

Function of Value Stream Mapping in Operations Management Journals

Mitsuhiro FUKUZAWA^{a)}

Abstract: Studies of the value stream mapping (VSM) in Western journals report that leveraging VSM as a lean tool results in performance improvements. However, in these articles, VSM is functioning as a tool for partial optimization, attempting to identify and resolve bottlenecks in individual functions and divisions, primarily in production activities. For that reason, the greater the degree to which VSM underpins success, the more it deviates from the original essence of lean production and flow management, promoting overall optimization by focusing on the flows across the value chain, and potentially leading to poorer performance in the overall value flows up to the customer.

Keywords: value stream mapping, lean production system, production and operations management, value chain

^{a)} Faculty of Business Administration, Seikei University, 3-3-1 Kichijoji-kitamachi, Musashino-shi, Tokyo, Japan, mfukuzawa@bus.seikei.ac.jp

A version of this paper was presented at the ABAS Conference 2020 Summer (Fukuzawa, 2020).

^{© 2020} Mitsuhiro Fukuzawa. This is an Open Access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted reuse, distribution, and reproduction in any medium, provided the original work is properly cited.

Introduction

The fundamental view of the enterprise taken by management scholars, notably Thompson (1967), is that the firm applies a technical transformation to inputs to produce outputs desired by customers, thus contributing to the economy and society and sustaining the enterprise and continuing its growth. Applying this view of the enterprise to an operations management context, what is important, as pointed out by Fujimoto (1999, 2012) is an understanding of corporate activity as creation and transformation of the design information (i.e., the creation of excellent value flow) ranging from product development to production, procurement, and sales activities. The entire flow of value-creating activities will only rarely be contained within a single function or enterprise; it is brought about by combining activities by multiple, diverse functions and enterprises or entities. It is the level of superiority and excellence around this flow of value creation in which enterprises compete.

Starting in the 1980s, the concept of lean production systems, based on international comparative studies on the characteristics and strengths of production systems at Japanese enterprises, has achieved worldwide acceptance as a key feature of organizations that create value streams more skillfully than their competitors (Fukuzawa, 2019; Holweg, 2007; Shah & Ward, 2003, 2007; Womack, Jones, & Roos, 1990).

An important tool which has come to be used at overseas enterprises in making their production systems for value streams lean is value stream mapping (VSM), an application of the "material and information flow chart" used in Japanese companies.

This paper reviews the ways in which VSM has been framed and analyzed in Western operations management journals, with a focus on the functions and activities to which VSM is applied.

Function of the Value Stream Mapping

(1) Value stream mapping: A guidance of the lean journey

One tool that has been employed to achieve lean value flows in corporate activities is VSM, an adaptation of the "material and information flow chart." It was Rother and Shook (1998) who first coined the use of the term VSM.

VSM was originally proposed by Rother and Shook (1998) as one of the most important tools to engender success on the lean journey, applying the concept of "material and information flow chart" used internally at Toyota in the context of lean production and management. This was one work product of the first lean toolkit project at the Lean Enterprise Institute. Mike Rother, one of the authors, was a lean production systems consultant; John Shook had experience working at Toyota. For them, it was a given to use the "material and information flow chart," a methodology that was used at Toyota to consider value flows in a customer-oriented fashion, make flows visible, eliminate *muda* (waste), and enhance processes going forward. As Rother and Shook (1998) mentioned in the preface, these "mappings" were used as a "communication tool" in their kaizen activities in Toyota.

Rother and Shook (1998) present approaches to improve the overall flow of the supply chain using VSM to visualize the current state of the supply chain (procurement, manufacturing, and sales), discover bottlenecks where waste arises, and eliminate those bottlenecks through workplace improvements. Introducing such VSM-based kaizen activities is expected to lead to performance improvements such as increasing the ratio of the value-adding time and reducing lead times. Subsequently, Rother (2010) explains in detail the notion of KATA, and groups of routines for kaizen and coaching at Toyota. These authors emphasize finding bottlenecks by means of making things visible.

Liker and Meier (2005) argue that what is important when trying to reduce inefficiencies is to look across the entire range of value creation activities to identify inefficiencies occurring in the entire value stream, rather than focusing on kaizen for individual process steps.

