DYNAMIC VALUE STREAM MAPPING FOR PRODUCTION LEAD TIME IMPROVEMENT USING FUZZY TRIANGULAR ANALYSIS

By

THULASI A/P MANOHARAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

January 2023

FK 2023 6

© COPYRIGHT UPM

All material contained within the thesis, including without limitation text, logos, icons, photographs and all other artwork, is copyright material of Universiti Putra Malaysia unless otherwise stated. Use may be made of any material contained within the thesis for non-commercial purposes from the copyright holder. Commercial use of material may only be made with the express, prior, written permission of Universiti Putra Malaysia.

Copyright © Universiti Putra Malaysia

© COPYRIGHT UPM

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

DYNAMIC VALUE STREAM MAPPING FOR PRODUCTION LEAD TIME IMPROVEMENT USING FUZZY TRIANGULAR ANALYSIS

By

THULASI A/P MANOHARAN

January 2023

Chair : Faieza binti Abdul Aziz, PhD
Faculty : Engineering

Value Stream Mapping (VSM) is one of the lean tools that visualize a production process at the plant level and illustrate the flow of materials and information in the entire supply chain. The ongoing rise of digitalization is currently a major feature of production that increased demands for flexibility in the production system. Even though VSM application helped in visualizing the benefits of applying lean principles, it had several limitations that prevented it from being applied in a broader perspective. In high-variety and low-volume factories, the conventional VSM which is more static in nature, unable to give a real vision of the variability problems concerning the production process. Secondly, the development of future state VSM is mostly based on the trial-and-error principle because the future state is not validated in conventional VSM. As of this lack of validation the findings remain in the investigation stage without being applied in the actual manufacturing scenario at all. Hence the objective of this research is to determine process variability using Fuzzy-Number in dynamic value stream mapping (VSM). A future VSM is designed by implementing lean improvement tools and integrating with Discrete Event Simulation (DES) to improve the accuracy of analysis. The hybrids of fuzzy VSM and DES are then validated by applying in an industrial case study. A conveyor manufacturing company was selected as a case study based on the high variety and low volume type of manufacturing process. Triangular Fuzzy Number (TFN) approach was used to analyze variabilities in process parameters to identify their mean, minimum and maximum values and remove all the outliers. A current VSM was then designed and highlights all the non-value -added activities processes that need to be improved. Based on the identifications, an appropriate lean improvement tools were applied to develop an optimized future VSM. Both the current state and future state maps were verified using ARENA simulation models. ARENA simulation helps to simulate more than one future state alternatives and shows improvement ratio in terms of production lead time and value -added time and compares with current state values. As a result, second alternative of future state

map shows 71.74% and 19.45% of improvement ratio in terms of production lead time and value- added time respectively compared to current VSM. In the second case study, the total production lead time of future value stream map shows 49.88% improvement compared to current VSM. The result of simulation validated using p-value analysis. The significance value of p-analysis shows less than 0.05 which is considered to be statistically significant and the null hypothesis should be rejected. It is concluded that, dynamic VSM is a suitable tool to visualize the value added and non-value- added activities in a flexible manufacturing system and apply appropriate lean tools in order to reduce the total production lead time and work-in-progress (WIP) inventory. This study can be further extended by investigating how the reduction of lead time and WIP inventory can be helpful in cost reduction of a company.

© COPYRIGHT UPM

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMETAAN ALIRAN NILAI DINAMIK UNTUK PENAMBAHBAIKAN MASA PENGELUARAN MENGGUNAKAN ANALISIS FUZZY SEGITIGA

