

Applying Value Stream Mapping in Manufacturing: A Systematic Literature Review

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Abstract: Value Stream Mapping is a critical tool when it comes to implement the lean approach and it has spanned to many sectors in industry. Although previous studies justify its use in manufacturing sector by identifying previous cases within the literature, none to the best of our knowledge has used our approach to explore the aspects covered in this review, yet the potential exists. Based on a systematic approach, we analyzed available literature published in refereed journals, providing academics and researchers with valuable findings related to the evolution, application and performance of the Value Stream Mapping in context of the manufacturing sector.

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Keywords: Value stream mapping, logistics in manufacturing, business process management systems, lean manufacturing, methodologies and tools for analysis of productive systems

1. INTRODUCTION

Lean Manufacturing has proved to be a resilient alternative that, when adequately adopted by the different actors through the supply chain, provides satisfactory results in terms of profits (Suhadak et al., 2015). This systematic approach focuses in doing more with less resources by eliminating non-value added activities and wastes (Womack et al., 1990); originating from Japan in the Toyota Production System, has been defined by its founder, Taichi Ohno, as “looking at the time line from the moment the customer gives us an order to the point when the cash is collected; and waste is reduced by removing the non-value-added wastes” (Liker & Meier, 2006).

Lean tools and principles have been widely used (Cox & Ulmer, 2015). Yet, Value Stream Mapping (VSM) is a lean manufacturing technique that since its creation has spanned to many sectors in industry and it has emerged as the preferred way to support and implement the lean approach (Grewal, 2008). It deepens the understanding of work systems that deliver value to customers and reflects the workflow from a customer’s perspective; as a result, the process of VSM provides effective ways to establish strategic directions for better decision making and work design (Li, 2014). Thus, it receives great attention when it comes improve enterprises.

2. CONTRIBUTION OF THE RESEARCH

The application of VSM has expanded to many industry sectors in recent years due to its ease of adaption to a wide range of environments. It is possible to apply it in solving different kind of issues related to reduce waste. An exemplary sample with real research and application of VSM in environments different from manufacture of parts is shown in Table 1. Regarding manufacturing environment, previous

studies justify the use of VSM in several industries by identifying its successful applicability through review and identification of literature (Table 2); however, none to the best of our knowledge has explicitly explored the same aspects that we did it in our literature review, yet the potential exists. Based on a systematic approach, this study covers available literature published in refereed journals, providing valuable information about aspects of evolution, application and performance of VSM in the field of manufacturing.

Table 1. VSM applied in different fields

Sector	Source
Construction	(Matt, et al., 2013)
Healthcare	(Kaale, et al., 2005)
Services: call centre	(Piercy & Rich, 2009)
Transport	(Villarreal, 2012)
Architecture	(Lima, et al., 2010)
Software product lines	(Musat & Rodríguez, 2010)
Product development	(Tyagi, et al., 2014)
Innovation management	(Peek & Chen, 2011)
Services: government	(Krings, et al., 2006)
Mining	(Kumar, 2014)
Industrial product-service systems	(Morlocka & Meier, 2015)
Reduction of food Looses	(Steur, et al., 2016)
Maintenance service	(Kasava, et al., 2015)

Based on a systematic review approach, this study considered the first to aggregate and examine evidence on the application of VSM in the manufacturing industry. The next section of this

article outlines the procedure that was used to search and select studies, from which relevant data was obtained. The third section gives an overview of studies characteristics, application of lean manufacturing mainly focusing on VSM and identification of wastes. The fourth section is devoted to a discussion of important findings which is followed by a conclusion.

