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ORIGINAL ARTICLE

State of the Art of Dynamic Value Stream Mapping In the Manufacturing Industry

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ABSTRACT – Value stream mapping (VSM) is considered as an important tool in lean manufacturing that allows analysts to visualize the actual situation that happens in the production value stream. However, in high-variety and low-volume factories, conventional VSM which is more static in nature, unable to give real vision of the variability problems concerning production process. As such, the purpose of this paper is to review the role of VSM in a dynamic context which is more efficient in today`s complex and dynamic manufacturing system.This paper discusses the conventional VSM, its applications and limitations as well as how conventional VSM integrates with computer simulation to display more dynamic behavior. Both these conventional and dynamic VSM have their own benefits and drawbacks according to their applications in the manufacturing industry. As a conclusion, this paper shows that simulation applications can help to support VSM for companies that intend to transform to lean. This work is very useful for both scholars and companies to know how much an output can be produced within the predicted lead time before making physical changes to the system in order to save both money and time.

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INTRODUCTION

Due to the increasing demand for product variation and product uniqueness based on the customers' requirements, manufacturing industries are compelled to upgrade their productivity and capability of their production and logistics processes, or called operational processes. This is to ensure they stay competitive in both local and global markets by committing to on-time delivery of quality products to customers [1]. As a response to these market-driven demands, many industries improved their internal flexibility and enhanced their operational processes by implementing lean manufacturing principles. The key theories of lean principles are for instance a continuous improvement of processes, waste reduction and also change in production control towards demand-oriented production that allows a quick response to varying market demands. According to history, lean manufacturing which was invented in the 1950s does not take into consideration the information and communication technologies (ICT) of today. Due to this limitation of lean principles which are unable to adapt to the growing technologies, many lean tools become inefficient and less being practiced to improve manufacturing operations [2].

Lean manufacturing is an umbrella term used to describe tools, a set of practices and techniques that serves the purpose of removing wastes and upgrading the performance plus effectiveness of a production system [3]. The ultimate purpose of lean manufacturing is waste identification or in the Japanese term called "Muda" [4]. Waste can be described as poor manufacturing activities and practices that overutilize resources which increase the costs of the products with less or no value-added [5]. Wastes occur in various forms and the most common types are categorized into seven types.

The main purpose of lean manufacturing is to produce products that meet customers' expectations and needs efficiently through a production system by removing all non-value-added activities that give zero value to customers. In order to achieve this purpose, it is crucial to analyze the value stream first that comprises all the activities including value-added and non-value-added, which are performed to fabricate an item (starting with raw materials to finished goods). Eventually, all the wasteful activities must be eliminated to ensure a continuous flow can be implemented within the value-added processes that remain [6].

On the other hand, the continuing growth of digitalization has become a major part of the production, as highlighted in Germany under the shelter of Industry 4.0. As a matter of fact, these trends lead to the increased demands for flexibility in the production system and subsequently results in shorter-term and inexpensive moderations of the value stream [7]. In order to control customized process chains, methods that follow Industry 4.0 principles, assure new possibilities for maintaining operational processes by contributing all relevant information via ICT-designed smart products and smart resources [8].

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LEAN MANUFACTURING

Womack et al. in 1990 discovered that after World War II, the concept of lean manufacturing was originated by Eiji Toyoda and Taiichi Ohno at the Toyota Motor Company in Japan. Toyota Motor Company expanded their pioneer active assembly line called "Toyota Production System (TPS)" to maintain the material flow smoothly.

Monden (1993) stated that the TPS was initiated and promoted by Toyota Motor Corporation and as a result of the 1973 oil shock, TPS was started to be embraced by many Japanese companies. The purposes of this system are to minimize costs, optimize the total output of a company as a whole and help to upgrade the turnover ratio of capital.

