InCITE 2019

A collaborative activity jointly organised by:

FACULTY OF ENGINEERING
UNIVERSITAS SURABAYA

THE UNIVERSITY of ADELAIDE

INTERNATIONAL CONFERENCE ON INFORMATICS, TECHNOLOGY, AND ENGINEERING

22-23 AUGUST 2019

PROCEEDINGS BOOK

Enhancing Engineering Innovation Towards A Greener Future

VENUE:
THE ANVAYA BEACH RESORT BALI
Jl. Kartika Plaza, Tuban, Kuta,
Kabupaten Badung, Bali 80361
Phone : (+62361) 2090477
www.theanvayabali.com

PUBLISHER:
UNIVERSITAS SURABAYA
Jl. Raya Kalirungkut
Surabaya 60293
Phone. (62-31) 298-1344
E-mail: ppi@unit.ubaya.ac.id

Faculty of Engineering - Universitas Surabaya

Preface

Welcome Remarks,
Chair of the Steering Committee

It is a great pleasure to welcome all of you to Bali and to the International Conference on Informatics, Technology, and Engineering 2019 (InCITE 2019) held by the Faculty of Engineering, University of Surabaya (UBAYA) in collaboration with The University of Adelaide, Australia and Sirindhorn International Institute of Technology (Thammasat University), Thailand. The first InCITE has been successfully held in Bali, Indonesia in 2017. We are very delighted to host the second InCITE here in Bali, Indonesia again.

There are more than 75 presentations in this conference. We welcome leading experts not only from Indonesia, but also from different parts of the world. The experts will share the knowledge and experiences in the fields of informatics, technology, science, and engineering. The main theme of this conference is **Enhancing Engineering Innovation Towards A Greener Future** in response to several world challenges including sustainable development, global convergence of information and communications technologies, climate change and global warming as well as the depletion of unrenewable natural resources. We hope this conference will provide you a good opportunity to get to know each other better and consolidate bonds of friendship and mutual trust.

We would like to express our sincere gratitude to the Keynote and Plenary speakers, International Scientific Committee, Steering Committee, and Organising Committee for their huge efforts to make this conference successful.

Thank you all for your support and attendance at InCITE 2019. Please enjoy the conference and Bali !

Asst. Prof. Djuwari, Ph.D.

Preface

Welcome Remarks,
Chair of The Organizing Committee

Welcome to Bali, Indonesia to all delegates and presenters. It is my pleasure and privilege to welcome all of you to the 2nd (second) International Conference on Informatics, Technology, and Engineering 2019 (InCITE 2019) held by the Faculty of Engineering, University of Surabaya (UBAYA) in collaboration with The University of Adelaide, Australia and Sirindhorn International Institute of Technology (Thammasat University), Thailand.

InCITE 2019 has received more than 75 papers to be presented in this conference. All papers represent four following parallel clusters: Green Design and Innovation, Green Manufacturing and Green Processes, Power System and Green Energy Management, and The Role of IT in Innovation Enhancement. Each cluster supports the main theme of the conference, which is **Enhancing Engineering Innovation Towards A Greener Future.** The engineering innovation is the key to increase our awareness in maintaining the sustainable growth and development in the world.

The Organising Committee of InCITE 2019 would like to express our sincere gratitude for the tremendous supports and contributions from many parties. The supports from The Faculty of Engineering of UBAYA, keynote and plenary speakers, our International Scientific Committee, the Steering and Organising Committees are really acknowledged.

The last but not the least, thank you for your supports, enjoy the conference and we hope through this meeting all of you can extend your networks and collaborations.

Asst. Prof. Putu Doddy Sutrisna, Ph.D.