VSM has become more widely used and popular in recent years as an important tool for enhancing the value chain flow. For example, Shou, Wang, Wu, Wang, and Chong (2017) conducted a wide-ranging survey of publications from 1999 through 2016, finding that VSM was being used and was effective not only in manufacturing but also in a broad range of other sectors, including healthcare, construction, product development, and services. Serrano Lasa, Laburu, and de Castro (2008) and Seth, Seth, and Dhariwal (2017) show that applying value stream maps in workplaces in which things are manufactured is also effective in improving the value-adding time in productive work and reducing lead times.

This has been an overview of the progress that has been made in academic research and initiatives to enhance the value chain flow using the "material and information flow chart" that originated in initiatives at Toyota and their adapted form, the lean tool known as VSM.

(2) VSM as a lean "production" tool

To explore trends in research on VSM outside of Japan, we searched the Web of Science for the topics of "value stream map" and "VSM" for the period 1997 through 2019. From the results, we selected and reviewed leading journals in the field of operations management. The journals selected for review in this paper are *International Journal of Production Research, Production Planning & Control, International Journal of Lean Six Sigma, Journal of Manufacturing Technology Management, Business Process* Management Journal, International Journal of Production Economics, Journal of Operations Management, International Journal of Operations and Production Management, ¹ and Production and Operations Management. We excluded search results clearly unrelated to VSM. ² Note that we found no hits in the two top operations management journals, Journal of Operations Management and Production and Operations Management, and another top journal, International Journal of Operations and Production Management, had only two articles (Hines & Rich, 1997; Holweg, 2005), a relatively small number. Ultimately, we chose 75 articles for our analysis.

Table 1 shows the number of selected articles and empirical papers by journals, along with the methodology (case study, questionnaire, simulation, combined case study and simulation, and combined case study and questionnaire) and the number of non-empirical articles. Non-empirical articles included two review papers, Shou, et al. (2017) and Vasconcelos Ferreira Lobo, Damasceno Calado, and Dalvo Pereira da Conceição (2018), and one model building paper, Nounou (2018). Table 2 also indicates the unit, function, and activity to which VSM was applied in the empirical papers. Leaving aside papers using questionnaires that asked about the degree of use of VSM, the great majority, albeit with some differences in details, describe VSM in actual subject companies.

As shown in Table 1, most of the studies used a case study methodology, accounting for 69% of the total (Agyapong-Kodua,

¹ Hines and Rich (1997) bring together information on the degree to which the seven tools that existed at the time for mapping value streams proved useful. Of the seven tools, it is processing activity mapping that is most relevant to reducing inefficiency. Hines and Rich (1997) are affiliated with the Lean Enterprise Institute, as are Rother and Shook (1998). Discussing the importance of focusing on the value stream and its visualization led to theorizing about VSM after Rother and Shook (1998).

² For example, we excluded the articles about the viable system model.

	# of	Empirical					
Journal name	articles	case study	questionnaire	simulation	case study & simulation	case study & questionnaire	
International Journal of Production Research	24	16	2	1	3	1	1
Production Planning & Control	17	13	1		2		1
International Journal of Lean Six Sigma	12	9	1		1		1
Journal of Manufacturing Technology Management	8	6	1		1		
Business Process Management Journal	7	5			2		
International Journal of Production Economics	5	1	1		3		
International Journal of Operations and Production Management	2	2					

Table 1. Distribution of method of VSM research

Ajaefobi, Weston, & Ratchev, 2012; Basu & Dan, 2014; Ben Fredj-Ben Alaya, 2016; Bertolini, Braglia, Romagnoli, & Zammori, 2013; Braglia, Carmignani, & Zammori, 2006; Camgöz-Akdağ & Beldek, 2019; Camgöz-Akdağ, Caliskan, & Toma, 2017; Carmignani, 2017; Chen, Li, & Shady, 2010; Chiarini, 2011; Choudhary, Nayak, Dora, Mishra, & Ghadge, 2019; Chowdary & George, 2011; Coronado & Lyons, 2007; Cottyn, Van Landeghem, Stockman, & Derammelaere, 2011: Dinis-Carvalho, Guimaraes, Sousa. & Leao. 2019: Dinis-Carvalho, Moreira, Bragança, Costa, Alves, & Sousa, 2015; Green, Lee, & Kozman, 2010; Gutierrez-Gutierrez, de Leeuw, & Dubbers, 2016; Henrique, Rentes, Filho, & Esposto, 2016; Hines & Rich, 1997; Hodge, Goforth Ross, Joines, & Thoney, 2011; Holweg, 2005; Jasti & Sharma, 2015; Jiménez, Tejeda, Pérez, Blanco, & Martínez, 2012; Lacerda, Xambre, & Alvelos, 2016; Librelato, Lacerda, Rodrigues, & Veit, 2014; Liu & Ming, 2019; Matt, 2014; Jevapaul, Vimal, & Mathiyazhagan, 2019; Nepal, Nagaraj, Natarajarathinam, & Balla, 2011; Powell, Lundeby, Chabada, & Drever, 2017; Raghavan, Yoon, & Srihari, 2014; Ramesh & Kodali, 2012; Ratnayake & Chaudry, 2017; Ray & John, 2011; Serrano Lasa, Laburu, & de Castro, 2008; Serrano Lasa, Ochoa, & de Castro, 2008; Serrano Lasa, de Castro, & Laburu, 2009; Seth & Gupta, 2005; Seth,