Lean manufacturing is denoted as a manufacturing philosophy that if accepted and carefully applied can develop the guideline for global manufacturing superiority without any doubt [9]. This is one point where both researchers and practitioners have a mutual agreement. However, further clarification is needed on the ingenuity of the system and how it is related to the production system as initiated by Toyota [10]. One possible way for this matter to be clarified is to investigate how the term "Lean" originated to describe either "Lean Manufacturing" or the "Lean Production" paradigm.

In the "Lean Thinking - Banish Waste and Create Wealth in your Corporation" book written in 2003, Womack and Jones discovered how the Toyota Production System varies from conventional mass production and how any present organization can achieve huge performance upgrades by implementing principles as follows:

1) Determine the value from the customer's point of view.
2) Pinpoint the value stream for each product or service family.
3) Allow the value to flow in the direction of the customer.
4) Customers pull demand from the downstream manufacturing station.
5) Continuously strive to approach perfection

Challenges in Today's Manufacturing System

In the past ten years, manufacturing organizations have encountered many obstacles that hindered them from attaining effective lean objectives. Lean practices gradually become less over time owing to the frequent modifications of technologies and products, although many investigations are being conducted on the application of lean in the production system [5]. In terms of value steam, the effectiveness of lean applications is being obstructed by either internal or external issues.

External issues occur related to high demand variability, product customization, market variation, ability to timely delivery, minimum product life cycles, competitive quality and cost [11]. From the external challenges, several internal challenges will occur that includes product complexity and high requirement for components in assembly lines, variability in production, issues in term of quality, high product variety but low volume manufacturing environment, cycle times variance for each process, different routings and priorities, lateness in schedule due dates.

In order to overcome these challenges, improving machine tools for a better machining process only will be insufficient. Instead, high consideration must be given to the interconnections of material flow and the essential elements for material handling. The expansion of the design scope allows the optimization of whole value chains with the aid of information technology [12].

Tools and Techniques

James Womack (1990) expressed the "Toyota Production System" as "Lean Manufacturing". Through this expression, related experience and developed knowledge lead to more frequent victory stories. As a result, the techniques developed by Ohno, Shingo and the co-workers at Toyota were called "lean tools and techniques".

Subsequently, various lean tools, concepts, techniques and practices have been created and expanded for discrete production upgrades and waste removal [13]. These tools may present with distinct names where some of the tools, function by overlapping with other tools, some can work independently while the others need boosters from other tools to give better effect and act as an integrative lean system [1].

Shortly, lean tools mutually support each other, and they should be applied in parallel for better results. According to Faulkener & Badurdeen [14], lean tools can be grouped into three main categories such as (1) Quality Tools, (2) Production Process Tools or Just-In-Time (JIT) Systems, and (3) Lean Methods Tools. These three categories are the pillars of the "House of Lean Manufacturing" as shown in Figure 1 [15].

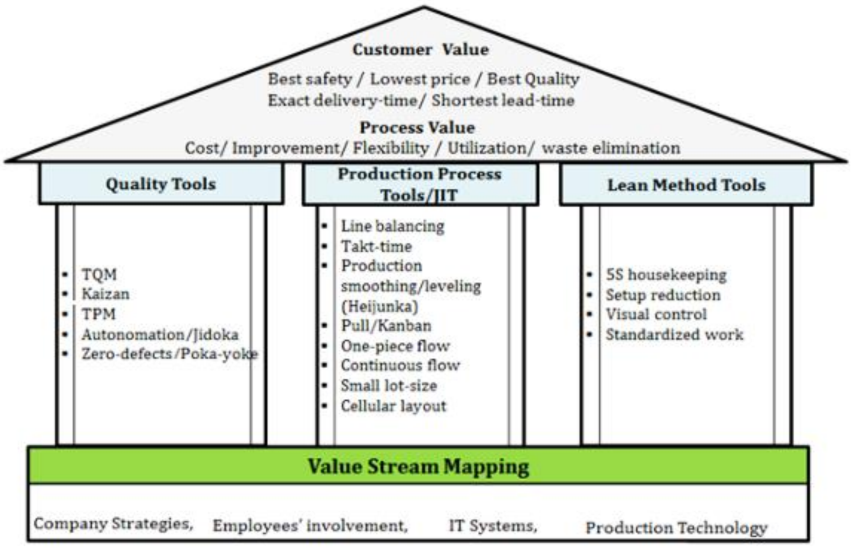

Figure 1. House of Lean Manufacturing [15]

Although multiple tools and techniques have been developed in the past, VSM has been a more effective tool used focusing on the analysis and improvement of manufacturing environments with unlinked flow lines.