Table 2. Previews literature research regarding VSM

Brief description	Source
It is part of a master thesis. Exposes the most relevant of VSM from about 13 sources including books and journals, without charts or graphics.	(Li 2014)
It is about the application of VSM reducing food loses. They considered the year and country of the publication and the types of wastes found	(Steur et al. 2016)
It is a review of 10 case studies, taking into account the Key Performance Indicators, and they presented percentage of improvement by graphs.	(Saraswat et al. 2014)
Reviews 47 works among books and journals. Authors focused on the type of work, and the attributes considered in each paper/book.	(Singh et al. 2011)
A review of 6 papers where VSM was applied. Improvement of Key Performance Indicators and applicability to different sectors is reported.	(Patel, et al., 2015)
This book chapter is a review about different types of value mapping tools, it offers an overview of each technique and their characteristics.	(Romero & Chávez, 2012)
A review of 57 papers from 1999 to 2013. Authors identified the main limitations to develop the actual state of VSM, and guidelines for its use.	(Forno, et al., 2014)
A review about how the use of VSM in new product development affect organizational learning in development processes, from 18 papers.	(Schulze, et al, 2013)
Presents some of the techniques commonly applied to analyze and the value stream. Authors include a table with 5 articles reviewed.	(Gunaki, et al., 2015)

3. METHODS

The structure of this systematic review follows applicable guidelines set in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement. Studies were identified by searching EBSCO, Science Direct and google scholar databases from 1990 to 2016. This time period was selected in order to cover a timeframe from when lean manufacturing started to be documented in literature to date (Womack et al., 1990).

The search targeted articles written in English and was not only limited to studies published in indexed Journals. Manuals, editorials and commentaries were disregarded. The search syntax used included the following search terms referring to lean and VSM. For confirmatory purposes and to identify additional studies, a reference list of a review on VSM (Singh et al., 2011) was also utilized. The search for articles was done by one researcher in October 2016.

The inclusion criteria used for selection of relevant studies, after removal of doubles, was initially based on title and abstract screening to ascertain the existence of both VSM and manufacturing related key words. A full paper review was performed where a more stringent inclusion criteria was applied. Studies that utilized VSM as (one of) the lean tool(s) were kept to carry out the systematic review. We found two papers where literature review in the field of manufacturing was performed and these were not considered as part of the article.

Key aspects were identified and gathered on a data extraction sheet. This was used to systematically extract and code necessary data from the studies. The information was related to: year and country where the study was carried out, type of VSM used (whether adapted or traditional), type of issue to solve, performance indicator utilized and results obtained, tools used along with VSM, and type of industry where it was applied.

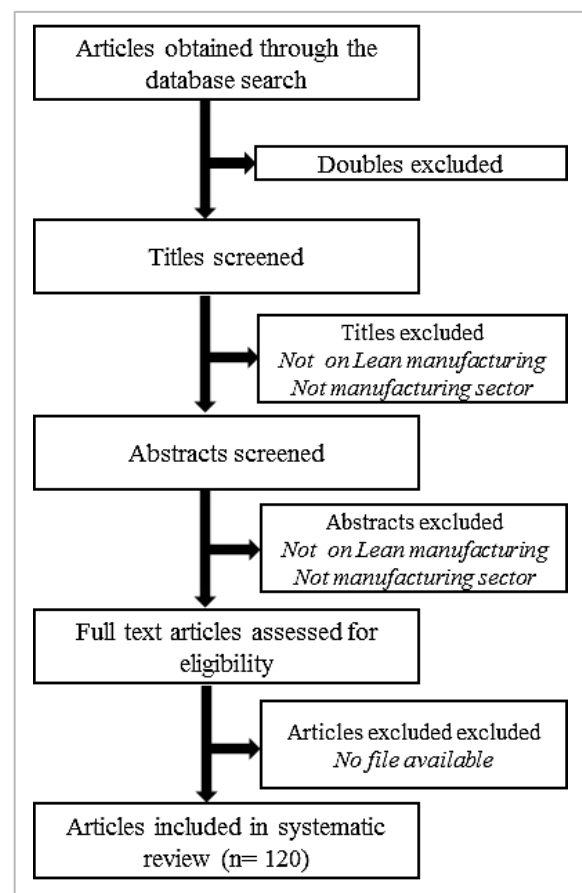


Fig. 1. Flow chart of selection of papers for the review

4. RESULTS

As illustrated in Fig. 1 by a flowchart, the literature was selected, starting with identification of studies that were of potential relevance, then, we removed doubles, title, abstract and full article screening, a total of 120 studies were selected, classified based on several aspects that we wanted to examine at a deep approach. Our research considered several attributes contained in the literature in order to offer a comprehensive insight of the evolution, application and performance of VSM in the field of manufacturing Fig. 2 depicts how the information was classified for this purpose.