Seth, & Dhariwal, 2017; Seth, Seth, & Goel, 2008; Singh, Garg, Sharma, & Grewal, 2010; Singh, Kumar, Choudhury, & Tiwari, 2006; Stadnicka & Ratnayake, 2017, 2018; Sunk, Kuhlang, Edtmayr, & Sihn, 2017; Thanki & Thakkar, 2016; Tuli & Shankar, 2015; Tyagi, Choudhary, Cai, & Yang, 2015; Villarreal, Garza-Reyes, & Kumar, 2016; Vinodh, Arvind, & Somanaathan, 2010; Vinodh, Kumar, & Vimal, 2014).

The next most common were combinations of case studies and simulation analysis, making up for 16% of the total (Abdulmalek & Rajgopal, 2007; Bhuvanesh Kumar & Parameshwaran, 2018; Cavdur, Yagmahan, Oguzcan, Arslan, & Sahan, 2019; Gurumurthy & Kodali, 2011; Huang & Liu, 2005; Mishra, Sharma, Sachdeo, & Kandasamy, 2019; Parthanadee & Buddhakulsomsiri, 2014; Persson, 2011; Schmidtke, Heiser, & Hinrichsen, 2014; Stadnicka & Litwin, 2019; Xie & Peng, 2012; Yang & Lu, 2011). Each of these papers includes simulations as a way to compensate for the shortcomings of VSM, including the need to limit the products being addressed, the difficulty of considering various criteria during the envisioning of the desired future state from the current state of thinking about which types of kaizen tactics are appropriate, and the difficulty of writing out by hand.

Quantitative method articles using questionnaires accounted for 8% of the total. These papers were Andreadis, Garza-Reyes, and Kumar (2017); Belekoukias, Garza-Reyes, and Kumar (2014); Garza-Reyes, Kumar, Chaikittisilp, and Tan (2018); Garza-Reyes, Villarreal, Kumar, and Molina Ruiz (2016); Lorenzon dos Santos, Giglio, Helleno, and Campos (2019); and Lugert, Batz, and Winkler (2018).

There was one paper that used simulation analysis alone (Lian & Van Landeghem, 2007), and one that combined a case study with a questionnaire.

All of the empirical studies that used VSM in our review regarded

Journal name	# of articles	production	product development	purchase/ logistics/sales/servi ce	supply chain	non-manufacturing sector
International Journal of Production Research	23	20	1	1		1
Production Planning & Control	16	13		2		1
International Journal of Lean Six Sigma	11	10		1		
Journal of Manufacturing Technology Management	8	6		1	1	
Business Process Management Journal	7	3				4
International Journal of Production Economics	5	3	1		1	
International Journal of Operations and Production Management	2	1			1	

Table 2. Distribution of application of empirical VSM research

VSM as an important tool for helping to achieve lean production systems. The basic commonalities in making progress in empirical research boil down to (1) visualization of the flow of things and information in current production processes; (2) discovering the bottlenecks therein; (3) envisioning the desired future state; (4) holding kaizen workshops to paint scenarios for improvement, carry out kaizen using other lean tools such as the seven QC tools, moving toward the desired state of affairs (or demonstrating outcomes of kaizen case studies); (5) expected results from kaizen in terms of performance; and (6) in cases where the case by itself fails to lead to improvement scenarios, combining with simulation analysis to predict the desired scenario and effects.