Among the existing redesigning tools in the manufacturing area, there are not any other frameworks that work similarly as VSM in terms of objectives or the same level or degree of completion of manufacturing systems design [16].

CONVENTIONAL VALUE STREAM MAPPING (VSM)

Value stream mapping is a pencil and paper tool using icons shown in Figure 2. Plotting value stream maps by hand with paper and pencil, contain a lot of benefits although software such as e-VSM can be used to generate and publish the drawings. The important benefit of manual mapping is that it enables analysts to directly transfer each observed item on the shop floor to the paper rather than being controlled or moderating the idea by the computer. Besides that, the practice of instantly visualizing the observed view of the current process flow on paper will enable us to understand the whole shop floor more clearly.

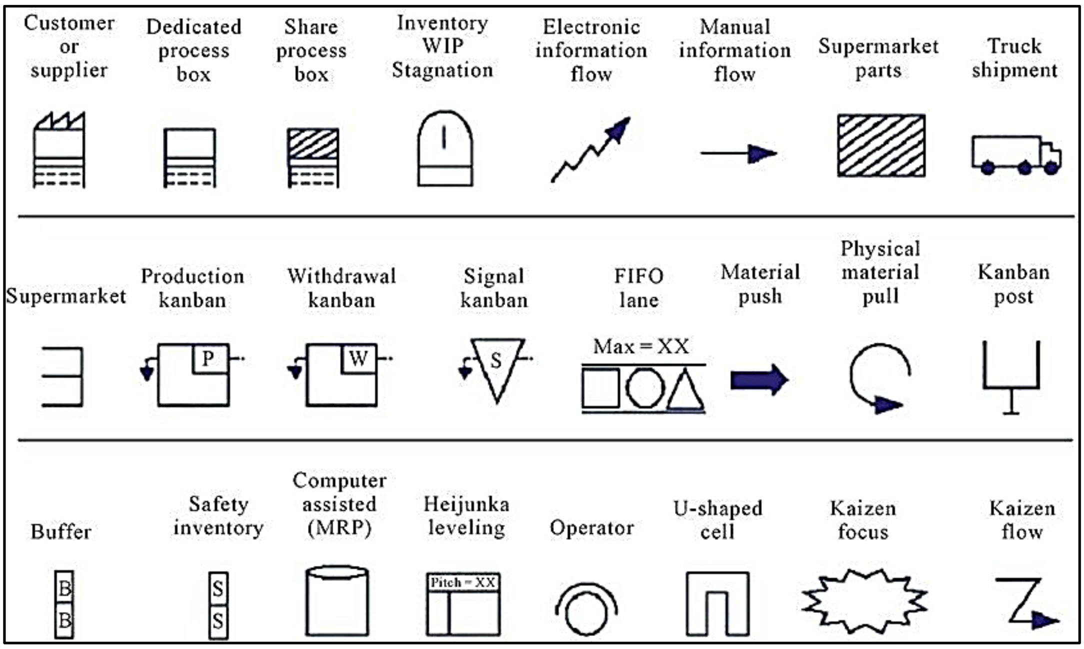

Figure 2. Value stream mapping icons (Adapted from Rother and Shook, 1999)

Mechanism of VSM

The term “value” refers to all the productive activities that involve changing materials or information from raw to worth which customer is willing to pay money for. Waste occurs when any activity or action does not add value to the product and thus, it must be removed or minimized. Womack et al., grouped these actions into three categories, such as Necessary but Non-Value Adding (NNVA); Value-Adding (VA); and Non-Value Adding (NVA).