Oleh

THULASI A/P MANOHARAN

Januari 2023

Pengerusi : Faieza binti Abdul Aziz, PhD
Fakulti : Kejuruteraan

Nilai stream (VSM) adalah merupakan salah satu alat ‘lean’ yang boleh menggambarkan proses pengeluaran dari segi tahap kilang dan menunjukkan aliran barang dan informasi dari segi seluruh rangkaian bekalan. Peningkatan digitalisasi yang berterusan menjadi ciri utama dalam pengeluaran yang meningkatkan permintaan untuk fleksibiliti dalam system pengeluaran dan dengan itu, melibatkan pengubahsuaian jangka pendek dan lebih murah kepada aliran nilai. Walaupun, aplikasi VSM membantu dalam menggambarkan faedah menerapkan prinsip ‘lean’, ia mempunyai beberapa batasan yang menghalangnya daripada digunakan dalam perspektif yang lebih luas. VSM konvensional yang bersifat lebih statik, tidak dapat memberikan gambaran sebenar tentang masalah kebolehubahan berkaitan proses pengeluaran di kilang-kilang yang mempunyai kepelbagaian tinggi dan isipadu rendah. Kedua, pembangunan VSM masa hadapan kebanyakannya berdasarkan prinsip percubaan dan kesilapan kerana keadaan masa hadapan tidak boleh disahkan dalam VSM konvensional. Disebabkan oleh kekurangan pengesahan ini, penemuan telah pun kekal dalam peringkat penyiasatan sahaja tanpa digunakan dalam senario pembuatan sebenar. Oleh itu objektif kajian ini adalah untuk menentukan kebolehubahan proses menggunakan Nombor Fuzzy dalam pemetaan aliran nilai dinamik (VSM). VSM masa hadapan direka bentuk dengan melaksanakan alat penambahbaikan ‘lean’ dan menyepadukan dengan Simulasi (DES) untuk meningkatkan ketepatan analisis. Sistem hibrid yang merangkumi fuzzy VSM dan DES kemudiannya disahkan dengan menggunakan dalam kajian kes industri. Sebuah syarikat pembuatan yang membuat tali penghantar telah dipilih sebagai kajian kes berdasarkan proses pembuatan yang mempunyai kepelbagaian tinggi dan jenis isi padu yang rendah. Pendekatan Triangular Fuzzy Number (TFN) digunakan untuk menganalisis kebolehubahan dalam parameter proses untuk mengenal pasti nilai purata, minimum dan

maksimumnya serta membuang semua nilai yang terperinci. Dengan menyepadukan TFN dengan VSM, ia memberikan sifat dinamik kepada VSM konvensional. VSM semasa kemudiannya direka bentuk dan menyerlahkan semua aktiviti yang tidak mempunyai nilai tambah dan proses kesesakan yang perlu diperbaiki. Berdasarkan pengenalpastian, alat peningkatan 'lean' yang sesuai telah digunakan untuk membangunkan VSM masa hadapan yang dioptimumkan. Kedua-dua kepetaan untuk keadaan semasa dan keadaan masa hadapan telah disahkan menggunakan model simulasi ARENA. Simulasi ARENA membantu mensimulasikan lebih daripada satu alternatif keadaan masa hadapan dan menunjukkan nisbah peningkatan dari segi masa utama pengeluaran dan masa nilai tambah dan membandingkan dengan nilai keadaan semasa. Hasilnya, alternatif kedua peta keadaan masa hadapan menunjukkan 71.74% dan 19.45% nisbah peningkatan masing-masing dari segi masa utama pengeluaran dan masa nilai tambah berbanding VSM semasa. Dalam kajian kes kedua, jumlah masa utama pengeluaran peta aliran nilai masa hadapan menunjukkan peningkatan 49.88% berbanding VSM semasa. Nilai keertian p-analisis menunjukkan kurang daripada 0.05 yang dianggap signifikan secara statistik dan hipotesis nol perlu ditolak. Disimpulkan bahawa, VSM dinamik ialah alat yang sesuai untuk menggambarkan aktiviti nilai tambah dan bukan nilai tambah dalam sistem pembuatan yang fleksibel dan menggunakan alat 'lean' yang sesuai untuk mengurangkan jumlah masa utama pengeluaran dan inventori WIP. Kajian ini boleh dilanjutkan lagi dengan menyiasat bagaimana pengurangan masa utama dan inventori WIP boleh membantu dalam pengurangan kos sesebuah syarikat.

© COPYRIGHT UPM

ACKNOWLEDGEMENTS

This thesis becomes reality with the kind support and help of many individuals. I would like to extend my sincere thanks to all of them.

Foremost, I want to offer this venture to the GOD for the wisdom he granted upon me, the strength, peace of mind and good health in order to finish this research.

I would like to express my gratitude towards my family for the encouragement which helped me in completion of this paper. My beloved and supportive husband, Ts. Jajendren Vereya who is always by my side when I needed him the most and helped me a lot in making this study. My lovable daughter Mahaashri and also my newborn daughter Dhivyashri, who served as my inspiration to pursue this undertaking.

I am highly indebted to my academic supervisor, Associate Professor Ir.Ts.Dr Faieza binti Abdul Aziz for her guidance and constant supervision as well as providing necessary information regarding this research and also for her support in completing this endeavor.

I would like to express my thanks to my co-supervisors, Associate Professor Dr. Zulkiflle bin Leman and Associate Professor Dr. Siti Azfanizam binti Ahmad for imparting their knowledge and expertise in this study.

My thanks and appreciations also go to my colleagues and people who have willingly helped me out with their abilities.

© COPYRIGHT UPM

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Faieza binti Abdul Aziz, PhD
Associate Professor Ir. Ts.
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Zulkiflle bin Leman, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Siti Azfanizam binti Ahmad, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 9 March 2023

© COPYRIGHT UPM

Declaration by the Graduate Student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any institutions;
- intellectual property from the thesis and the copyright of the thesis are fully-owned by Universiti Putra Malaysia, as stipulated in the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from the supervisor and the office of the Deputy Vice-Chancellor (Research and innovation) before the thesis is published in any written, printed or electronic form (including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials) as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld in accordance with the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2015-2016) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software

Signature: ________________________ Date: __________________

Name and Matric No.: __Thulasi a/p Manoharan___________

© COPYRIGHT UPM

Declaration by Members of the Supervisory Committee

This is to confirm that:

- the research and the writing of this thesis were done under our supervision;
- supervisory responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2015-2016) are adhered to.