Worthy of note in Table 2 is the fact that most applications of VSM, accounting for 78% of the total, are concentrated on production processes (units or activities). When drawing VSM, production management information and lead times for procurements from suppliers or selling to retailers are also noted, but the main targets of the flow improvements using VSM are production processes. In research that targets other manufacturing processes as well, VSM has been used on particular activities involved in the supply chain,³

³ Three empirical articles such as Holweg (2005), Persson (2011), and Seth et al. (2008) focused on the activities throughout the supply chain. However,

as seen in its application to the field of development (Tuli & Shankar, 2015; Tyagi et al., 2015) and to procurement, logistics, and transportation (Aamer. 2018: Garza-Reves al.. et 2016: Gutierrez-Gutierrez et al., 2016; Stadnicka & Ratnayake, 2018; Villarreal et al., 2016). VSM is also being applied to non-manufacturing industries such as health care (Camgöz-Akdağ & Beldek, 2019; Camgöz-Akdağ et al., 2017; Henrique et al., 2016; Xie & Peng, 2012) and service organizations. For example, in Camgöz-Akdağ et al. (2017), process improvements are carried out in the radiology unit, which is a limited application of VSM to a particular unit.

The journals shown in Table 2 are in the field of operations management and as such may well be biased toward the application of VSM to production. The literature search using the Web of Science we did for this paper, however, was not limited to production management; we also included journals in the field of supply chain management. In fact, there is one paper from *Supply Chain Management*, a leading journal in the field of supply chain management, which qualified. This paper, Wee and Wu (2009), applies VSM to the supply chain at Ford's Taiwan Plant. It limits itself, however, to depicting and analyzing VSM that is internal to the plant, from deliveries of parts from suppliers to shipment.

Discussion and Conclusion

As we have seen here, the primary role and function of VSM in Western journals in the field of operations management is as a lean tool for making individual unit and activity streams more efficient; it is most commonly applied in production activities within a

these articles have not been sufficiently done to draw and analyze the VSM in detail and make improvements for the entire supply chain and product development activities.

Fukuzawa

plant. Using VSM as a lean tool to improve the workplace such as production unit, lean states have long been achieved in specific units and activities. Given the risk of viewing easily understandable tools such as kanban, which are used as a shortcut on the lean journey, the contribution of VSM was to remind people of the importance of looking at the value stream, identifying bottlenecks and blockages within it, and resolving them. It is conceivable that this had the effect of reducing the number of people who got lost on their lean journey.

Applying VSM to particular divisions and functions as has been done in prior studies, moving ahead with kaizen and pushing for partial or unit-level optimizations, can potentially lead to lower overall performance in the supply chain and value chain. For example, even if applying kaizen using VSM to a particular inefficiency improves the flow inside a plant, bottlenecks within the units and activities surrounding the plant, such as purchasing, logistics, sales, and development remain unaddressed, and it is conceivable that bottlenecks between units and activities will increase.

VSM originated as a tool adapted from the "material and information flow chart" that had been used "as a matter of course" (Rother & Shook, 1998) at Toyota to "improve the flow" of a series of customer-oriented values. Subsequently, it seems that as VSM research has progressed and has become popular as an effective lean tool that is used mainly for shortening lead times, improving the value-adding time ratio, and reducing waste in specific departments and activities, it has deviated from the original design concept and flow management seen in the Toyota production system and the lean production system that aimed to realize "overall optimization" by improving the flow of a series of values.

It is important that future research takes a broad view of value creation activities, visualizes and continues to eliminate the various bottlenecks in it, and allocates resources necessary for that purpose and for collaboration among departments and companies, to consider the ideal way for management to realize overall optimization through coordination. For these reasons, it will be necessary to develop research methods and empirical analysis that focus on improving VSM for use as an overall optimization-oriented tool that can be used to visualize the overall state of the value stream across departments and companies, and facilitate the "awareness" of problems in the overall value stream and promote the improvement activities.

Acknowledgments

This work was supported by JSPS Grant-in-Aid for Publication of Scientific Research Results, Grant Number JP16HP2004.

