



**INTERNATIONAL CONFERENCE ON  
INFORMATICS, TECHNOLOGY, AND  
ENGINEERING**

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**FACULTY OF ENGINEERING  
UNIVERSITAS SURABAYA**



**THE UNIVERSITY  
of ADELAIDE**



# ***PROCEEDINGS BOOK***

***Enhancing Engineering  
Innovation Towards  
A Greener Future***

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***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 2<sup>nd</sup> (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.

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# Table of Content

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<b>Preface</b>	<b>i</b>
<b>Conference Organizers</b>	<b>iii</b>
<b>Table of content</b>	<b>viii</b>

## **Green Design and Innovation**

A Systematic Literature Review for Developing Sustainability Assessment Tool: Formulating the State of the Art and Future Direction <i>Y Sari, A Hidayatno, A Suzianti, M Hartono</i>	A-1
---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	-----

Perceived Kansei and Performance-Based Usability Impact on Satisfaction for Web- Based Applications <i>M Hartono</i>	A-8
----------------------------------------------------------------------------------------------------------------------------	-----

Passive Design Implementation as Sustainable Development Approach on Vertical Housing Case Study: Sentra Timur Residence <i>T Riotama and H Herdiansyah</i>	A-14
-------------------------------------------------------------------------------------------------------------------------------------------------------------------	------

Development and Usability Evaluation of Virtual Guide Using Augmented Reality for Candi Gunung Gangsir in East Java <i>I M Ronyastra, I Hapsari and F P Pani</i>	A-19
------------------------------------------------------------------------------------------------------------------------------------------------------------------------	------

Combined Structural Equation Modelling – Artificial Neural Networks Model for Predicting Customer Loyalty <i>M A Hadiyat</i>	A-25
------------------------------------------------------------------------------------------------------------------------------------	------

How the Indonesian Ecologically Conscious Millennials Value Upcycled Clothing? <i>C A P Parung</i>	A-31
-------------------------------------------------------------------------------------------------------	------

Animated Video as Health Promotion Tool for Community Supplementary Feeding <i>S Limanto, Liliana, S Purba and M Oeitheurisa</i>	A-37
-------------------------------------------------------------------------------------------------------------------------------------	------

Slow - Fashion: Case Study of Tenun Sesek as Local Wisdom from Pringgasela, East Lombok, West Nusa Tenggara

*N Juniati* A-43

Expertise-based decision makers' importance weights for solving group decision making problems under fuzzy preference relations

*E Herowati* A-49

Measurement of Student Satisfaction and Loyalty Using Service Quality Model for Higher Education (HedQual) at Industrial Engineering Department University of Pelita Harapan

*N Hartono, Laurence and B F Tjahjadhi* A-56

Development Initial Model of Intention to Use Halodoc Application Using PLS-SEM

*N Hartono, Laurence and T O Tedja* A-63

The Role of Ergonomics in Supporting Supply Chain Performance in Manufacturing Companies: a Literature Review

*Sampouw N and Hartono M* A-71

Green Dynamic Capability for Enhancing Green Innovations Performance in a Manufacturing Company: a Conceptual Framework

*R Amaranti, D Irianto and R Govindaraju* A-77

Kansei Engineering Application in Redesigning Carica Packaging to Support Local-Small Industry in Central Java

*H Prastawa, M Mahachandra and D A Harman Donida* A-84

Organic-Inorganic Nanocomposite Membranes for Molecular Separation and Bioapplications

*J Hou, P D Sutrisna, L Li, V Chen* A-90

Fluazinam Potential as a Fungicide in Liquid Culture System for the Growth of Haematococcus pluvialis Microalgae

*J R Witono, V Novianty, H Santoso, A Miryanti and A J Kumalaputri* A-95

Tensile properties of kenaf fiber by alkalinization treatment: effect of variations in concentration