Conference Organizers

SCIENTIFIC COMMITTEE

- Prof. Willy Susilo, Ph.D. (University of Wollongong, AUSTRALIA)
- Prof. Dr. Anton Satria Prabuwono (King Abdulaziz University, SAUDI ARABIA)
- Assoc. Prof. Oki Muraza, Ph.D. (King Fahd University of Petroleum & Minerals, KINGDOM OF SAUDI ARABIA)
- Prof. Ravindra S. Goonetilleke, Ph.D. (Hong Kong University of Science & Technology, PRC)
- Assoc. Prof. Tan Kay Chuan, Ph.D. (National University of Singapore, SINGAPORE)
- Asst. Prof. Aldy Gunawan, Ph.D. (Singapore Management University, SINGAPORE)
- Asst. Prof. Hendry Raharjo, Ph.D. (Chalmers University of Technology, SWEDEN)
- Assoc. Prof. Dr. A. F. M. Saifuddin Saif (American International University, BANGLADESH)
- Asst. Prof. Itthisek Nilkhamhang, Ph.D. (Sirindhorn International Institute of Technology, THAILAND)
- Assoc. Prof. Akawut Siriruk, Ph.D. (Suranaree University of Technology, THAILAND)
- Assoc. Prof. Avirut Chinkulkijniwat, Ph.D. (Suranaree University of Technology, THAILAND)
- Assoc. Prof. Peerapong Uthansakul, Ph.D. (Suranaree University of Technology, THAILAND)
- Assoc. Prof. Dr. Andi Cakravastia Arisaputra Raja (Institut Teknologi Bandung, INDONESIA)
- Assoc. Prof. Dr. Anas Maruf (Institut Teknologi Bandung, INDONESIA)
- Assoc. Prof. Yassierli, Ph.D. (Institut Teknologi Bandung, INDONESIA)
- Prof. Dr. Ali Altway (Institut Teknologi Sepuluh Nopember, INDONESIA)
- Prof. Dr-Ing. I Made Londen Batan (Institut Teknologi Sepuluh Nopember, INDONESIA)
- Assoc. Prof. Setiyo Gunawan, Ph.D. (Institut Teknologi Sepuluh Nopember, INDONESIA)
- Prof. Renanto Handogo, Ph.D. (Institut Teknologi Sepuluh Nopember, INDONESIA)
- Prof. Mauridhi Hery Purnomo, Ph.D. (Institut Teknologi Sepuluh Nopember, INDONESIA)
- Prof. Nur Iriawan, Ph.D. (Institut Teknologi Sepuluh Nopember, INDONESIA)
- Prof. I Nyoman Pujawan, Ph.D. (Institut Teknologi Sepuluh Nopember, INDONESIA)
- Asst. Prof. Budi Hartono, Ph.D. (Universitas Gadjah Mada, INDONESIA)
- Prof. Sarjiya, Ph.D. (Universitas Gadjah Mada, INDONESIA)
- Asst. Prof. Nemuel Daniel Pah, Ph.D. (Universitas Surabaya, INDONESIA)
- Assoc. Prof. Markus Hartono, Ph.D (Universitas Surabaya, INDONESIA)
- Prof. Joniarto Parung, Ph.D. (Universitas Surabaya, INDONESIA)
- Prof. Lieke Riadi, Ph.D. (Universitas Surabaya, INDONESIA)

Conference Organizers

STEERING COMMITTEE
Chair:
Asst. Prof. Djuwari, Ph.D.

Honorary Members:
Prof. David Lewis, Ph.D.
Prof. Joniarto Parung, Ph.D.
Prof. Lieke Riadi, Ph.D.
Asst. Prof. Dr. Steve Kardinal Jusuf
Asst. Prof. Dr. Itthisek Nilkhamhang

Members:
Assoc. Prof. Amelia Santoso, Ph.D.
Mr. Agung Prayitno
Assoc. Prof. Emma Savitri, Ph.D.
Assoc. Prof. Markus Hartono, Ph.D., CHFP.
Assoc. Prof. Budi Hartanto, Ph.D.
Mr. Sunardi Tjandra
Assoc. Prof. Eric Wibisono, Ph.D.
Asst. Prof. Nemuel Daniel Pah, Ph.D.
Assoc. Prof. Elieser Tarigan, Ph.D.
Assoc. Prof. Jaya Suteja, Ph.D.
Prof. Joniarto Parung, Ph.D.
Assoc. Prof. Hudiyo Firmanto, Ph.D.
Assoc. Prof. Restu Kartiko Widi, Ph.D.

ORGANIZING COMMITTEE

Chair	:Asst. Prof. Putu Doddy Sutrisna, Ph.D.
Vice Chair	:Dr. Delta Ardy Prima
Secretary	:Ms. Aprilia Karina
Treasurers	:Ms. Dhiani Tresna Absari
Secretariat	:Maria Agatha E.Gunawan, Ph.D.
	Asst. Prof. Lanny Sapei, Ph.D.
	Mr. Rahman Dwi Wahyudi
	Ms. Yenny Sari
	Ms. Yuana Elly Agustin
	Ms. Susana Limanto
	Ms. Monica Widiasri

Conference Organizers

Program :Mr. Yunus Fransiscus
Ms. Melissa Angga
Mr. I Made Ronyastra
Mr. Henry Hermawan
Mr. Felix Handani
Ms. Indri Hapsari
Mr. Mochammad Arbi Hidayat
Website :Mr. Daniel Soesanto
Mr. Marcellinus Ferdinand Suciadi
Design :Ms. Tyrza Adelia
Sponsorship :Assoc. Prof. Susila Candra, Ph.D.
Logistic: Mr. Arief Rachman Hakim
Mr. Muhamad Yulham Effendy