The “value stream” term is used to describe the coordination of specific activities that consist of both value-added, and non-value added. These activities are drivers that carry down output or group of outputs from the state of raw material until it reaches the customers as a finished product by using the same resources [17]. There are three main steps to establishing material and information flow in Value Stream Mapping (VSM) [18].

The first step is selecting a specific product or product family as the target for improvement. The second step is to draw a current state map that captures the actual situation on how things are currently being done. This is carried out while walking along the actual process or called ‘gemba’ and provides the basic details for analyzing the system and pinpointing its drawbacks. The third step in VSM is to develop the future state map, that outlines a better manufacturing system that is effective and should be implemented by eliminating all the non-value-added activities. The future state map is developed by finding solutions for a set of questions related to process effectiveness and then implementing action plans by utilizing the lean tools.

The value stream map outlines a complete path starting from the supplier to the customer by visualizing the material and information flows of every process that is involved. The objective of this visual tool is for recognizing all types of waste in the value stream and carrying out corrective action to remove them. According to the value stream, corrective actions are conducted holistically rather than focusing on the activities and thus optimizing the overall process system instead of just a segment of the system. This value stream tool also acts as a communication medium for all parties to work towards a common goal which is to improve the value stream [19].

According to the diagram flow chart, process mapping is a famous tool to imitate any business activities or sub-activities [20]. VSM is supported generally by business activities due to mainly two reasons: Primarily it is based on the calculation and analysis of quantitative data [21] and the second reason is that it has no language barriers which makes the tool more beneficial and feasible [22]. But because of its feature which is more generic, sometimes it is less adapted to manufacturing system modeling [23].

Thus, it can be ensured that the VSM itself has a field of application due to the lack of use of redesign tools described and that it differs from other techniques and tools for improving manufacturing systems [24]. Furthermore, VSM was chosen as an analysis tool because it explicitly includes both information and material flow, which allows for an effective depiction of varying systems of manufacturing processes (such as kanbans, Materials Requirements Planning (MRP)-type systems, *etc*.). As such, VSM was considered an effective and suitable modeling tool for analyzing the current state and defining a future state for the production line, due to its structured approach, giving priority to eliminating waste and the requirement to achieve stated improvement goals compared to other tools.

Waste Reduction Thinking

In terms of the customer's perspective, value Stream mapping focuses on minimizing waste and on optimizing or wholly upgrading processes that add value to the product. In addition, anything that a customer is willing to pay for, either product or service is considered a value. Waste is defined as an activity that does not provide value to the product and which cannot gain profit from the customer [17]. Based on the industrialist perspective, waste comes in various forms. However, a Toyota production engineer called Taiichi Ohno in 1998 is the first person who successfully categorized wastes based on seven sources. Besides that, in order to make improvements toward minimizing waste, it is recommended that at least a basic understanding of the waste must be achieved before carrying out any mapping activities.

Recognizing the wastes whilst walking on the shop floors, the value-added activities also can be discovered in order to make the stream. Although wastes vary according to the types of industries, they can still be grouped into different categories depending on production structure. The most common sorting which was developed by Ohno will be introduced by seven wastes [20, 25, 26].

Application of Value Stream Mapping

VSM has some special features that make it main and distinctive for lean manufacturing compared to other mapping techniques. As an example, apart from managing production operations, VSM also optimizes the complete system by designing an overall picture of it [1]. VSM not only controls the individual process level but can demonstrate visuals of the whole plant level of the production process from door to door. As such, VSM reflects a systematic view and maintains the process details by visually joining the material flow, information flow and timeline by including information on production times as well as the inventory levels [2]. In addition, VSM connects production planning and flow shop control by utilizing operational parameters such as takt time. Takt time controls the production pace for each processing station in the manufacturing system to function. With the aid of a value stream map, which acts as a blueprint can help to implement lean and by integrating with numerous quantitative and qualitative analysis-based tools to redesign strategic improvements [27].