Signature:	
Name of Chairman of Supervisory Committee:	Associate Professor Ir. Ts. Dr. Faieza binti Abdul Aziz, PhD
Signature:	
Name of Member of Supervisory Committee:	Associate Professor Dr. Zulkiflle bin Leman, PhD
Signature:	
Name of Member of Supervisory Committee:	Associate Professor Dr. Siti Azfanizam binti Ahmad

© COPYRIGHT UPM

TABLE OF CONTENTS

© COPYRIGHT UPM

© COPYRIGHT UPM

© COPYRIGHT UPM

LIST OF TABLES

© COPYRIGHT UPM

LIST OF FIGURES

© COPYRIGHT UPM

© COPYRIGHT UPM

© COPYRIGHT UPM

LIST OF ABBREVIATIONS

CSM	Current Stream Map
DES	Discrete Event Simulation
FTN	Fuzzy Triangular Numbers
ICT	Information and Communication Technologies
JIT	Just in Time
LR-type	Left and Right type
LP	Lean Production
LPT	Lean Production Tool
MES	Manufacturing Execution System
RM	Raw Material
VSM	Value Stream Mapping
VS	Value Stream
WIP	Work in Process

© COPYRIGHT UPM

CHAPTER 1

INTRODUCTION

1.1 Introduction

Product variation due to increasing customer demand refers to the process of adapting or modifying a product to meet the changing needs and preferences of customers. This can include introducing new features, changing the design, or offering different sizes, colors, or styles. Product variation can be a good way for companies to stay competitive and meet the evolving needs of their customers (Abdulmalek et al., 2017). Due to the implementation of lean manufacturing concepts, numerous industries increased their internal flexibility and refined their operating procedures in response to these market-driven needs. Examples of key lean principles include continuous process improvement, waste reduction, and a shift in production management toward demand-oriented production that allows a quick response towards varying market demands.

Lean manufacturing is a production philosophy that emphasizes the elimination of wastes and the continuous improvement of processes in order to increase efficiency and reduce costs. Information and Communication Technology (ICT) can play a key role in lean manufacturing by providing the tools and systems that help companies achieve these goals. By integrating ICT with lean manufacturing principles, companies can gain a more comprehensive and accurate view of their operations, and can use this information to identify opportunities for improvement (Lugert & Winkler, 2018).

Lean manufacturing work towards removing any activities that produce zero value to the customers through a strained and levelled production system in order to achieve customers` expectations and need in a better way especially focusing on the manufacturing products (Zahraee et al., 2020). Analyzing value stream that consists of activities of both value-added and non-value added that are carried out during production to convert an item from raw material to finished goods is considered as a first necessary action that need to be carried out in order to achieve lean manufacturing objective. Eventually, for introducing a levelled flow within the remaining process that contribute to value, all the identified wasteful processes need to be stopped (Singh et al., 2017).

Utilization of minimal resources during production that includes work force, working space, equipment, less engineering output and less inventory to develop and create the same or better output as developed by traditional mass production system is the system defined as “lean” (Braglia & Zammori, 2011). Lean manufacturing is an extensive system comprised of tools, techniques and practices that have the purpose of enhancing the performance and effectiveness of a production system by removing wastes (Abdulmalek & Rajgopal, 2017). The

© COPYRIGHT UPM

primary goal of lean manufacturing is the recognition of wastes or as known as "Muda" in Japanese term. The definition of waste is ineffective manufacturing activities or practices that creates zero value to output by using resources which add unproductive cost to the products (Jordan et al., 2020). The causes of wastes can be grouped in two classes such as behavioral and information factors (Hashim et al., 2019). Hashim conducted study on pickle manufacturing company to reduce non-value added activities by eliminating wastes. The root of each waste distinguished by behavioral and information factors.

In order to attain the basics goal of any company that includes improving productivity, enhancing flexibility, minimizing costs and to prioritize activities that are beneficial from customer`s perspective, wastes need to be removed (Taj et al., 2016). Value can be anything where customer ready to pay either for a product or for the services that comes after, from the customer's perspective (Pacchini et al., 2019). As such, lean manufacturing focuses on the flow of material, starting where the material enters the process until it ready for shipping to the customer.