REVIEWER

- Prof. David Lewis, Ph.D. (University of Adelaide, AUSTRALIA)
- Prof. Willy Susilo, Ph.D. (University of Wollongong, AUSTRALIA)
- Dr. Jingwei Hou (University of Queensland, AUSTRALIA)
- Asst. Prof. Hendry Raharjo, Ph.D. (Chalmers University of Technology, SWEDEN)
- Prof. Dr. Anton Satria Prabuwono (King Abdulaziz University, SAUDI ARABIA)
- Assoc. Prof. Oki Muraza, Ph.D. (King Fahd University of Petroleum & Minerals, KINGDOM OF SAUDI ARABIA)
- Prof. Dr. Winarto Kurniawan (Tokyo Institute of Technology, JAPAN)
- Dr. Wahyudiono (Nagoya University, JAPAN)
- Prof. Ravindra S. Goonetilleke, Ph.D. (Hong Kong University of Science & Technology, PRC)
- Asst. Prof. Dr. Steve Kardinal Jusuf (Singapore Institute of Technology, SINGAPORE)
- Assoc. Prof. Tan Kay Chuan, Ph.D. (National University of Singapore, SINGAPORE)
- Asst. Prof. Aldy Gunawan, Ph.D. (Singapore Management University, SINGAPORE)
- Assoc. Prof. Dr. A. F. M. Saifuddin Saif (American International University, BANGLADESH)
- Asst. Prof. Itthisek Nilkhamhang, Ph.D. (Sirindhorn International Institute of Technology, THAILAND)
- Assoc. Prof. Akawut Siriruk, Ph.D. (Suranaree University of Technology, THAILAND)
- Assoc. Prof. Avirut Chinkulkijniwat, Ph.D. (Suranaree University of Technology, THAILAND)
- Assoc. Prof. Peerapong Uthansakul, Ph.D. (Suranaree University of Technology, THAILAND)
- Asst. Prof. Dr. Phuong Lan Tran Nguyen (Can Tho University, VIETNAM)
- Assoc. Prof. Dr. Anas Maruf (Institut Teknologi Bandung, INDONESIA)
- Dr. Khoiruddin (Institut Teknologi Bandung, INDONESIA)
- Assoc. Prof. Dr. Veinardi Suendo (Institut Teknologi Bandung, INDONESIA)

Conference Organizers

REVIEWER

- Assoc. Prof. Dr. Andi Cakravastia Arisaputra Raja (Institut Teknologi Bandung, INDONESIA)
- Assoc. Prof. Yassierli, Ph.D. (Institut Teknologi Bandung, INDONESIA)
- Assoc. Prof. Dr. Judy Retti B. Witono (Universitas Parahyangan, INDONESIA)
- Asst. Prof. Budi Hartono, Ph.D. (Universitas Gadjah Mada, INDONESIA)
- Prof. Sarjiya, Ph.D. (Universitas Gadjah Mada, INDONESIA)
- Asst. Prof. Dr. Hendri Himawan Triharminto (Akademi Angkatan Udara Yogyakarta, INDONESIA)
- Assoc. Prof. Dr. Djoko Budiyanto Setyohadi (Universitas Atmajaya Yogyakarta, INDONESIA)
- Prof. Dr. Ali Altway (Institut Teknologi Sepuluh Nopember, INDONESIA)
- Prof. Renanto Handogo, Ph.D. (Institut Teknologi Sepuluh Nopember, INDONESIA)
- Prof. Mauridhi Hery Purnomo, Ph.D. (Institut Teknologi Sepuluh Nopember, INDONESIA)
- Prof. Nur Iriawan, Ph.D. (Institut Teknologi Sepuluh Nopember, INDONESIA)
- Asst. Prof. Astria Nur Irfansyah, Ph.D.(Institut Teknologi Sepuluh Nopember, INDONESIA)
- Prof. Dr-Ing. I Made Londen Batan (Institut Teknologi Sepuluh Nopember, INDONESIA)
- Assoc. Prof. Setiyo Gunawan, Ph.D. (Institut Teknologi Sepuluh Nopember, INDONESIA)
- Prof. I Nyoman Pujawan, Ph.D. (Institut Teknologi Sepuluh Nopember, INDONESIA)
- Asst. Prof. Rr. Poppy Puspitasari, S, Ph.D (Universitas Negeri Malang, INDONESIA)
- Asst. Prof. Ratna Surya Alwi, S.T., M.Si., Ph.D (Universitas Fajar Makassar, INDONESIA)
- Prof. Joniarto Parung, Ph.D. (Universitas Surabaya, INDONESIA)
- Prof. Lieke Riadi, Ph.D. (Universitas Surabaya, INDONESIA)
- Asst. Prof. Nemuel Daniel Pah, Ph.D. (Universitas Surabaya, INDONESIA)
- Assoc. Prof. Markus Hartono, Ph.D (Universitas Surabaya, INDONESIA)
- Asst. Prof. Dr. Hazrul Iswadi (Universitas Surabaya, INDONESIA)
- Asst. Prof. Gunawan, Ph.D (Universitas Surabaya, INDONESIA)
- Assoc. Prof. Dr. Evy Herowati (Universitas Surabaya, INDONESIA)
- Assoc. Prof. Dr. Amelia Santoso (Universitas Surabaya, INDONESIA)
- Assoc. Prof. Eric Wibisono, Ph.D. (Universitas Surabaya, INDONESIA)
- Asst. Prof. Dr. Joko Siswantoro (Universitas Surabaya, INDONESIA)
- Assoc. Prof. Dr. Budi Hartanto (Universitas Surabaya, INDONESIA)
- Asst. Prof. Dr. Delta Ardy Prima (Universitas Surabaya, INDONESIA)
- Asst. Prof. Jimmy (Universitas Surabaya, INDONESIA)
- Assoc. Prof. Lisana (Universitas Surabaya, INDONESIA)
- Assoc. Prof. Dr. Emma Savitri (Universitas Surabaya, INDONESIA)
- Assoc. Prof. Restu Kartiko Widi, Ph.D. (Universitas Surabaya, INDONESIA)
- Assoc. Prof. Akbarningrum Fatmawati (Universitas Surabaya, INDONESIA)