In 2018, Sunil and Bhim Singh [28] investigated the ways to reduce cost and improve productivity in the production system through the application of VSM-Fuzzy TOPSIS in small-scale enterprises. This approach was effective in removing waste in the organization. Devanshu Mudgal [1] studied on new approach to VSM in Make-to-Order (MTO) manufacturing environment by combining it with commonality analysis to get a better understanding of the processes. End of the study, commonality analysis was shown to be satisfactory and more detailed work can be conducted in future work. James C. Chen et al., [29] investigated the integration of VSM with RFID application in a case study. VSM was used to draw the current state map and future state map through lean production and RFID. As a result, by integrating lean and RFID, the total operation time can be saved by 81% in terms of transportation time and value-added time. In 2021, Farook Abdullah et al., [30] investigated sustainability in downstream operations in the Indian surimi supply chain by using VSM. VSM was integrated with performance analysis for various supply chain scenarios. As a result, the author identified that creating a surimi supply chain with cleaner downstream operations will lead to sustainability enhancement.

In 2018 also, Dario and Dorota [4] integrated VSM with a computer system (CS) before the actual application in the factory. This approach proposed a different fundamental concept of production such as a deterministic flow of material against a stochastic queueing network. End of the result, the author suggested that the integration of VSM with CS showed many improvements and predicted to optimize of most of the performance measures. However, it required an additional tool for the uncertainty and complexity of data. In 2020, Qingqi Liu & Hualong Yang, [31] integrated variability in lean manufacturing by using a fuzzy value stream mapping approach. In order to handle the variabilities of value stream parameters computationally, fuzzy set theory was applied to transform the uncertainties into fuzzy numbers. Two forms of fuzzy numbers such as triangular fuzzy numbers (TFN) and normal fuzzy numbers (NFN) methods were performed and validated in an industrial case study. The drawback of this study was that the TFN tends to overestimate the variability of the process in a complex production environment.

Benefits of VSM

The application of VSM in proposals to reduce production lead time has been widely studied in discrete manufacturing. This means that in the current competitive market, manufacturers are seeking to increase their market share with the lowest investment costs. This is expected to be influenced by adopting an improvement approach that focuses on removing non-value-added work and waste (especially from excessive inventory that affects lead time). Some experimental studies related to the application of VSM for manufacturers in the discrete sector and the derived production lead time are highlighted.

Chen & Huang [29] aimed to achieve improvements in steel supply chain lead times. The Current State Map detected a long lead time and large inventories. A Future State Map was then created. Various lean tools were focused on specific areas in the Future State Map, including kanban, supermarket and continuous flow. The outcome achieved by applying the future state map was a minimization in lead time from 47 and 57 days to 12.7 days and a reduction in cycle time from 7365 seconds to 6807 seconds [29].

There is another VSM application in a motion control product manufacturing plant. This is a motor manufacturer that is facing increased pressure from both outside and inside to improvise the execution of a particular product line. Azizi & Manoharan [23] found that they were able to reduce production lead time from 7 days and 3.1 hours to 16.45 hours using VSM.

Limitations of VSM

Although the VSM tool aided to visualise the advantages of applying lean principles, it had a few drawbacks that blocked its application in a broader perspective. The existing drawbacks of VSM, which is rather static in nature and unable to give a true scenario of the variability problems related to the production process analysed, make it incapable of achieving lean principles in the current dynamic and complex manufacturing systems [26]. In factories with high variability and low volumes, the traditional VSM method becomes complicated and inefficient. In a more dynamic operating process, variabilities have increased and the method to control variability becomes more complex [32].

As a matter of fact, paying minimal focus on the process variability that occurs in the actual value stream situations, has become one of the main limitations of VSM [33]. In order to control these drawbacks, computer simulation using discrete event simulation (DES) has been used in conventional VSM to demonstrate dynamic behavior and simulate possible future value stream alternatives [12].

Dynamic Value Stream Mapping

Simulating a product flow using computer software is a common design method used prior to the implementation in a production line [34]. Simulation modeling is an effective tool that is widely used in the manufacturing sector. Its popularity is due to its high flexibility and large capacity for simulation and evaluation of both static and dynamic systems.