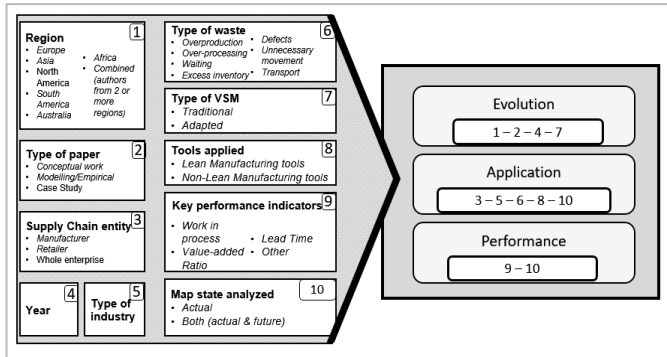


Fig. 2. Attributes of papers considered to be analyzed

Concerning the evolution of VSM in the context of manufacturing, majority of studies were carried out between 2007 and 2012, in Europe. However, recently the region from Asia had a significant increase of contributions; we noted that the region of North America has also grown in proportion of publications. South America as well as Africa shows little participation, which has kept evenly over time (Fig. 3). Most of the research done is advocated to modelling, rather than conceptual or hands-on work as shown in Fig. 4 and Fig. 6, followed by case study papers; in Fig. 5 it is possible to observe how VSM has been adapted since its introduction. However, last years the number of adaptations has grown.