Lately, manufacturing businesses have faced numerous challenges in the distribution and use of lean tools in manufacturing systems, which prevent them from reaching their lean objectives. Many researches have investigated lean application in manufacturing systems. Many research papers (Busert & Fay, 2019; Rafique et al., 2019; Hashim et al., 2019 and Kumar et al., 2013) have looked at the implementation of lean manufacturing techniques, but due to ongoing changes in product model and technology, lean projects have long since collapsed. From the standpoint of the value stream, both internal and external difficulties and barriers may hinder the lean transformation from being successful.

Due to external sources, there are external obstacles that includes: high demand variability, competitive cost and quality, shorter product life cycles, product customization, fluctuating markets, a significant degree of supplier uncertainty in delivering the requested quantity, and the ability to fulfill on schedule (Singh & Mann, 2018). On the other hand, the external challenges will develop a number of internal challenges that includes, product complexity, production variability, different routings, high product variety-low volume production environment, numerous required parts in assembly lines, similarity between parts and subassemblies, and quality problems, turbulences in schedule due dates, priorities and variance in the cycle times for each process.

Digitalization, or the integration of digital technologies into various aspects of business and industry, is having a significant impact on various industries. Some of the ways that digitalization is affecting different industries. For instance, in manufacturing with the help of digital technologies, manufacturers can now monitor and control machines, equipment and processes remotely, optimize production and reduce downtime (Valencia et al., 2019).

© COPYRIGHT UPM

Therefore, focusing just on the machining process on the machine tool itself is insufficient to fulfill the requirements. Instead, it is necessary to take into account both the links to the material flow and the intralogistics components for material handling.

1.2 Problem Statement

Even though value stream mapping strategy assisted in reaping the rewards of putting lean ideas into practice, it carries several drawbacks that hindered it from being applied in a broader perspective. In order to implement lean techniques in today's complex and dynamic manufacturing systems, VSM must overcome its current limitations, which include its more static nature and inability to provide a clear picture of the variability issues pertaining to the investigated production process. The traditional VSM approach becomes difficult and ineffective in factories with high variation and low volume (Mudgal, 2020).

In a more dynamic operation process, the variabilities have increased and the method to control the variability become more complex. As an example, there is a manufacturing company which is a high-variety, low-volume conveyor chain manufacturing facility is situated in Balakong, Malaysia. High work-in-progress (WIP) is caused by high product variety and high process unpredictability, which results in longer waiting times and greater production lead times that can be up to 1.5 months according to company's annual performance report (Kendek Group, 2017). High WIP, distorts the effectiveness of the material requirement planning (MRP) system. As a result, the production lead time becomes longer and delayed delivery time to customers from 3 to 4 months (Annual Output Report, 2020). This problem causes dissatisfaction among the customers and leads to poor performance of the company. However, the detailed root cause of this situation cannot be easily represented and solved using a conventional value stream map.

According to the conventional value stream mapping, the identification of a product family is the first step in the optimization of VSM in industrial practice, which is then followed by an analysis of the current value stream, the development of a better future state, and the implementation of optimization measures at specific locations (Liu, 2020). However, because the future state has not been validated, real implementation is typically dependent on the trial-and-error principle (Kumar et al., 2018). As of this lack of validation and the associated absence of hard facts about the parameters of manufacturing processes, the findings remain in the investigation stage without being applied in the actual manufacturing scenario at all (Mojib, 2020).

In addition to that, in practice, designing an alternative system is very rare and only a single future state is commonly pursued. At the same time, the variability of internal elements like technical availability, cycle times, setup times, or idle

© COPYRIGHT UPM

periods, as well as variability of external factors like variations in demand, are not included in a value stream map that has been retrieved from a volatile production system (Deshkar & Korde, 2018).

Hence, this study provides a realistic picture of the variable issues affecting the production process. It is necessary since it appears that there is a dearth of technical work addressing this criticality. Besides that, one of the key downsides of VSM is that it ignores the true unpredictability of a process. In fact, variability is one of the primary sources of waste and must be thoroughly examined and managed in order to shorten the lead time for production.

1.3 Objectives

For attaining the objective of a comprehensive progress on the production system-level, the approach of value stream mapping should be optimized and validated. The previous studies show the actual application is mostly based on the empirical nature due to non-validated of the future state. Besides that, in most cases, a value stream map which is obtained from an elusive production system does not include the unpredictability of internal factors like technical availability, setup or idle times, cycle times, as well as variability of external factors like variations in demand.

Hence, in order to shorten the total production lead time of conveyor manufacturing company and to give the real vision of the variability problems related to the production process, this research seek an improved procedure model which is to integrate fuzzy triangular analysis with simulation to optimize value steam that is more dynamic in nature.

To fulfill the primary objective of this study, this present study holds the four key research objectives as follows:

1. To determine process variability using fuzzy-number in dynamic value stream mapping (VSM).
2. To design future value stream mapping by implementing lean improvement tools.
3. To integrate the fuzzy VSM with Discrete Event Simulation (DES) to improve the accuracy of analysis.
4. To validate the future state value stream mapping with DES by applying in an industrial case study.