According to Gurumurthy & Kodali [34], most simulation studies in the literature have concentrated on the study of LM elements such as kanban (finding the optimal number of kanbans), push and pull systems (comparison) and mixed-model assembly (sequencing and scheduling) [15, 35, 36]. Other elements of LM such as multi-machine activity (order expansion), minimizing cycle time and process improvements were not given enough priority.

According to Stadnicka & Litwin [12], the most common simulation technique used to express production processes is Discrete Event Simulation (DES), which is a numerical solution for queueing networks. The major advantages of DES are its ability to understand the behavior of a system prior to the construction stage, identification of nonconformities that happen out of sudden and also the ability to search various uses of case problems [19]. The major problem is related to how far a simulation output and the present value stream is matching. This issue is especially notable when discrete event simulation is performed on the manufacturing operation as denoted by value stream mapping. The objectives of these two techniques are varied, and this is indicated in the type of collected data by VSM, which differs from the data required by DES. The purpose of VSM is to identify the redundant actions (without value-added) and activities with mean cycle times, while DES pays closer attention to the queueing network. Hence the distribution of cycle times and the distribution of arrival times are required. Nonetheless, many samples exist to show how simulations are implemented to VSM, especially to establish the results of future stream maps.

Simulation in Support of VSM

A simulation is an effective tool discovered for the dynamic nature of the production operation [4, 12, 34]. The output from the simulation software can be used to differentiate the optimized future value stream and current value stream of the production floor by the management [31]. In other words, simulation enables managers to see the impact prior to a major implementation: the effect of layout changes, resource planning, etc. on key performance indicators before and after the lean transformation, and without a large upfront investment [37].

The simulation can be adapted to cater to the particular needs of the organization and is able to generate the requirements of the resources and statistics of the performances of both current state and expected future value streams. Hence, management can evaluate that the execution of the future value stream can operate optimally compared to the current value stream without impacting any core function of the production system based on simulation software result [38].

Discrete event simulation is commonly used in many lean manufacturing industries by researchers. Suresh [39] progressed a simulation model to study the impact of differences in processing times and demand on JIT system performances and to distinguish between pull systems and push systems for picking strategies using different kanban levels. Tabanli & Ertay [20] used simulation to answer a chemical company's questions about switching from a conventional to a JIT system and investigated various designs for the JIT system. Tasdemir & Hiziroglu [40] also utilized simulation to verify changes to a conventional system when it was transformed into a JIT system. Table 1 shows the systematic analysis of the literature on the application of dynamic VSM.

Table 1. Systematic analysis of literature

AUTHOR/ YEAR	OBJECTIVES	METHODOLOGY - VSM TOOL OR VSM ALTERNATIVES	FINDINGS	REMARKS
Marcus Lewin et al., (2017)[41]	A possible elongation of the value stream method was discussed.	A method for the visualization of Industrie 4.0 systems in the conception phase of Industrie 4.0 projects was designed according to the method of value stream	The conventional value stream technique lacks the ability to visualize the network of Industry 4.0 systems and data streams.	Research is needed into what waste-free Industrie 4.0 systems look like and which systems or logics offer added value for the customer or the company.
Dorota Stadnicka, Paweł Litwin (2019)[12]	To apply a method of indicating and prioritising major problems using computer simulations. To support prediction of future problems. To combine VSA and system dynamics analysis (SDA).	Collecting information of the manufacturing process such as cycle time, CT and production time, PT collects set-up time (c/o) (SDM) developed with VENSIM SOFTWARE.	The authors of this study introduce the theory of integrating VSM, VSA and SD. The advantages of using such a solution in a case study was demonstrated in the later part.	Future research also includes creating a model of the entire company in the market environment.
Stephen L. Woehrle & Louay Abou-Shady (2010)[42]	To show how simulation with VSM together with the use of lean accounting box scores can bridge both operational and financial views in a pool.	The fusion of simulation with VSM has countered the limitations of traditional VSM. Simulation is considered as an integral part of VSM.	Value stream map and simulation help to find a result to the disadvantages of using static VSM in terms of forecasting inventory levels of the entire manufacturing system.	Simulation can be seen as an effective tool for illustration, for finance and accounting administration.
Andreas Lugerta,b, & Herwig Winkler (2018)[2]	To discuss a conceptual extension of VSM based on an analysis of the literature.	The DVMM is developed as an incorporated method with VS at its core.	Most of the time, the planned level between tactical arrangement and operational production processes has often been less concentrated. Hence this paper highlights this issue and fills the research gap.	There is a pending scientific validation in the form of a case study. In order to improves this matter, this paper suggests to collaborate with the digital