References

- Aamer, A. M. (2018). Outsourcing in non-developed supplier markets: A lean thinking approach. International Journal of Production Research, 56(18), 6048–6065.
- Abdulmalek, F. A., & Rajgopal, J. (2007). Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study. *International Journal of Production Economics*, 107(1), 223–236.
- Agyapong-Kodua, K., Ajaefobi, J. O., Weston, R. H., & Ratchev, S. (2012). Development of a multi-product cost and value stream modelling methodology. *International Journal of Production Research*, 50(22), 6431–6456.
- Andreadis, E., Garza-Reyes, J. A., & Kumar, V. (2017). Towards a conceptual framework for value stream mapping (VSM) implementation: An investigation of managerial factors. *International Journal of Production Research*, 55(23), 7073–7095.

- Basu, P., & Dan, P., K. (2014). Capacity augmentation with VSM methodology for lean manufacturing. *International Journal of Lean Six Sigma*, 5(3), 279–292.
- Belekoukias, I., Garza-Reyes, J. A., & Kumar, V. (2014). The impact of lean methods and tools on the operational performance of manufacturing organisations. *International Journal of Production Research*, 52(18), 5346–5366.
- Ben Fredj-Ben Alaya, L. (2016). VSM a powerful diagnostic and planning tool for a successful Lean implementation: A Tunisian case study of an auto parts manufacturing firm. *Production Planning and Control*, 27(7-8), 563–578.
- Bertolini, M., Braglia, M., Romagnoli, G., & Zammori, F. (2013). Extending value stream mapping: The synchro-MRP case. *International Journal of Production Research*, 51(18), 5499–5519.
- Bhuvanesh Kumar, M., & Parameshwaran, R. (2018). Fuzzy integrated QFD, FMEA framework for the selection of lean tools in a manufacturing organisation. *Production Planning and Control*, 29(5), 403–417.
- Braglia, M., Carmignani, G., & Zammori, F. (2006). A new value stream mapping approach for complex production systems. *International Journal of Production Research*, 44(18), 3929–3952.
- Camgöz-Akdağ, H., & Beldek, T. (2019). Process improvement in a radiology department. Business Process Management Journal, 26(3), 786–797.
- Camgöz-Akdağ, H., Çalişkan, E., & Toma, S. (2017). Lean process design for a radiology department. Business Process Management Journal, 23(4), 779–791.
- Carmignani, G. (2017). Scrap value stream mapping (S-VSM): A new approach to improve the supply scrap management process. *International Journal of Production Research*, *55*(12), 3559–3576.
- Cavdur, F., Yagmahan, B., Oguzcan, E., Arslan, N., & Sahan, N. (2019). Lean service system design: A simulation-based VSM case study. *Business Process Management Journal*, 25(7), 1802–1821.
- Chen, J. C., Li, Y., & Shady, B. D. (2010). From value stream mapping toward a lean/sigma continuous improvement process: An industrial case study. *International Journal of Production Research*, 48(4), 1069–1086.

- Chiarini, A. (2011). Integrating lean thinking into ISO 9001: A first guideline. *International Journal of Lean Six Sigma*, 2(2), 96–117.
- Choudhary, S., Nayak, R., Dora, M., Mishra, N., & Ghadge, A. (2019). An integrated lean and green approach for improving sustainability performance: A case study of a packaging manufacturing SME in the U.K. Production Planning and Control, 30(5-6), 353–368.
- Chowdary, B. V., & George, D. (2011). Improvement of manufacturing operations at a pharmaceutical company: A lean manufacturing approach. *Journal of Manufacturing Technology Management*, 23(1), 56–75.
- Coronado M., A. E., & Lyons, A. C. (2007). Evaluating operations flexibility in industrial supply chains to support build-to-order initiatives. *Business Process Management Journal*, 13(4), 572–587.
- Cottyn, J., Van Landeghem, H., Stockman, K., & Derammelaere, S. (2011). A method to align a manufacturing execution system with lean objectives. *International Journal of Production Research*, 49(14), 4397–4413.
- Dinis-Carvalho, J., Guimaraes, L., Sousa, R. M., & Leao, C. P. (2019). Waste identification diagram and value stream mapping: A comparative analysis. *International Journal of Lean Six Sigma*, 10(3), 767–783.
- Dinis-Carvalho, J., Moreira, F., Bragança, S., Costa, E., Alves, A., & Sousa, R. (2015). Waste identification diagrams. *Production Planning and Control*, 26(3), 235–247.
- Fujimoto, T. (1999). *The evolution of a manufacturing system at Toyota*. New York, NY: Oxford University Press.
- Fujimoto, T. (2012). The evolution of production systems. Annals of Business Administrative Science, 11, 25–44. doi: 10.7880/abas.11.25
- Fukuzawa, M. (2019). Critique on the lean production system research. Annals of Business Administrative Science, 18, 85–101. doi: 10.7880/abas.0190403a
- Fukuzawa, M. (2020, August). The function of the Value Stream Mapping. Paper presented at ABAS Conference 2020 Summer, University of Tokyo, Japan.
- Garza-Reyes, J. A., Kumar, V., Chaikittisilp, S., & Tan, K. H. (2018). The effect of lean methods and tools on the environmental performance of