*Ismojo, K A Zahidah, E Yuanita, E Kustiyah and M Chalid* A-103

### **Green Manufacturing and Green Processes**

Regulatory Performance of Two Different Tuning Method for Milk Cooling Control System

*R Agustriyanto* B-1

A Review of a Machine Design of Chocolate Extrusion Based Co-Rotating Twin Screw Extruder

*P Pitayachaval and P Watcharamaisakul* B-7

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* B-14

Controlled Release Fertilizer Based on Starch Chitosan Encapsulation

*E Savitri, E Purwanto, A N Kodrat and E Yonathan* B-20

Assessing Materials from Hoarded Mobile Phones: Hidden E-Waste Subject for Reverse Logistics

*R Siring, H Herdiyansyah, R D Kusumastuti and A E Lucianto* B-26

Optimisation of Subtractive Rapid Prototyping Process Parameters Using Response Surface Methodology

*T J Suteja and M A Hadiyat* B-32

A Kinetic Study of Oil-in-Water Emulsion Formation Stabilized by Rice Husk Ash and Lecithin

*L Sapei, S W Kurniawan and A P Siantoro* B-38

Improvement of Salt Raw Material Procurement and Inventory Planning at Bitung

*I Hapsari, D N Prayogo, C M G Liembath* B-44

Price and Inventory Policy Strategy Model in a Price Sensitive Dual Channel Supply Chain Structure Considering Product Substitution

*R Y H Silitonga and N Christina* B-50

Tofu Wastewater Treatment Through a Combined Process of Coagulation-Flocculation and Ultrafiltration

*P Prawati, A Oktariany, S S Putri, I Aditya and S Kartohardjono* B-56

Risk-Based Sustainability Balanced Scorecard to Prioritize Integrated Improvement and to Consider High Level Structure

*R D Wahyudi, Y Sari, E Wibisono, F Rafael and A F Tanujaya* B-63

Effect of NR-g-cellulose Coupling Agent into NR-Cellulose Composite Dispersibility and Its Physical Properties

*H Handayani, A Cifriadi, A S Handayani, M Chalid, S Savetlana, M Christwardana* B-69

Carbon Emission Modelling in Container Terminal Operations Planning Using a System Dynamics Approach

*D N Prayogo* B-75

The Effect of Soygurt Fortification with Black Rice Bran Extract Anthocyanin in Hyperlipidemia Wistar Rats (*Rattus norvegicus*)

*E P Nurlaili, S Hartati and Nurhidajah* B-81

Container Storage Tariff Policy Analysis Using Combining Game Theory and System Dynamics Approach

*A G Budianto and B Wirjodirdjo*

B-87

Formulation and Characterization of Chitosan-Alginate Freeze Dried Matrices Loaded with Oleoresin Extract of Red Ginger

*E A Krisanti, A Safiya and K Mulia*

B-93

Preparation and Characterization of Polyvinyl Alcohol-Chitosan-Tripolyphosphate Hydrogel for Extended Release of Anti-Tuberculosis Drugs

*K Mulia, S A Chadarwati, A J Rahyussalim and E A Krisanti*

B-101

Effects of Initial Concentration, Adsorbent Mass, pH and Temperature to Personal Care Products Waste Removal with Activated Carbon as Adsorbent

*H R Priyantini, L Riadi, C Effendi, F Effendi and A Mitayani*

B-111

Surface Roughness Analysis Using Sound Signal in Turning of Mild Steel

*Anayet U Patwari, Anas Azmayeen Zamee, Mehedi Hasan Bhuiyan and Sultan Mahmud Sakib*

B-117

Environmental Life Cycle Costing of Boiler System: a Case Study

*C A Sulistio, Laurence, N Hartono and J Hanafi*

B-123

The Integration of Social Responsibility into Business Operation: Case Study of Indonesian Manufacturing Industry

*E D Rinawiyanti, C Huang and S As-Saber*

B-128

Solubility Correlation of Azobenzene Derivatives in Supercritical Carbon Dioxide: a Short Review

