh, Pakistan to motivate and guide them. The authors also acknowledge their industry friends to guide them in the local & global scenario of lean manufacturing in the industry. The authors are also very thankful to the administrative and technical support from the administration & management of Mehran UET, Jamshoro, Sindh, Pakistan for the due cooperation and support. The authors are especially thankful to Mehran UET Library & Online Information Centre to provide the free access to the valuable databases and relevant books, magazines, journals etc at their premises.

9. Future implications

In the present paper, one of the major lean tool i.e. Value Stream Mapping (VSM) is discussed but in the future research, other lean tools can be discussed in depth in order to put more clear and broad picture of effectiveness and loopholes. More research papers can be considered in order to draw better and effective conclusion.

10. Conflict of interest

There was no conflict of interest among the authors of the present research paper.

References

De Steur, H., Wesana, J., Dora, M. K., Pearce, D., &Gellynck, X., Applying Value Stream Mapping to reduce food losses and wastes in supply chains: A systematic review. *Waste Management*, vol. 58, pp. 359–368, 2016.

Dinis-Carvalho, J., Guimaraes, L., Sousa, R. M., &Leao, C. P., Waste identification diagram and value stream mapping: A comparative analysis. *International Journal of Lean Six Sigma*, vol. 10, no. 3, pp. 767–783, 2019.

Ferrari, R., Writing narrative literature reviews. *The European Medical Writers Association*, vol. 24, no. 4, pp. 230–235.

Frennert, S., &Östlund, B., Narrative Review: Welfare Technologies in Eldercare. *Nordic Journal of Science and Technology Studies*, vol. 6, no. 1, pp. 21–34, 2018.

Garza-Reyes, J. A., Torres Romero, J., Govindan, K., Cherrafi, A., &Ramanathan, U. A PDCA-based approach to Environmental Value Stream Mapping (E-VSM). *Journal of Cleaner Production*, vol. 180, pp. 335–348, 2018.

Huang, Z., Kim, J., Sadri, A., Dowey, S., &Dargusch, M. S. Industry 4.0: Development of a multi-agent system for dynamic value stream mapping in SMEs. *Journal of Manufacturing Systems*, vol. 52, pp. 1–12, 2019.

Jia, S., Yuan, Q., Lv, J., Liu, Y., Ren, D., & Zhang, Z. Therblig-embedded value stream mapping method for lean energy machining. *Energy*, vol. 138, 2017.

Kalwar, M. A., & Khan, M. A. Increasing Performance of Footwear Stitching Line by Installation of Auto-Trim Stitching Machines. *Journal of Applied Research in Technology & Engineering*, vol. 1, no. 1, pp. 31–36, 2020a.

Kalwar, M. A., & Khan, M. A. Optimization of Procurement & Purchase Order Process in Foot Wear Industry by Using VBA in Ms Excel. *International Journal of Business Education and Management Studies*, vol. 5, no. 2, pp. 80–100, 2020b.

Kalwar, M. A., Khan, M. A., Shaikh, S. A., Salam, A., Memon, M. S., &Khaskheli, S. A. Aggressive Driving Behavior : A Case Study of Mehran UET, *Proceedings of the International Conference on Industrial Engineering and Operations Management Dubai*, pp. 2350–2359, 2020.

Kalwar, M. A., Khaskheli, S. A., Khan, M. A., Siddiqui, A. A., &Gopang, M. A. Comfortable Waiting Time of Patients at the OPD with Varying Demographics. *Industrial Engineering Letters*, vol. 8, no. 2, pp. 20–27, 2018.

Kalwar, M. A., Mari, S. I., Memon, M. S., Tanwari, A., & Siddiqui, A. A. Simulation Based Approach for Improving Outpatient Clinic Operations. *Mehran University Research Journal of Engineering and Technology*, vol. 39, no. 1, pp. 153–170, 2020.

Khan, M. A., Preliminary study on lean manufacturing practices at yarn manufacturing industry: A case study, Masters of Engineering (Thesis), Department of Industrial Engineering & Management, Mehran University of Engineering & Technology, Jamshoro, 76062, Sindh, Pakistan, 2018.

Khan, M. A., Shaikh, S. A., & Marri, S., Systematic review of lean manufacturing practices in pharmaceutical industry, *Proceedings of the 5th NA International Conference on Industrial Engineering and Operations Management Detroit, Michigan, USA,* August 10 - 14, 2020

Khan, M. A., Khatri, A., & Marri, H. B., Descriptive Analysis of Lean Manufacturing Practices in Textile Industry, *Proceedings of the 5th NA International Conference on Industrial Engineering and Operations Management Detroit, Michigan, USA,* August 10 - 14, 2020

Khan, M. A., Soomro, A. S., Shaikh, S. A., Memon, M. S., & Marri, S., Lean Manufacturing in Pakistan: A Comprehensive Review, *Proceedings of the 5th NA International Conference on Industrial Engineering and Operations Management Detroit, Michigan, USA*, August 10 - 14, 2020

Khaskheli, S. A., Kalwar, M. A., Siddiqui, A. A., Nagar, M. A. K., &Wadho, T. H. Impatience Among Drivers With Varying Demographics. *Professional Trends in Industrial and Systems Engineering*, pp. 465-469, 2018.

Khaskheli, S. A., Marri, H. B., Nebhwani, M., Khan, M. A., & Ahmed, M. Comparative Study of Queuing Systems of Medical Out Patient Departments of Two Public Hospitals. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 1913, pp. 2702–2720, 2020.