manufacturing organisations. International Journal of Production Economics, 200, 170–180.

- Garza-Reyes, J. A., Villarreal, B., Kumar, V., & Molina Ruiz, P. (2016). Lean and green in the transport and logistics sector: A case study of simultaneous deployment. *Production Planning and Control*, 27(15), 1221–1232.
- Green, J. C., Lee, J., & Kozman, T. A. (2010). Managing lean manufacturing in material handling operations. *International Journal of Production Research*, 48(10), 2975–2993.
- Gurumurthy, A., & Kodali, R. (2011). Design of lean manufacturing systems using value stream mapping with simulation: A case study. *Journal of Manufacturing Technology Management*, 22(4), 444–473.
- Gutierrez-Gutierrez, L., de Leeuw, S., & Dubbers, R. (2016). Logistics services and Lean Six Sigma implementation: A case study. *International Journal of Lean Six Sigma*, 7(3), 324–342.
- Henrique, D. B., Rentes, A. F., Filho, M. G., & Esposto, K. F. (2016). A new value stream mapping approach for healthcare environments. *Production Planning and Control*, 27(1), 24–48.
- Hines, P., & Rich, N. (1997). The seven value stream mapping tools. International Journal of Operations and Production Management, 17(1), 46–64.
- Hodge, G. L., Goforth Ross, K., Joines, J. A., & Thoney, K. (2011). Adapting lean manufacturing principles to the textile industry. *Production Planning* and Control, 22(3), 237–247.
- Holweg, M. (2005). The three dimensions of responsiveness. *International Journal of Operations and Production Management*, 25(7), 603–622.
- Holweg, M. (2007). The genealogy of lean production. Journal of Operations Management, 25(2), 785–805.
- Huang, C. C., & Liu, S. H. (2005). A novel approach to lean control for Taiwan-funded enterprises in mainland China. *International Journal of Production Research*, 43(12), 2553–2575.
- Jasti, N. V. K., & Sharma, A. (2015). Lean manufacturing implementation using value stream mapping as a tool: A case study from auto components industry. *International Journal of Lean Six Sigma*, 5(1), 89–116.

- Jiménez, E., Tejeda, A., Pérez, M., Blanco, J., & Martínez, E. (2012). Applicability of lean production with VSM to the Rioja wine sector. *International Journal of Production Research*, 50(7), 1890–1904.
- Lacerda, A. P., Xambre, A. R., & Alvelos, H. M. (2016). Applying value stream mapping to eliminate waste: A case study of an original equipment manufacturer for the automotive industry. *International Journal of Production Research*, 54(6), 1708–1720.
- Lian, Y. H., & Van Landeghem, H. (2007). Analysing the effects of Lean manufacturing using a value stream mapping-based simulation generator. *International Journal of Production Research*, 45(13), 3037–3058.
- Librelato, T. P., Lacerda, D. P., Rodrigues, L. H., & Veit, D. R. (2014). A process improvement approach based on the value stream mapping and the theory of constraints thinking process. *Business Process Management Journal*, 20(6), 922–949.
- Liker, J. K., & Meier, D. (2005), *The Toyota way fieldbook: A practical guide* for implementing Toyota's 4Ps. New York, NY: McGraw-Hill.
- Liu, Z., & Ming, X. (2019). A framework with revised rough-DEMATEL to capture and evaluate requirements for smart industrial product-service system of systems. *International Journal of Production Research*, 57(22), 7104–7122.
- Lorenzon dos Santos, D., Giglio, R., Helleno, A. L., & Campos, L. M. S. (2019). Environmental aspects in VSM: A study about barriers and drivers. *Production Planning and Control*, 30(15), 1239–1249.
- Lugert, A., Batz, A., & Winkler, H. (2018). Empirical assessment of the future adequacy of value stream mapping in manufacturing industries. *Journal* of Manufacturing Technology Management, 29(5), 886–906.
- Matt, D. T. (2014). Adaptation of the value stream mapping approach to the design of lean engineer-to-order production systems: A case study. *Journal of Manufacturing Technology Management*, 25(3), 334–350.
- Mishra, A. K., Sharma, A., Sachdeo, M., & Kandasamy, J. (2019). Development of sustainable value stream mapping (SVSM) for unit part manufacturing: A simulation approach. *International Journal of Lean Six Sigma*, 11(3), 493–514.