				factory of an combined automotive supplier
Anand Gurumurthy & Rambabu Kodali (2011)[34]	To develop a simulation model for the design of a lean manufacturing system based on real data for the door and window manufacturing company. This paper indicates how a simulation model can be developed	The data collected during the development of the current VSM is also used for the development of the simulation model	Simulation studies were conducted for various phenomena, such as "before LM" (current state VSM) and "after LM" (future state VSM).	It was identified that the case organisation can attain an established performance improvement and cope with rising demand without additional resources.
Devanshu Mudgal & Konstantinos Salonitis (2020)[1]	Using a case study based method and demonstrating a methodology for applying VSM to an MTO and intending to focus on some unique features of the MTO scenario.	Regression commonality analysis gives a level of interpretation of regression impacts that cannot be disclosed when only the regression structure coefficient and standardized regression coefficient are examined.	DCI is produced by commonality analysis which is used to map the value stream with the conventional approach. Commonality analysis gives data on all common operations that can be inserted into the value stream map.	The commonality analysis was found to be satisfactory and a thorough commonality analysis could be performed as future work
James C. Chen et al., (2013)[29]	This study investigates the implementation of RFID method lean production to upgrade logistical efficiency in a three-stage supply chain management.	The value stream of the current state and future state are designed using Value Stream Mapping (VSM) to indicate material, information and time flows with lean production and RFID) with	The total operation time, from the current stage to the future stage with the joining of Lean and RFID, can be minimized by 78% (with 79% reduction in waiting and transport time and 64% reduction in value added time).	Further improve the read rate of UHF RFID readers by adjusting the location and position of tags and the distance between tags and readers, as the current 99.5 % can still be improved
Dario Antonelli & Dorota Stadnicka (2018)[4]	Present a case study analyzing a production flow of vulcanized sleeves using VSA and identifying existing problems.	VSM is created using Microsoft Visio Professional, while CS is implemented in FlexSimTM.	The VSM analysis makes it possible to indicate the managerial level issues caused by excessive non-value added	The simulation of the process requires data that is unknown and not present,

			activities and by longer lead time. The suggested future map has many benefits and is expected to optimize most of the discharging metrics.	since the FS is still in the design phasee
Dario Antonelli & Dorota Stadnicka (2015)[26]	to visualize the current value stream of the production operation of sleeves, pinpointing the wastes that present, investigate the issues and present proposals for a value stream progress based on the future value stream.	A manufacturing system is modelled using the FlexSimTM programme, which is used for simulation software. The results recommended in FSM are presented in CS	Additional data of every machine such as WIP, C/T, C/O can be provided in the current stream. Based on the analysis on the current stream, appropriate changes can be applied on the manufacturing system to obtain an effective output.	As a summary, it`s concluded that current value streams provide actual value-added to stream analysis and help to decide and plan the development of manufacturing systems.
Seyed Mojib Zahraeea et al., (2020)[37]	This work aims to combine the VSM lean tool and computer simulation to identify the root cause of the waste and increase the production rate to meet customer demand in a small heating industry small-scale heater industry	This paper finds answers for the questions of whether the solution can be achieved as planned and determines the necessity of using simulation.	The outcome explains that the method able to achieve significant improvisions in production lead time, value added time and Takt time	Future studies can pay attention on the application of "green" manufacturing factors to minimize waste and pollution, enable developments in economic and recycle waste generated by industrial activities
Qingqi Liu & Hualong Yang (2020)[31]	Hence, a combination of fuzzy number and VSM is used for overcoming uncertainties and varieties issues in lean manufacturing systems.	Fuzzy theorem is applied to convert to fuzzy numbers from varieties in order to handle the uncertainties of VSM specifications computationally.	As the case study shows, by introducing fuzzy logic into conventional VSM, the varieties and uncertainties that occur in both the individual process and overall value stream can be controlled.	Recommended to conduct research in future to prevent the limitations of fuzzy VSM in terms of normal and triangular as well as maintaining the corresponding benefits.
Daniel Nåfors et al., (2018)[43]	Evaluate the advantages and disadvantages of a DES model	3D laser scanning is used to detect and digitize the structural data of	VSM has proven to be most beneficial in the initial stage of a	For future work, the potential of advancing