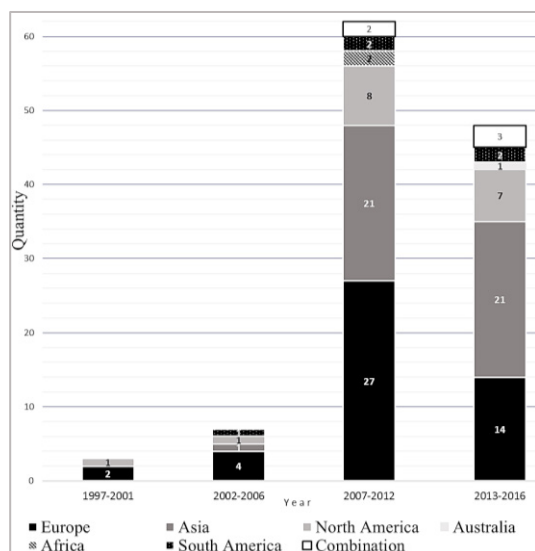


Fig. 3. Number of Publications per year in each region

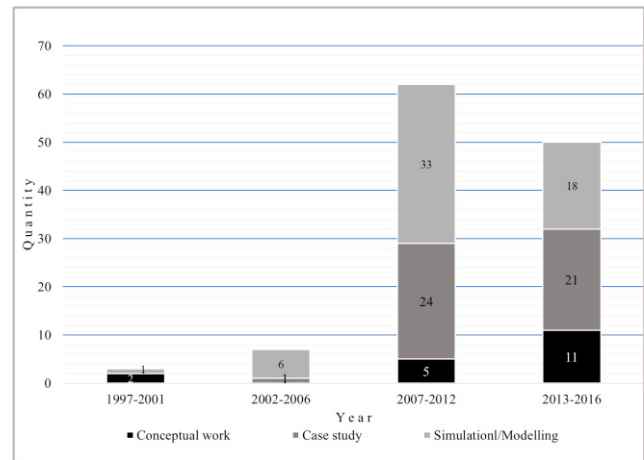


Fig. 4. Publications per year by type of work

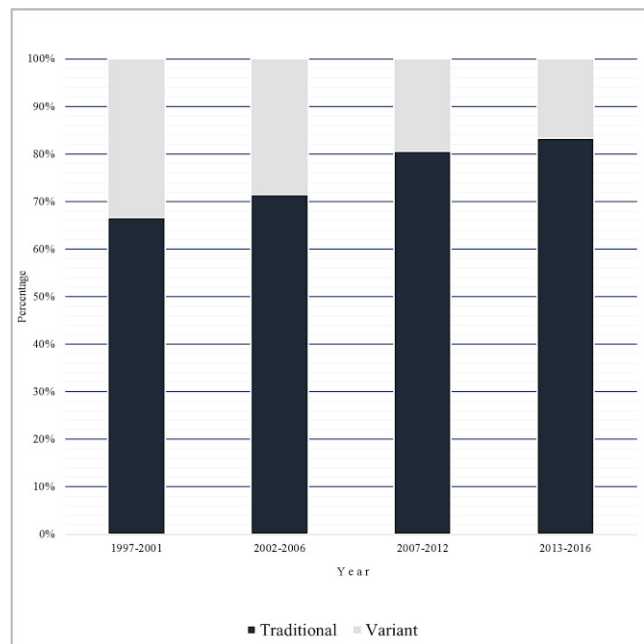


Fig. 5. Proportions of type of VSM applied over time

The methodology to analyze the value stream by the VSM approach explicitly states that it is necessary to draw both actual and future state maps (Serrano, et al., 2008), however, some of the papers did not present the future state map (see Fig. 7). Among other findings, we realized that only 2.4% of the articles focused on the whole enterprise, while the rest did it a single manufacturer plant. The industries where the research was carried out were very different from each other, ranging from apparel industry to automotive sector, to satellite dishes manufacturers. Concerning the automation level, while it was not possible to deduce it in every paper, we considered those where the information available allowed to know it and we found out that in 63% of the times the VSM was applied in environments where the automation level was medium, and any of the studies claimed to be done in low automation environments.