Nagaraj, T. S., Jeyapaul, R., Vimal, K. E. K., & Mathiyazhagan,

Fukuzawa

K. (2019). Integration of human factors and ergonomics into lean implementation: Ergonomic-value stream map approach in the textile industry. *Production Planning and Control*, *30*(15), 1265–1282.

- Nepal, B., Natarajarathinam, M., & Balla, K. (2011). Improving manufacturing process for biomedical products: A case study. *Journal of Manufacturing Technology Management*, 22(4), 527–540.
- Nounou, A. (2018). Developing a lean-based holistic framework for studying industrial systems. *Production Planning and Control*, *29*(13), 1096–1111.
- Parthanadee, P., & Buddhakulsomsiri, J. (2014). Production efficiency improvement in batch production system using value stream mapping and simulation: A case study of the roasted and ground coffee industry. *Production Planning and Control*, 25(5), 425–446.
- Persson, F. (2011). SCOR template: A simulation based dynamic supply chain analysis tool. *International Journal of Production Economics*, 131(1), 288–294.
- Powell, D., Lundeby, S., Chabada, L., & Dreyer, H. (2017). Lean Six Sigma and environmental sustainability: The case of a Norwegian dairy producer. *International Journal of Lean Six Sigma*, 8(1), 53–64.
- Raghavan, V. A., Yoon, S., & Srihari, K. (2014). Lean transformation in a high mix low volume electronics assembly environment. *International Journal of Lean Six Sigma*, 5(4), 342–360.
- Ramesh, V., & Kodali, R. (2012). A decision framework for maximising lean manufacturing performance. *International Journal of Production Research*, 50(8), 2234–2251.
- Ratnayake, R. M. C., & Chaudry, O. (2017). Maintaining sustainable performance in operating petroleum assets via a lean-six-sigma approach: A case study from engineering support services. *International Journal of Lean Six Sigma*, 8(1), 33–52.
- Ray, S., & John, B. (2011). Lean Six-Sigma application in business process outsourced organization. *International Journal of Lean Six Sigma*, 2(4), 371–380.
- Rother, M. (2010). Toyota Kata: Managing people for improvement, adaptiveness, and superior results. New York, NY: McGraw Hill.
- Rother, M., & Shook, J. (1998). Learning to see: Value stream mapping to create value and eliminate muda. Cambridge, MA: Lean Enterprise

Institute.

- Schmidtke, D., Heiser, U., & Hinrichsen, O. (2014). A simulation-enhanced value stream mapping approach for optimisation of complex production environments. *International Journal of Production Research*, 52(20), 6146–6160.
- Serrano Lasa, I., Laburu, C. O., & de Castro, R. (2008). An evaluation of the value stream mapping tool. *Business Process Management Journal*, 14(1), 39–52.
- Serrano Lasa, I., Ochoa, C., & de Castro, R. (2008). Evaluation of value stream mapping in manufacturing system redesign. *International Journal* of Production Research, 46(16), 4409–4430.
- Serrano Lasa, I., de Castro, R., & Laburu, C. O. (2009). Extent of the use of Lean concepts proposed for a value stream mapping application. *Production Planning and Control*, 20(1), 82–98.
- Seth, D., & Gupta, V. (2005). Application of value stream mapping for lean operations and cycle time reduction: An Indian case study. *Production Planning and Control*, 16(1), 44–59.
- Seth, D., Seth, N., & Dhariwal, P. (2017). Application of value stream mapping (VSM) for lean and cycle time reduction in complex production environments: A case study. *Production Planning and Control*, 28(5), 398–419.
- Seth, D., Seth, N., & Goel, D. (2008). Application of value stream mapping (VSM) for minimization of wastes in the processing side of supply chain of cottonseed oil industry in Indian context. *Journal of Manufacturing Technology Management*, 19(4), 529–550.
- Shah, R., & Ward, P. T. (2003). Lean manufacturing: Context, practice bundles, and performance. *Journal of Operations Management*, 21(2), 129–149.
- Shah, R., & Ward, P. T. (2007). Defining and developing measures of lean production. *Journal of Operations Management*, *25*(4), 785–805.
- Shou, W., Wang, J., Wu, P., Wang, X., & Chong, H. Y. (2017). A cross-sector review on the use of value stream mapping. *International Journal of Production Research*, 55(13), 3906–3928.
- Singh, B., Garg, S. K., Sharma, S. K., & Grewal, C. (2010). Lean implementation and its benefits to production industry. *International*