1.4 Scope and Limitation of the Study

This study aims to determine how dynamic value stream mapping can improve the production lead time in a conveyor manufacturing company in Malaysia. The

© COPYRIGHT UPM

data for this study come from a local manufacturing firm. This study relies on the data collected from the manufacturing processes of the company and information gathered from the production line leaders to test the research model of the proposed study.
A 100 sets of data were collected and carefully examined by production experts to produce an adequate sample for further analysis. In order to generate a descriptive statistics of the sample at least a 100 groups of observation data relevant to the process cycle times, volume of raw materials, WIP and finished products were gathered.

This study uses Edraw Max software to capture the current situation of the production floor. The software helps to draw current value streams of material and information flow in a more systematic way. For the data analysis, the study uses fuzzy distribution to control the variability of the collected data to design future value streams to show an improved production performance.

The future value stream of the study was simulated using discrete event simulation (DES). DES simulates multiple potential future value streams that indicate various ways to improve production performance with less production lead time. However, it is not practical to apply all the suggested methods in the production. Hence multidimensional fuzzy assessment is used to determine the most suitable value stream alternative.

Among many multidimensional fuzzy assessments, Triangular Fuzzy Number is used to derive multidimensional decisions in this study. Lastly, the findings of this study apply in the production floor to validate the outcome of the result of this research study.

1.5 Organization of Thesis

This thesis is organized in six chapters. The first chapter provides background information of the topic that is going to be discussed and investigated in this study. This chapter shows the existing study related to the topic and the research gaps that need to be investigated further especially in the manufacturing firm in Malaysia. This chapter further explains about the existing problem in the manufacturing industry and highlights the objectives of this study that correlate with the problem statement. By outlining the study's scope and flowchart, this chapter comes to a close.

Chapter two discusses the literature review and tabulates the summary of previous research, their findings and recommendations for future study. This chapter also demonstrates the progress done within the research discipline to fill up the gaps left in the previous studies. The research model for the study and a related hypothesis are introduced at the end of chapter two.

© COPYRIGHT UPM

Chapter three discusses further the steps that have been performed throughout this study to accomplish the research goals.

The study's findings are presented in chapter four along with a hypothesis test. The results of the experimental study and the case study are discussed in chapter five of the current study. The study is finally concluded in chapter six, which also suggests a direction for further research.

© COPYRIGHT UPM

REFERENCES

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.

Abideen, A., & Mohamad, F. B. (2020). Improving the performance of a Malaysian pharmaceutical warehouse supply chain by integrating value stream mapping and discrete event simulation. Journal of Modelling in Management, 14 (1), 70-77.

Ahmad, N., Ghani, N. A., Kamil, A. A., Tahar, R. M., & Teo, A. H. (2012). Evaluating emergency department resource capacity using simulation. Modern Applied Science, 6(11), 9–19.

Antonelli, D., & Stadnicka, D. (2018). Combining factory simulation with value stream mapping: A critical discussion. Procedia CIRP, 67, 30–35.

Azizi, A., & Manoharan, T. A. (2015). Designing a Future Value Stream Mapping to Reduce Lead Time Using SMED-A Case Study. Procedia Manufacturing, 2, 153-158.

Azizi, Amir, & Manoharan, T. a/p. (2015). Designing a Future Value Stream Mapping to Reduce Lead Time Using SMED-A Case Study. Procedia Manufacturing, 2, 153–158.

Abdi, M.R., (2012). Product Family Formation and Selection for Configurability Using Analytical Network Process. International Journal of Production Research, 50/17, 4908–4921.

Balaji, V., Venkumar, P., Sabitha, M. S., & Amuthaguka, D. (2020). DVSMS: Dynamic value stream map-ping solution by applying IIoT. Sādhanā, 45(1), 38-40.

Braglia, M., Frosolini, M., & Zammori, F. (2009). Uncertainty in value stream mapping analysis. International Journal of Logistics Research and Applications, 12(6), 435–453.

Bramer M. (2013). Principles of Data Mining. London: Springer.

Busert, T., & Fay, A. (2019). Extended value stream mapping method: Harmonizing information flows for the control of production processes. IFAC-PapersOnLine, 52(13), 54–59.

Chen, J. C., Cheng, C. H., & Huang, P. B. (2013). Supply chain management with lean production and RFID application: A case study. Expert Systems with Applications, 40(9), 3389–3397.

© COPYRIGHT UPM

Chen, Y., Zhou, H., Huang, P., Chou, F., & Huang, S. (2019). A refined order release method for achieving robustness of non-repetitive dynamic manufacturing system performance. Annals of Operations Research, 40(9), 89–97.

Chiasson, M.-È., Imbeau, D., Aubry, K., & Delisle, A. (2012). Comparing the results of eight methods used to evaluate risk factors associated with musculoskeletal disorders. International Journal of Industrial Ergonomics, 42(5), 478–488.