Type of paper		
Conceptual Work	Modelling/case study simulated	Case study applied
(Hines et al., 1997)	(Lian & Van Landeghem, 2002)	(Abuthakeer et al., 2010)
(Khaswala & Irani, 2001)	(Shararah, et al., 2011)	(Serrano, et al., 2008) a
(Gracanin, et al., 2014)	(Abdulmalek & Rajgopal, 2007)	(S.K.P.N., 2012)
(Mostafa & Dumrak, 2015)	(Hines et al., 1999)	(Dushyanth Kumar, et al., 2015)
(Kuhlang, et al., 2011)	(Joshi, 2012)	(Azizi & Manoharanb, 2015)
(Lourenço et al., 2016)	(Whitman, et al., 2006)	(Schönemann et al., 2016)
(Brown, et al., 2014)	(Matt, 2006)	(Rohani & Zahraee, 2015)
(Edtmayr, et al., 2016)	(Braglia, et al., 2006)	(Joshi & Naik, 2012)
(Verma & Sharma, 2016)	(Agyapong-Kodua, et al., 2012)	(Ar & Al-Ashraf, 2012)
(Kuhlang, et al., 2013)	(Kumar & Gureja, 2015)	(Haefner, et al., 2014)
(Sihn & Pfeiffer, 2013)	(Pandhi & Verma, 2012)	(Rohac & Januska, 2014)
(Al-Odeh, et al., 2014)	(Schmidtke, et al., 2014)	(Ramesh, et al., 2008)
(Yusof, et al., 2015)	(Ramesh & Kodali, 2012)	(Venkataraman, et al., 2014)
(Sultana & Islam, 2013)	(Lu, et al., 2011)	(Theide, et al., 2016)
(Ramadan, et al., 2012)	(Huang & Liu, 2005)	(Faulkner & Badundeen, 2014)
(Solding & Gullander, 2009)	(Dotoli, et al., 2012)	(Lacerda, et al., 2016)
(Khalid, et al., 2014)	(Geldum, et al., 2011)	(Murugesan, et al., 2016)
(Suci, et al., 2011)	(Karim, et al., 2012)	(Lian & Van Landeghem, 2007)
(Kayakutlu, et al., 2007)	(Wang, et al., 2011)	(Miyake, et al., 2010)
	(Chong, et al., 2013)b	(Serrano, et al., 2008) b
	(Sasikumar & Kumar, 2013)	(Bertolini, et al., 2013)
	(Tanco, et al., 2013)	(Chen, et al., 2010)
	(Pattanaik & Sharma, 2009)	(Dotoli, et al., 2011)
	(Persson, 2011)	(Jiménez, et al., 2011)
	(Helleno, et al., 2015)	(Chen & Chen, 2014)
	(Agyapong-Kodua, et al., 2009)	(Dotoli, et al., 2014)
	(Kolic, et al., 2014)	(Dotoli, et al., 2015)
	(Sahoo, et al., 2008)	(Durank, et al., 2011)
	(Ismail, et al., 2014)	(Wolniak & Skotnicka-Zasadzien, 2014)
	(Chen, et al., 2013)a	(Das, et al., 2014)
	(Haque, et al., 2012)	(Alvarez, et al., 2009)
	(Al-Aomar, 2011)	(Rajenthirakumar & Shankar, 2011)
	(Singh & Sharma, 2009)	(Reddy, et al., 2013)
	(Xia & Sun, 2013)	(Saifuddoha, et al., 2013)
	(Belokar, et al., 2012)	(Shetty, et al., 2009)
	(Braglia, et al., 2009)	(McKenzie & Jayanthi, 2007)
	(Esfandiyari, et al., 2011)	(Ferreira & Ristof, 2008)
	(Faulkner, et al., 2012)	(Chong, et al., 2013)a
	(Singh, et al., 2010)	(Vendan & Sakthidhasan, 2010)
	(Kurdve, et al., 2011)	(Favaro & Lima, 2005)
	(Zahraee, et al., 2014)	(Tyagi & Vadrevu, 2015)
	(Vamsi Krishna Jasti & Sharma, 2014)	(Villareal, et al., 2012)
	(Miller, et al., 2010)	(Mohanraj, et al., 2011)
	(Sobczyk & Koch, 2008)	(Aluca & Ceylan, 2011)
	(Paju, et al., 2010)	(Domingo, et al., 2007)
	(Mahfouz & Arisha, 2013)	(Thomas, et al., 2008)
	(Kolic, et al., 2012)	
	(Shararah, et al., 2010)	
	(Mahfouz, et al., 2011)	
	(Chen, et al., 2013)b	
	(Plehn, et al., 2012)	
	(Ozkan, et al., 2005)	
	(Rajenthirakumar, et al., 2011)	
	(Bhat & Shivakumar, 2011)	
	(Seyedhosseini & Ebrahimi-Taleghani, 2015)	

Fig. 6. Classification of papers about VSM and manufacturing

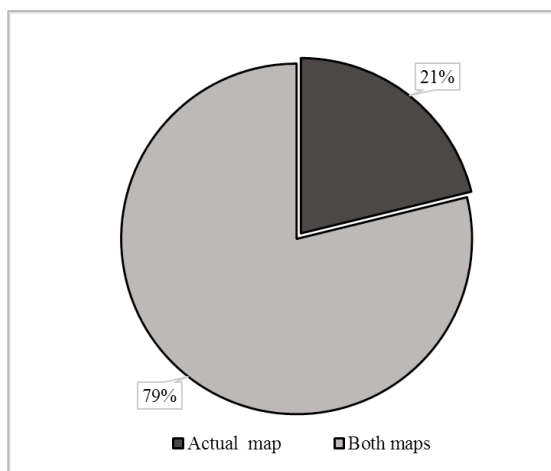


Fig. 7. States of map developed

Respecting to the types of wastes, we found that many of the papers advocated to more than one at the time, Fig. 8 shows that waiting time, excess of inventory and overproduction are