Journal of Lean Six Sigma, 1(2), 157–168.

- Singh, R. K., Kumar, S., Choudhury, A. K., & Tiwari, M. K. (2006). Lean tool selection in a die casting unit: A fuzzy-based decision support heuristic. *International Journal of Production Research*, 44(7), 1399–1429.
- Stadnicka, D., & Litwin, P. (2019). Value stream mapping and system dynamics integration for manufacturing line modelling and analysis. *International Journal of Production Economics*, 208, 400–411.
- Stadnicka, D., & Ratnayake, R. M. C. (2017). Enhancing performance in service organisations: A case study based on value stream analysis in the telecommunications industry. *International Journal of Production Research*, 55(23), 6984–6999.
- Stadnicka, D., & Ratnayake, R. M. C. (2018). Development of additional indicators for quotation preparation performance management: VSM-based approach. *Journal of Manufacturing Technology Management*, 29(5), 866–885.
- Sunk, A., Kuhlang, P., Edtmayr, T., & Sihn, W. (2017). Developments of traditional value stream mapping to enhance personal and organisational system and methods competencies. *International Journal of Production Research*, 55(13), 3732–3746.
- Thanki, S. J., & Thakkar, J. J. (2016). Value-value load diagram: A graphical tool for lean-green performance assessment. *Production Planning and Control*, 27(15), 1280–1297.
- Tuli, P., & Shankar, R. (2015). Collaborative and lean new product development approach: A case study in the automotive product design. *International Journal of Production Research*, 53(8), 2457–2471.
- Tyagi, S., Choudhary, A., Cai, X., & Yang, K. (2015). Value stream mapping to reduce the lead-time of a product development process. *International Journal of Production Economics*, 160, 202–212.
- Thompson, J. D. (1967). Organizations in action: Social science bases of administrative theory. New York, NY: McGraw-Hill.
- Vasconcelos Ferreira Lobo, C., Damasceno Calado, R., & Dalvo Pereira da Conceição, R. (2018). Evaluation of value stream mapping (VSM) applicability to the oil and gas chain processes. *International Journal of Lean Six Sigma*, 11(2), 309–330.
- Villarreal, B., Garza-Reyes, J. A., & Kumar, V. (2016). Lean road

transportation: A systematic method for the improvement of road transport operations. *Production Planning and Control*, *27*(11), 865–877.

- Vinodh, S., Arvind, K. R., & Somanaathan, M. (2010). Application of value stream mapping in an Indian camshaft manufacturing organisation. *Journal of Manufacturing Technology Management*, 21(7), 888–900.
- Vinodh, S., Kumar, S. V., & Vimal, K. E. K. (2014). Implementing lean sigma in an Indian rotary switches manufacturing organisation. *Production Planning and Control*, 25(4), 288–302.
- Wee, H. M., & Wu, S. (2009). Lean supply chain and its effect on product cost and quality: A case study on Ford Motor Company. Supply Chain Management, 14(5), 335–341.
- Womack, J. P., Jones, D. T., & Roos, D. (1990). The machine that changed the world: Based on the Massachusetts Institute of Technology 5-million dollar 5-year study on the future of the automobile. New York, NY: Rawson Associates.
- Xie, Y., & Peng, Q. (2012). Integration of value stream mapping and agent-based modeling for OR improvement. Business Process Management Journal, 18(4), 585–599.
- Yang, T., & Lu, J. C. (2011). The use of a multiple attribute decision-making method and value stream mapping in solving the pacemaker location problem. *International Journal of Production Research*, 49(10), 2793–2817.