Conference Organizers

REVIEWER

- Assoc. Prof. Akbarningrum Fatmawati (Universitas Surabaya, INDONESIA)
- Asst. Prof. Putu Doddy Sutrisna, Ph.D. (Universitas Surabaya, INDONESIA)
- Asst. Prof. Djuwari, Ph.D. (Universitas Surabaya, INDONESIA)
- Asst. Prof. Elieser Tarigan, Ph.D. (Universitas Surabaya, INDONESIA)
- Assoc. Prof. The Jaya Suteja, Ph.D (Universitas Surabaya, INDONESIA)
- Assoc. Prof. Dr. Susila Candra (Universitas Surabaya, INDONESIA)
- Asst. Prof. Sunardi Tjandra (Universitas Surabaya, INDONESIA)
- Asst. Prof. Yuwono Budi Pratiknyo (Universitas Surabaya, INDONESIA)

CONFERENCE ORGANIZING COMMITTEE:
FACULTY OF ENGINEERING, UNIVERSITAS SURABAYA
DEAN BUILDING TB 2, RAYA KALIRUNGKUT
SURABAYA, 60293, INDONESIA
PHONE: +62-31-2981150, FAX: +62-31-2981151
E-MAIL: incite@unit.ubaya.ac.id
WEBSITE: https://incite.ubaya.ac.id; http://teknik.ubaya.ac.id

Table of Content

Green Manufacturing and Green Processes

Power System and Green Energy Management

An empirical study of how the deployment of lean sigma can reduce its enemies: waste, overburden and defect

Y Sari, E Wibisono and I Pangkiey

Department of Industrial Engineering, Faculty of Engineering, University of Surabaya
Raya Kalirungkut, Surabaya 60293, East Java, Indonesia
E-mail: ysari@staff.ubaya.ac.id

Abstract. Lean thinking focuses on shortening cycle time by eliminating non-value-added activities in every process so that the production can flow efficiently. Six sigma focuses on increasing process capability by eliminating process variation to reduce defects. Both concepts are integrated into Lean Sigma methodology and offered to companies in a form of DMAIC framework to achieve two benefits: quality and speed. In terms of lean implementation, several empirical studies have used the DMAIC framework to emphasis on defining and analysing *muda* (waste), measuring the level of process cycle efficiency, and making the improvement initiatives to remove waste. This research proposed an additional analysis to the existing DMAIC framework on identifying and evaluating *muri* (overburden), measuring the *muri* score, and formulating the improvement plans by identifying less ergonomic work conditions that create overburden activities. The proposed DMAIC framework has been deployed in an Indonesian-footwear manufacturer and the implementation indicated that *muri* analysis can be aligned with *muda* analysis to create better process improvement. The research also showed that the proposed framework was able to give significant impacts on reducing the two enemies of lean: *muda* and *muri*.

1. Introduction

Lean Sigma is a methodology that can be used to maximize shareholder value by achieving the fastest rate of customer satisfaction, price, and quality, process speed, and capital turn over. It is a combination of the ability of lean manufacturing to accelerate the process and the ability of six sigma to improve the quality of output [1]. Integration of the concepts between lean and six sigma offers a complete and holistic approach to bring business to gain the efficiency advantages. The principles and strategies of both methods will produce a business solution for a better, faster, and more economical business process. For manufacturing industry, Lean Sigma can be used to fasten the process cycle time, increase the capability of sigma level and business flexibility, and operate at the lower cost [2].