Knoll, D., Reinhart, G., &Prüglmeier, M. Enabling value stream mapping for internal logistics using multidimensional process mining. *Expert Systems with Applications*, vol. 124, pp. 130–142, 2019.

Lugert, A., Batz, A., & Winkler, H. Empirical assessment of the future adequacy of value stream mapping in manufacturing industries. *Journal of Manufacturing Technology Management*, vol. 29, no. 5, pp. 886–906, 2018.

Meudt, T., Metternich, J., & Abele, E. Value stream mapping 4.0: Holistic examination of value stream and information logistics in production. *CIRP Annals - Manufacturing Technology*, vol. 66, no. 1, pp. 413–416, 2017.

Nallusamy, S., Kumar, V., Yadav, V., Parsad, U. K., &Suman, S. K. Implementation of total productive maintenance and overall equipment effectiveness evaluation,*International Journal of Mechanical Engineering and Technology*, vol. 8, no. 1, pp. 1027–1038, 2018.

Nurprihatin, F., Angely, M., &Tannady, H. Total productive maintenance policy to increase effectiveness and maintenance performance using overall equipment effectiveness. *Journal of Applied Research on Industrial Engineering*, vol. 6, no. 3, pp. 184–199, 2019.

Rajput, S., Khan, M. A., Samejo, S., Murtaza, G. & Rao, A. A.,, Productivity Improvement by the Implementation of lean manufacturing practice (takt time) in an automobile assembling plant, *Proceedings of the International Conference on Industrial Engineering and Operations Management Dubai, UAE,* March 10-12, 2020

Romero, L. F., & Arce, A. Applying Value Stream Mapping in Manufacturing: A Systematic Literature Review. *IFAC-Papers OnLine*, vol. 50, no. 1, pp. 1075–1086, 2017.

Sahito. S. A., Khan, M. A., Arain, A. A., Bhutto, S. A., Wadhyo, R., & Memon, S. A., A Study For The Identification And Elimination Of Lean Manufacturing Wastes At The Pharmaceutical Production Plant, *Proceedings of the International Conference on Industrial Engineering and Operations Management Dubai, UAE,* March 10-12, 2020

Shou, W., Wang, J., Wu, P., Wang, X., & Chong, H. Y. A cross-sector review on the use of value stream mapping. *International Journal of Production Research*, vol. 55, no. 13, pp. 3906–3928, 2017.

Singh, S., Singh, K., Mahajan, V., & Singh, G., Justification of Overall Equipment Effectiveness (OEE) in Indian Sugar mill industry for attaining core excellence. *International Journal of Advance Research and Innovation*, vol. 8, no. 1, pp. 34–36, 2020.

Tyagi, S., Choudhary, A., Cai, X., & Yang, K.. Value stream mapping to reduce the lead-time of product development process. *International Journal of Production Economics*. 2014.

Biographies

Engr. Muhammad Ali Khan currently works as Assistant Professor in the Department of Industrial Engineering and Management, Mehran UET, Jamshoro, Sindh, Pakistan. He has sixteen years university teaching experience. He has supervised more than a dozen theses at undergraduate level. He is pursuing his PhD in the same department. He has completed his Bachelor of Engineering, Post Graduate Diploma and Master of Engineering in Industrial Engineering and Management. He has also completed his MBA in Industrial Management from IoBM, Karachi, Pakistan. He has authored various research papers for conferences and journals. He has participated in many professional seminars, workshops, symposia and trainings. He is registered with Pakistan Engineering Council and many other professional bodies. He does research in diversified fields of Industrial Engineering. The current projects

are related to Lean manufacturing, Six Sigma, Project management, Operations management; MIS and Entrepreneurship. He has also earned various certifications in his areas of research.

Dr. Shakeel Ahmed Shaikh currently works as Associate Professor in the Department of Industrial Engineering and Management, Mehran UET, Jamshoro, Sindh, Pakistan. He has completed his Bachelor of Engineering in Industrial Engineering from the same department. Dr. Shakeel completed his Master of Engineering in Manufacturing from the same department. He has received scholarship for PhD from University of Nottingham, United Kingdom. He has completed his PhD in 2015 with specialization in Manufacturing Engineering and Operations Management from University of Nottingham, United Kingdom. He has supervised many theses at undergraduate and post graduate level. He published his research work in many journals , book chapters, and conference proceedings. He has participated in many professional seminars, workshops, symposia and trainings. He is registered with Pakistan Engineering Council and many other professional bodies. He does research in Human Factors Engineering, Total Quality Management, Motion Capture Analysis, Cloud Manufacturing. He has also earned various certifications in his areas of research.

Tahir Hussain Lakho is the final year undergraduate student at the Department of Industrial Engineering and Management of Mehran University of Engineering and Technology, Jamshoro, Sindh, Pakistan. He has attended various seminars, workshops and short courses in the various areas of Industrial Engineering and Operations Management. He has completed the various certificate courses in lean manufacturing , OEE and simulation as well. He has performed various leadership roles at multiple extracurricular and academic activities at the department level and the university level. He is also the group leader of the Final Year Project of lean manufacturing & OEE.

Usama Khursheed Mughal is the final year undergraduate student at the Department of Industrial Engineering and Management of Mehran University of Engineering and Technology, Jamshoro, Sindh, Pakistan. He has attended various seminars, workshops and short courses in the various areas of Industrial Engineering and Operations Management. He has completed the various certificate courses in lean manufacturing and six sigma as well. He has performed various leadership roles at multiple extracurricular and academic activities at the department level and the university level. He is also the group leader of the Final Year Project of lean manufacturing & Six Sigma.