Christina Reuter et al., (2016). Improving data consistency in production control by adaptation of data mining algorithms. 9th International Conference on Digital Enterprise Technology, 56, 545-550.

Dai, Q., Zhong, R., Huang, G. Q., Qu, T., Zhang, T., & Luo, T. Y. (2012). Radio frequency identification-enabled real-time manufacturing execution system: A case study in an automotive part manufacturer. International Journal of Computer Integrated Manufacturing, 25(1), 51–65.

De Paula Ferreira, W., Armellini, F., & De Santa-Eulalia, L. A. (2020). Simulation in industry 4.0: A state-of-the-art review. Computers and Industrial Engineering, 149-152.

Deshkar, A., Kamle, S., Giri, J., & Korde, V. (2018). Design and evaluation of a Lean Manufacturing framework using Value Stream Mapping (VSM) for a plastic bag manufacturing unit. Materials Today: Proceedings, 5(2), 7668–7677.

Douwes, M., & de Kraker, H. (2014). Development of a non-expert risk assessment method for hand-arm related tasks (HARM). International Journal of Industrial Ergonomics, 44(2), 316–327.

Faulkner, W., & Badurdeen, F. (2014). Sustainable Value Stream Mapping (Sus-VSM): Methodology to visualize and assess manufacturing sustainability performance. Journal of Cleaner Production, 85, 8–18.

Galan, R., Racero, J., Eguia, I., & Garcia, J. M. (2007). A systematic approach for product families formation in Reconfigurable Manufacturing Systems. Robotics and Computer-Integrated Manufacturing, 23(5), 489–502.

Garza-Reyes, J.A., Romero, J.T., Govindan, K., Cherrafi, A., Ramanathan, U., 2018. A PDCA-based approach to environmental value stream mapping (E-VSM).J. Clean. Prod, 85 (2), 8–18.

Gungor, Z. E., & Evans, S. (2018). Understanding the hidden cost and identifying the root causes of changeover impacts. Journal of Cleaner Production, 167, 1138–1147.

Gul, M., & Guneri, A. F. (2015). A comprehensive review of emergency department simulation applications for normal and disaster conditions. Computers & Industrial Engineering,83, 327–344.

© COPYRIGHT UPM

Guo, W., Jiang, P., Xu, L., & Peng, G. (2019). Integration of value stream mapping with DMAIC for concurrent Lean-Kaizen: A case study on an air-conditioner assembly line. Advances in Mechanical Engineering, 11(2), 200-212

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.

Harpring, R., Evans, G. W., Barber, R., & Deck, S. M. (2014). Improving efficiency in social services with discrete event simulation. Computers & Industrial Engineering,70, 159–167.

Hakimah Sharifuddin, F., Azhar, A., Mulubrhan, F., Alemu, T., & Asmelash, M. (2019). Process Simulation Modelling and Improvement on Energy Consumptions Efficiency, 576, 727–730.

Henao, R., Sarache, W., & Gómez, I. (2019, January 20). Lean manufacturing and sustainable performance: Trends and future challenges. Journal of Cleaner Production, Vol. 208, pp. 99–116.

Hines, P., & Rich, N. (1997). The seven value stream mapping tools. International Journal of Operations and Production Management, Vol. 17, pp. 46–64.

Karim, A. N. M., Jaafar, A. A. B., Abdullah, M. A. I., Haque, M., Ali, M. Y., & Azline, S. A. (2012). Applying Value Stream Mapping for Productivity Improvement of a Metal Stamping Industry. Advanced Materials Research, 576, 727–730.

Krishnan, S., Dev, A. S., Suresh, R., Sumesh, A., & Rameshkumar, K. (2018). Bottleneck identification in a tyre manufacturing plant using simulation analysis and productivity improvement. Materials Today: Proceedings, 5(11), 24720–24730.

Kumar, Sanjay, Singh, B., Qadri, M. A., Kumar, Y. V. S., & Haleem, A. (2013). A framework for comparative evaluation of lean performance of firms using fuzzy TOPSIS. International Journal of Productivity and Quality Management, 11(4), 371–392.

Kumar, S., Dhingra, A.K., Singh, B., (2018). Process improvement through Lean-Kaizen using value stream map: a case study in India. Int. J. Adv. Manuf. Technol, 11(4), 96-100.

Koonce, DA, Tsai SC. (2000). Using data mining to find patterns in genetic algorithm solutions to a job shop schedule. Computers & Industrial Engineering, 38(3), 361–374.

Kwak DS. Kim KJ. (2012). A data mining approach considering missing values for the optimization of semiconductor-manufacturing processes. Expert Systems with Applications. 39(3), 2590–2596.