The concept of lean thinking introduces three lean enemies, namely *muda*, *muri* and *mura* [3]. *Muda* is defined as non-value-added activities that occur in business process and are commonly categorized into seven waste covering excessive transportation, unnecessary inventory, waiting, unnecessary motion, over-production, defects, and over-processing [4]. *Muri* is referring to overloading of facilities or human resources that can be caused by untidy workstation, lack of work standardization, and fluctuated output volume [3]. *Mura* is unevenness or unbalanced working load among workers [3]. Six sigma creates a five-phase improvement process, i.e. Define, Measure, Analyze, Improve, Control, or better known as the DMAIC methodology [5].

Several empirical studies which adopted Lean Sigma methodology focus on analyzing waste (*muda*), because *muda* is something that companies can identify. The integration of Lean and Six Sigma methodology was used to identify non-value-added activities and seven types of waste during the processes, to measure efficiency and defect level, and to formulate action plans to eliminate *muda* [5, 6]. However, two other lean enemies (*mura* and *muri*) are usually failed to be identified although they are often the main causes of *muda*. In this research, *muri* analysis is added because there is a linkage between *muda*, defects and *muri*. As an illustration, waste in over-processing and defective products can cause extra work and fatigue to operators, and vice versa, overburden can cause a decrease in worker's performance and an increase either in operation time or more defective products. *Muri* analysis can be aligned with *muda* analysis to improve process performance. This research was an empirical study aimed to deploy the DMAIC framework in an Indonesian-footwear manufacturer. It starts from identifying the problems, measuring the current condition, analyzing root causes, formulating the improvement plans, and designing control mechanism to prevent the potential errors or waste to re-occur in the future. *Mura* analysis was not included because this particular footwear production process is a continuous flow carried out by a group of workers and neither the imbalance process nor inconsistent outputs were found.

2. Research Methodology

Data-driven life-cycle approach called as DMAIC methodology was used for problem exploration, data collection and analysis, problem solving and designing solutions. Lean activities are integrated into the steps of Six Sigma's DMAIC and the framework of DMAIC methodology (Figure 1) is briefly described below.

Define. The main outputs of this first stage are problem identification and determination of goals. There are several ways to identify problems and goals such as knowing the needs of customers as well as process owner's by exploring the Voice of Customer (VoC) and the Voice of Business (VoB). VoC and VoB are then translated to the Critical to Quality (CtQ) and defect criteria. CtQ should be measured so that it can be controlled. Another primary output from the Define stage is to identify *muda* and *muri* through the observation on overall production process and interview with process owners.

Measure. This stage is about collecting the data. There are two types of collected data: (i) primary data which can be collected through direct observation and exploration, such as production processes, production activities, activity times, defect types, and number of defects, and (ii) secondary data which can be collected from the company, such as the company's profile and history, business process, products and materials list, and production capacity. The outputs of this phase are: (i) the value of defect per million opportunities (DPMO) and current sigma level for each process that can describe the capability of each production process, (ii) Process Activity Mapping (PAM) that maps the distribution of value-added, non-value-added, and necessary-non-value-added activities, and the level of Process Cycle Efficiency (PCE), (iii) *muri* score, which can be obtained from direct observation in every process using an industrial template of *muri* analysis [6].

Analyze. In this phase, Failure Mode and Effects Analysis (FMEA) and 5-Whys are used as tools to find the potential causes of the problems. The analysis of FMEA provides the value of Risk Priority Number (RPN) of each failure which can be used to set the improvement priorities.

Improve & Control. The follow-up from finding the root cause of the problem is to figure out how potential solutions can be formulated and implemented. Control phase is needed to standardize the current improvement so that the same errors in the future can be prevented. An example of control initiative is designing new work procedures/guidelines. However, the results of implementation and control design are not discussed here, since the focal issue of the article is to propose additional *muri* analysis and to discuss their benefits for the manufacturer.