	incorporated with 3D laser scanning and value stream	production systems, which provides suitable references.	study, while 3D laser scanning can be useful.	simulation software for improvising the functionality and cooperation of cloud data can be helpful for future studies.
Christoph Koch and Hermann Lödding (2014)[44]	The objective of the paper is to denote the limitations of VSM when applied in a make-to-order manufacturing system.	In order to provide the foundation to apply value streams in make-to-order industries, the necessities for administration goals of value stream and the associated activities of production control are described	Based on the scope, the logistical goals sought with VSM are not the same as the logistical goals of an MTO organization.	The development of a future state map should be acquired from the typical manufacturing control arrangement. Also, the appropriate technique needs to be assessed with various industry allies for covering various make-to -order manufacturing systems.

Arena simulation

One of the software simulators for performing discrete event simulation is Arena [37]. William et al., [27] utilized Arena simulation software to help a retailer electronics company decide to apply lean manufacturing by measuring the advantages of applying lean principles. Ahmed Abedeen [45] used arena simulation for a high-performance motion control product manufacturing system to show that simulation can be a very important tool in evaluating various future state plans. In addition, their study showed that simulation can give and explore various scenarios to accompany those attained from future state mapping. Abdulmalek and Rajgopal [15] use System Modeling Corporation's Arena 5 software to show a simulation model designed to compare "before" and "after" information in specific to show potential benefits to managers, such as minimized production lead time and reduced labor inventory.

To solve the highlighted constraint, a supportive tool is required to deal with VSM uncertainties. Simulation allows resource requirements and performance statistics to be generated while remaining flexible for specific organizational details. It can be used to deal with uncertainties and generate dynamic views of inventory levels and lead times for various future state maps [15]. It is important that everything runs as effectively as possible and that the simulation approves the lean transition with VSM. Based on the focus given in today's competitive market of "getting it right the first time", the message becomes clear: if success was not achieved initially, then it should be simulated [47].

Arena simulation is suitable for this case study because a simulated factory is frequently beneficial in helping manufacturing managers and workers understand the fundamentals of factory dynamics. This can be achieved with a computer simulation, but usually, a practical approach is preferred. By studying the simulated factory, the basic laws become clear and important insights into the behavior of an actual factory are gained [4].

CONCLUSION

The literature review recommended that Value Stream Mapping (VSM) is an effective entry-level tool for industries that intend to practice lean and reduce production cycle time. In the following, results have been reported for subtracted production lead time for steel manufacturers. There are shortcomings associated with value stream mapping (VSM), which is a static tool. Hence simulation applications can help to support VSM for companies that intend to transform to lean. Knowing how much a system can produce within the predicted lead time before making physical changes to the system saves both money and time. Also, if a simulation can be created, it is possible to see both the static and dynamic influences. This means that the effects of dynamic behaviors, such as inventory, on production lead time are included in the simulation. In order to check the accuracy of the models developed with the VSM tool, the software System Modelling Corporation's Arena 5 was used.

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