the wastes that received more attention in the literature. On the other hand, over-processing is the one that fewer papers have taken into account when it comes to research about the VSM approach. Further, our analysis showed that more than 44% of the work emphasized on the application of other lean tools along with VSM, where the most commonly applied were kaizen events and pull system; 62.5% used tools that are not part of lean manufacturing, being simulation the most frequently used. It is important to note that in some cases authors utilized both lean and non-lean tools. In the subject of performance, available literature indicated that reduction of lead-time is key performance indicator that most of the researchers targeted in their papers, where the average improvement is 52.26% when applied. Additional information is shown in Fig. 8 and Table 3.

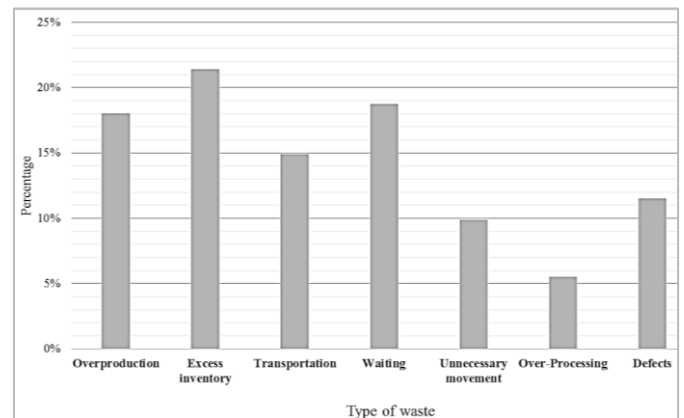


Fig. 8. Type of wastes analyzed in the literature

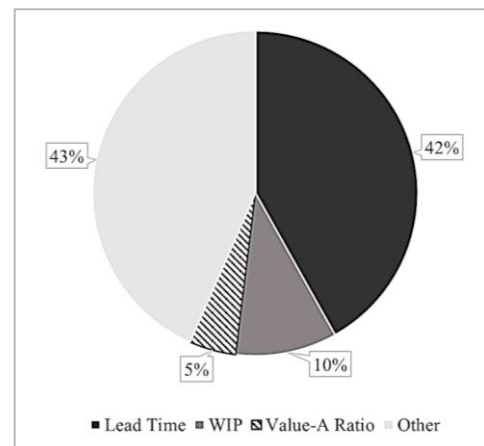


Fig. 9. Frequency of use of key performance indicators

Table 3. Use and performance of indicators

KPI	Times applied	Average improvement
Lead Time	54	52.26%
WIP	13	64.75%
Value-A Ratio	6	172.79%
Other	56	N/A

5. DISCUSSION

In recent years, the interest on VSM techniques has increased significantly; our review demonstrates a mix of regions where the applicability of VSM in the manufacturing sector has been examined. Practitioners and academics can further utilize the information herein presented, since it provides useful insights regarding the impacts of the addressed tools in the performance metrics of many companies. Our research shows that Europe is the area where more research about VSM has been done; however, Asia has notably contributed to the development of knowledge in this field too, especially in recent years; these efforts have advocated primarily to modelling and simulation works. Additionally, most of the variants of VSM have been developed recently; this could be due to many reasons such as new challenges in the market, the weaknesses of the traditional VSM, and due to its ease of adaption to different characteristics of production environments. There are some cases where VSM is not properly implemented as it happened in the cases of those papers where only the current state map was developed (see Fig. 7), therefore, more preparation is needed in order to obtain better results from its implementation. The investigation allows analyzing the potential level of improvement, reflected in the key performance indicators; we remark that many indicators are used according to the interests and needs of each particular case.

6. CONCLUSION

By conducting the present work, it was possible to realize of the great evolution of the available research work regarding VSM. We confirmed how it has spanned to 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 (see Table 1), where further reviews could help to understand how VSM could be developed in diverse sectors, offering a view of the possibility to improve performance indicators. Therefore, 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.

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