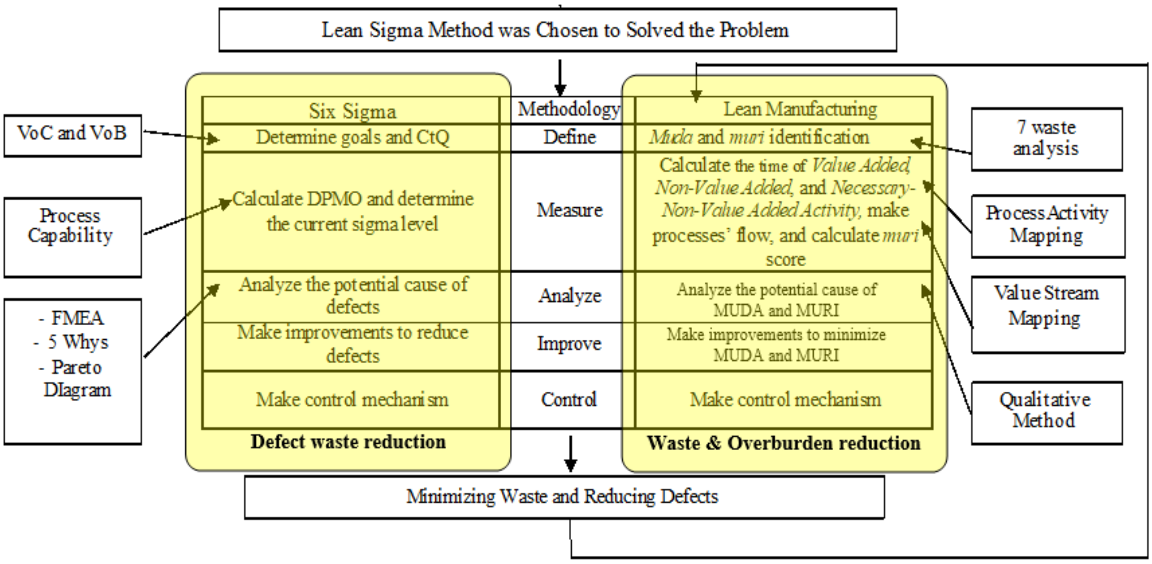


Figure 1. Framework of DMAIC Approach

3. Results and Discussion

3.1 Define

In the Define stage, the footwear manufacturer decided to deploy the DMAIC framework on the product brand San Carbone slipper. There are seven main processes in slipper manufacturing, from raw materials processing to finished goods packaging, as shown in Figure 2. Although the study was done to all of the seven production processes, the process of pressing and sewing were particularly selected for the issues of discussion in this article. Pressing is a process of strap/motif making to the slipper component in which the raw material sheets are passed to the oven conveyor and afterward they are taken by the operator to be pressed by the pressing machine using a cold-temperature mattress. Stitching is a process to combine the two components of sandal using threads including the process of adding stitching line for the slipper model.

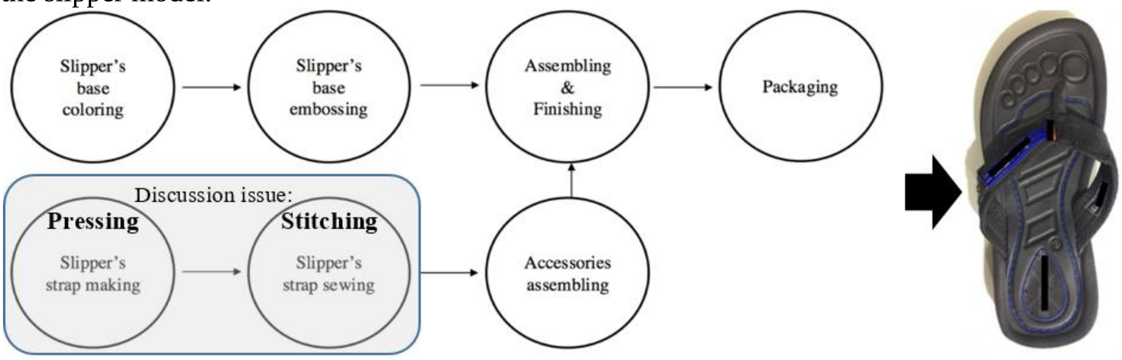


Figure 2. Production process flow (product type: San Carbone slipper)

Table 1. Critical to Quality (CtQ) and defect criteria (examples are for pressing process)

VoC / VoB	CtQ	Criteria for defect
"Good quality" "Good design" "Comfortable" "Neat stitching" "Strap sandals do not make pain" "Durability of slippers" "Packaging is in good condition"	For pressing process: - The maturity level of pressing output - The conformity of the strap making (the strap result is not outside of material size	- Raw or burnt component - Oblique/cut off component

The outcomes of interview with the customers and business owner were translated to the Critical to Quality (CtQ) and defect criteria (see Table 1). Furthermore, *muda* and *muri* were identified by observing pressing and stitching processes in advance and the results are shown in Table 2 and Table 3.