© COPYRIGHT UPM

Lewin, M., Voigtländer, S., & Fay, A. (2018). Method for process modelling and analysis with regard to the requirements of Industry 4.0 An extension of the value stream method, 11(4), 96-100.

Li, M., & Wang, Z. (2017). An integrated replenishment and production control policy under inventory inaccuracy and time-delay. Computers and Operations Research, 5(2), 400-415.

Lin, D. Y., & Chu, Y. M. (2013). The mixed-product assembly line sequencing problem of a door-lock company in Taiwan. Computers and Industrial Engineering, 64(1), 492–499.

Liu, X., Yang, T., Pei, J., Liao, H., & Pohl, E. A. (2019). Replacement and inventory control for a multi-customer product service system with decreasing replacement costs. European Journal of Operational Research, 5(2), 400-415.

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.

Lugert, A., Völker, K., & Winkler, H. (2018). Dynamization of Value Stream Management by technical and managerial approach. Procedia CIRP, 72, 701–706.

Lu, J. C., Yang, T., & Wang, C. Y. (2011). A lean pull system design is analyzed by value stream mapping and multiple criteria decision-making methods under demand uncertainty. International Journal of Computer Integrated Manufacturing,24(3), 211–228.

Mahmood, A. (2020). Smart lean in ring spinning—a case study to improve the performance of the yarn manufacturing process. The Journal of The Textile Institute, 9(1), 400-415.

Melin, M., & Barth, H. (2020). Value stream mapping for sustainable change at a Swedish dairy farm. International Journal of Environment and Waste Management,25(1), 130–140.

Moussa, F. Z. B., De Guio, R., Dubois, S., Rasovska, I., & Benmoussa, R. (2019). Study of an innovative method based on complementarity between ARIZ, lean management, and discrete event simulation for solving warehousing problems. Computers & Industrial Engineering,132, 124–140.

Mudgal, D., Pagone, E., & Salonitis, K. (2020). Approach to Value Stream Mapping for Make-To-Order Manufacturing. Procedia CIRP, 93, 826–831.

Narayanamurthy, G., Gurumurthy, A., Subramanian, N., Moser, R., 2018. Assessingthe readiness to implement lean in healthcare institutions. A case study. Int. J.Prod. Econ. 197, 123-142.

© COPYRIGHT UPM

Nilashi, M., Mardani, A., Liao, H., Ahmadi, H., Manaf, A. A., & Almukadi, W. (2019). A hybrid method with TOPSIS and machine learning techniques for sustainable development of green hotels considering online reviews. Sustainability (Switzerland), 11(21), 715-800.

Noor, A. Z. M., Fauadi, M. H. F. M., Jafar, F. A., & Rhaffor, K. A. (2020). Data prediction of reject unit from manufacturing company using auto regressive integrated moving average (ARIMA) algorithm. International Journal of Emerging Trends in Engineering Research, 8(9), 6164–6169.

Noor, N. A., Kasolang, S., & Jaffar, A. (2012). Simulation of Integrated Total Quality Management (TQM) with Lean Manufacturing (LM) practices in forming process using Delmia Quest. Procedia Engineering, 41, 1702–1707.

Omogbai, O., & Salonitis, K. (2016). Manufacturing system lean improvement design using discrete event simulation. Procedia CIRP,57, 195–200.

Pacchini, A. P. T., Lucato, W. C., Facchini, F., & Mummolo, G. (2019). The degree of readiness for the implementation of Industry 4.0. Computers in Industry, 113 (1), 212-214.

Rafique, M. Z., Ab Rahman, M. N., Saibani, N., & Arsad, N. (2019, February 17). A systematic review of lean implementation approaches: a proposed technology combined lean implementation framework. Total Quality Management and Business Excellence, Vol. 30, pp. 386–421.

Rahani, A. R., & Al-Ashraf, M. (2012). Production flow analysis through Value Stream Mapping: A lean manufacturing process case study. Procedia Engineering, 41, 1727–1734.

Ramadan, M., Wang, Z., & Noche, B. (2019). RFID-Enabled Dynamic Value Stream Mapping, 30(4), pp. 386–421.

Roessler, Markus P., Wolff, M., & Abele, E. (2013). Design and simulation-based assessment of lean material flows considering imprecision. IFAC Proceedings Volumes (IFAC-PapersOnline), 6(PART 1), 559–564.

Roessler, Markus Philipp, Kleeberg, I., Kreder, M., Metternich, J., & Schuetzer, K. (2015). Enhanced value stream mapping potentials and feasibility of IT support through manufacturing execution systems. Lecture Notes in Electrical Engineering, 349, 393–402.

Roh, P., Kunz, A., & Wegener, K. (2019). Information stream mapping: Mapping, analysing and improving the efficiency of information streams in manufacturing value streams. CIRP Journal of Manufacturing Science and Technology, 25, 1–13.

Robinson, S., Radnor, Z. J., Burgess, N., & Worthington, C. (2012). SimLean: Utilising simulation in the implementation of lean in healthcare. European Journal of Operational Research,219(1), 188–197.

© COPYRIGHT UPM

Romero, L. F., & Arce, A. (2017). Applying Value Stream Mapping in Manufacturing: A Systematic Literature Review. IFAC-Papers OnLine, 50(1), 1075–1086.

Shakil S.I., Parvez M. (2020) Application of value stream mapping (VSM) in a sewing line for improving overall equipment effectiveness (OEE): A case study. In: Reddy A.

Shahbaz, M., Srinivas, M., Harding, JA., Turner, M, (2006). Product Design and Manufacturing Process Improvement Using Association Rules. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 220(2):243–254.

Singh, H., Bahl, A., Kumar, A., & Mann, G. S. (2018). Materials and Information Flow Analysis and Optimization of Manufacturing Processes in MSMEs by the Application of Value Stream Mapping (VSM) Technique. Materials Today: Proceedings, 5(14), 28420–28426.

Stadnicka, D., & Antonelli, D. (2015). Application of value stream mapping and possibilities of manufacturing processes simulations in automotive industry. FME Transactions, 43(4), 279–286.

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.

Suresh, A., & John Sathya, A. (2019). ScienceDirect Value stream mapping & Manufacturing process design for elements in an auto-ancillary unit-A case study, 220(2):243–254.

Tabanli, R. M., & Ertay, T. (2013). Value stream mapping and benefit-cost analysis application for value visibility of a pilot project on RFID investment integrated to a manual production control system - A case study. International Journal of Advanced Manufacturing Technology, 66(5–8), 987–1002.

Tayal, A., Gunasekaran, A., Singh, S. P., Dubey, R., & Papadopoulos, T. (2017). Formulating and solving sustainable stochastic dynamic facility layout problem: A key to sustainable operations. Annals of Operations Research, 253(1), 621–655.

Tasdemir, C., & Hiziroglu, S. (2019). Achieving cost efficiency through increased inventory leanness: Evidences from oriented strand board (OSB) industry. International Journal of Production Economics, 208, 412–433.

Teichgräber, U. K., & De Bucourt, M. (2012). Applying value stream mapping techniques to eliminate non-value-added waste for the procurement of endovascular stents. European Journal of Radiology, 81(1), 1207–1210

© COPYRIGHT UPM

Thiede, S., Schonemann, M., Kurle, D., Herrmann, C., 2016. Multi-level simulation in manufacturing companies: the water-energy nexus case. J. Clean. Prod. 139, 1118-1127.

Vafaei-Zadeh, A., Thurasamy, R., & Hanifah, H. (2019). Modeling anti-malware use intention of university students in a developing country using the theory of planned behavior. Kybernetes, 48(8), 1565–1585.

Valencia, E. T., Lamouri, S., Pellerin, R., Dubois, P., & Moeuf, A. (2019). Production planning in the fourth industrial revolution: A literature review. IFAC-PapersOnLine, 52(13), 2158–2163.

Venkataraman, K., Ramnath, B. V., Kumar, V. M., & Elanchezhian, C. (2014). Application of Value Stream Mapping for Reduction of Cycle Time in a Machining Process. Procedia Materials Science, 6, 1187–1196.

Womack, J. P., & Jones, D. T. (1997). Lean thinking—banish waste and create wealth in your corporation. Journal of the Operational Research Society, 48(11), 1148-1148.

Yang, T., Kuo, Y., Su, C. T., & Hou, C. L. (2015). Lean production system design for fishing net manufacturing using lean principles and simulation optimization. Journal of Manufacturing Systems, 34, 66–73.

Yang, T., Wen, Y. F., Hsieh, Z. R., & Zhang, J. (2020). A lean production system design for semiconductor crystal-ingot pulling manufacturing using hybrid Taguchi method and simulation optimization. Assembly Automation, 40, 1–13.

Zahraee S.M., Tolooie A., Abrishami S.J., Shiwakoti N., Stasinopoulos P., Lean manufacturing analysis of a Heater industry based on value stream mapping and computer simulation, Procedia Manuf. 51 (2020) 1379–1386.

Zahoor, S., Abdul-Kader, W., Ijaz, H., Khan, A.Q., Saeed, Z., Muzaffar, S., 2019.A combined VSM and kaizen approach for sustainable continuous process improvement. Int. J. Indus. Eng. 1 (2), 125-137.

Zhou, B. (2016). Lean principles, practices, and impacts: A study on small and medium-sized enterprises (SMEs). Annals of Operations Research, 241(1–2), 457–474.

Zhu, X.Y., Zhang, H., Jiang, Z.G., 2020. Application of green-modified value stream mapping to integrate and implement lean and green practices: a case study. Int.J. Comput. Integrated Manuf. 33 (7), 716-731.

© COPYRIGHT UPM