Table 2. *Muda* analysis: identification of seven waste

Process	Type of waste	Description of waste	Impact
Pressing	Inappropriate processing	Oven and cooler are not stable The material is not neat when placed on the floor so it must be tidied up again	Longer process time
	Transportation	Too much mobilization of operators and materials	Fatigue worker
Stitching	Inappropriate processing	The process is not continuous; the product must be put in the sack before moved to the next process	Longer process time

Table 2. *Muri* analysis

Process	Activity	Description	Visual proof	
Pressing	Placing and taking material from the floor	The body position of workers must frequently bend when sorting the material (left)		
	Writing the code on the material	Workers sometimes face difficulty in taking material that is located too high (right)		
Stitching	Inspection	Inspection is done on the floor, so sometimes the operator has to squat for a long time (left)		
	Transfer the material	The operator's body position must bend to take material that is located on the floor (right)		

3.2 Measure & Analyze

After data collection on defective products according to the defect criteria, the sigma level can be measured. In general, sigma capability for all processes are above 3.9, with the lowest one in pressing process with the score of 3.929 (current sigma level). Table 4 shows the calculation of the current sigma level for pressing process. FMEA was then used to calculate the risk priority number (RPN = Severity × Occurrence × Detection) and the results show that raw component and cut off defect/failure in pressing process caused by material problems and human errors should be prioritized because of the associated high RPN (Table 5).

Table 4. Current sigma level for pressing process

Date	Production Quantity	Defect		
		Cut off	Burnt	Raw
17/9/2018	7585	31	77	39
18/9/2018	7752	41	65	69
19/9/2018	7737	42	98	70
20/9/2018	7332	22	83	79
21/9/2018	7777	24	62	64
Total	**38183**	**160**	**385**	**321**
Sigma Level		**3.929**		

SIGMA LEVEL CALCULATOR DISCRETE DATA

Enter Number of Defects:	866
Enter Number of Units:	38,183
Enter Number of Opportunities Per Unit:	3
Defects Per Million Opportunities:	7,560
Sigma Level	3.9

To find out the level of Process Cycle Efficiency (PCE), Process Activity Mapping (PAM) was used to measure time and distance for every activity in a certain process, which were then categorized into Value-Added Activity (VA) or Non-Value-Added Activity (NVA). PCE is calculated by dividing the amount of time for VA and the total cycle time. PCE for stitching process was found at 95.12%. The results of PAM and the calculation of PCE for stitching process are shown in Table 6.

Table 5. FMEA and RPN for pressing process

No	Mode of Failure	Effect of Failure	SEV	Causes of Failure	OCC	Current Process Control	DET	RPN
1	Burnt component	Scrap	8	Material too soft	6	*Visual check*	1	48
			8	Temperature of oven too high	5	*Visual check*	1	40
2	**Raw component**	**Scrap**	**8**	**Material too hard**	**5**	***Visual check***	**2**	**80**
			8	Air con not cool enough	4	*Visual check*	2	64
3	**Cut off**	**Scrap**	**8**	**Human error**	**5**	***Visual check***	**2**	**80**

Table 6. Process Activity Mapping for stitching process

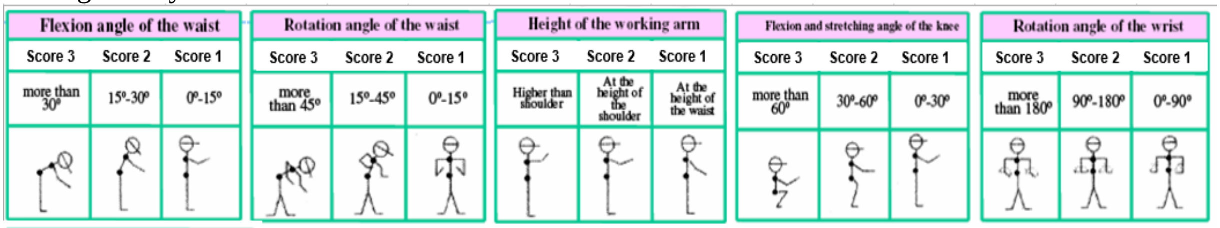
No.	Activities	Machine / Distance	Activity time (sec)	VA	NVA
1	Take the materials from the storage	Distance: 10 m	169.97		169.97
2	Untie the knots		45.36		45.36
3	Prepare the machine		235.72		235.72
4	Stitch the material into component	Machine: Stitching	46350	46350	
5	Change threads if they run out		11.72		11.72
6	Pile up, inspect, and count		2144.46		2144.46
7	Bind the materials		257.26		257.26
8	Put materials in storage	Distance: 10 m	173.57		173.57
9	Take the materials from the storage	Distance: 2 m	68.03		68.03
10	Untie the knots		90.72		90.72
11	Prepare the machine		235.72		235.72
12	Stitch the material into another component	Machine: Stitching	77250	77250	
13	Change threads if they run out		11.72		11.72
14	Pile up, inspect, and count		2465.51		2465.51
15	Bind the materials		257.26		257.26
16	Put materials in storage	Distance: 10 m	173.57		173.57
	Total		**129940.59**	**123600**	**6340.59**

For *muri* identification, the results were obtained from quantitative analysis using *muri* analysis [7], in which every activity for each process is analyzed based on 9 categories (category A to I). The range of scores is 1 to 3, with 1 being the lightest (good) and 3 the heaviest (bad). These categories, as shown in Figure 3, are: (A) flexion angle of the waist, (B) rotation angle of the waist, (C) height of the working arm, (D) flexion and stretching angle of the knee, (E) rotation angle of the wrist, (F) pick up parts and materials, (G) working range, (H) walk, (I) transport. If an activity scores 1 in all categories (total *muri* score of 9), the activity contributes low risk of working condition. If the *muri* score is higher than 12, the activity should be improved because it contributes a high occupational hazard. From *muri* analysis, these causes of overburden were found: (i) the position of materials was too low or too high because of space limitation in the production area, (ii) materials must be cooled on the floor in pressing process that caused operators to move frequently, (iii) the inspections were done on the floor and there were no seats for operators, (iv) some activities required operators to bend because the materials are on the floor.

4. Conclusion

This research proposed briefly a framework of DMAIC to deploy Lean Sigma. Two processes of footwear production, i.e. pressing and stitching, were selected to explain how the tools could be applied.

The results presented how the alignment between *muda* and *muri* analysis can develop better improvement plans. For instance, the improvement plans in pressing process which were generated from muda analysis include: (i) proposing regular maintenance in order to solve the air con problem, (ii) reviewing the supplier performance in order to solve raw material problem. *Muri* analysis enhanced the improvement plans by suggesting to: (iii) add extra trolleys, (iv) provide small seats, and (v) use a cooling conveyor.



Nine categories of MURI analyses

Activities in Stitching Process	A	B	C	D	E	F	G	H	I	MURI SCORE
1	3	1	1	1	1	1	1	1	3	13
2	1	1	1	1	1	1	1	1	1	9
3	1	1	1	1	1	1	1	1	1	9
4	1	1	1	1	1	1	1	1	1	9
5	1	1	1	1	1	1	1	1	1	9
6	1	1	1	3	1	1	1	1	1	11
7	1	1	1	1	1	1	1	1	1	9
8	3	1	1	1	1	1	1	1	3	13
9	3	1	1	1	1	1	1	1	3	13
10	1	1	1	1	1	1	1	1	1	9
11	1	1	1	1	1	1	1	1	1	9
12	1	1	1	1	1	1	1	1	1	9
13	1	1	1	1	1	1	1	1	1	9
14	1	1	1	3	1	1	1	1	1	11
15	1	1	1	1	1	1	1	1	1	9
16	3	1	1	1	1	1	1	1	3	13
TOTAL										144

LOW	MURI score <= 9
MEDIUM	10 <= Muri Score <= 12
HIGH	Muri score > 12

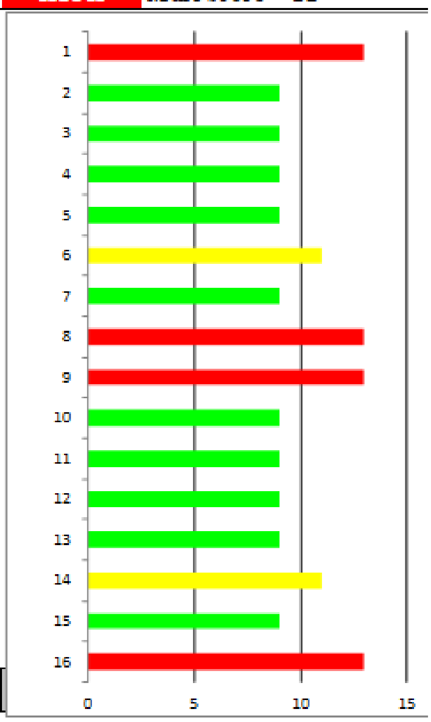


Figure 4. *Muri* analysis (for stitching process)

References

[1] George M L 2002 *Lean Six Sigma: Combining six sigma quality with lean speed* (New York: McGraw-Hill)
[2] Antony J, Escamilla J L and Caine P 2003 *Manuf. Eng.* **82** pp 40–42
[3] Pieńkowski M 2014 Waste measurement techniques for lean companies *Int. J. Lean Thinking* **5** pp 9–24
[4] Hines P and Taylor D 2000 *Going Lean* (Cardiff: Lean Enterprise Research Centre)
[5] Snee R D 2010 Lean Six Sigma – getting better all the time *Int. J. Lean Six Sigma* **1** pp 9–29
[6] Sari Y, Hadiyat M A and Yunita 2013 The implementation of Lean Sigma to increase the process efficiency and product quality *Proc. Integr. Conf. Ind. Eng. Sci* **1** p 1–6
[7] Sari Y, Agung S N and Nabila S 2018 *Elimination of changeover time – case study: Unilever Indonesia* (Surabaya: University of Surabaya)