*Ratna Surya Alwi and Andi Sry Iryani*

B-134

Xylanase Production from Combined *Reutealis trisperma* with Potato Dextrose Broth by *Tricoderma reesei*: Effect of Pretreatment  
*Y E Agustin, L Riadi and T P Utami* B-140

### **Power System and Green Energy Management**

Analysis of the Potential of Solar Panel Implementation Towards Green Affordable Housing Development  
*A E Lucianto and H Herdiansyah* C-1

Integration of Biogas Technology into Goat Farming to Achieve Zero Waste System: Effect of Substrate Composition and Concentration  
*K Cahyari* C-7

Single-Phase DC-AC Inverter with Low Power Dissipation with Transformer and Filter for Photovoltaic-Based Home-Scale Electric Power System  
*I Hidayat, F Samman and R Sadjad* C-11

The Influence of Water and Catalyst Leach Process toward Propane Oxidation on MoVTenb Catalyst  
*R K Widi* C-21

Gas Sensitive Properties Of ZnO Nanorods Formed on Silicon and Glass Substrates  
*V Petrov, A Starnikova, Y Varzarev, K Abdullin and D Makarenko* C-27

The Study of The Properties of Lead Zirconate-Titanate Films on Silicon Substrate After Halogen Lamps Rapid Thermal Annealing  
*V Petrov, A Kamentsev, V Polyakov and Y Varzarev* C-33

Temperature Dependence of Electrical Properties of ZnO Nanorods Array  
*V Petrov, Y Varzarev and K Abdullin* C-37

- Utilization of Rice Straw and Used Paper for the Recycle Papermaking  
*N Suseno, T Adiarto, M S P Tentoea and V E Sugihartono* C-41
- Mass Transfer Kinetic Model and Removal Capacity of Acid Blue 29 Adsorption onto Activated Carbon  
*P Setyoprato, H R Priyantini and R Agustriyanto* C-47
- Effects of Electroculture on Shoot Proliferation of Garlic (*Allium sativum* L.)  
*VL Manguiam, A M Margate, R D Hilahan, H G Lucin, K R Pamintuan, A Adornado* C-53
- The Use of Pyrolusite to Remove Pb and Cd in Aqueous Solutions : Isotherm and Thermodynamic  
*Y F Liem, M W B Kembie and N M Tanusaputra* C-57
- Current Perspectives and Mini Review on Zeolitic Imidazolate Framework-8 (ZIF-8) Membranes on Organic Substrates  
*P D Sutrisna, N F Himma, N Prasetya and I G Wenten* C-63
- Power generation in a Plant-Microbial Fuel Cell Assembly with Graphite and Stainless Steel Electrodes Growing *Vigna Radiata*  
*K R Pamintuan and K Sanchez* C-69
- Drying of Celery Leaves (*Apium graveolens* L.) using a PV/T Solar Dryer  
*L Sapei, E Tarigan, D N Sugiarto and D Gianluca* C-75
- Kinetics Oxidative Degradation of Chitosan in Formic Acid with The Presence of Hydrogen Peroxide  
*E Purwanto, J Connor and Y Ngothai* C-81
- The Role of IT in Innovation Enhancement**
- Smart urban farming using arduino in residential area  
*D A Prima, W D Savitri, V R Prasetyo, E Suryadjaja* D-1

Towards power supply efficiency in IoT for image-based transmission scheme <i>N Karna, M Safira</i>	D-7
E-commerce for Japanese pop-products in Indonesia: the sign of decline stage <i>Gunawan, Yu Noda</i>	D-14
Enhancement of weighted centroid algorithm for indoor mobile non-cooperative localization system <i>R D Ainul</i>	D-20
E-commerce development using object oriented analysis and design (OOAD), a case study in Marenggo Natural Dyes Batik SME in Indonesia <i>D P Sari, N U Handayani, Y Widharto, M F M Raharjo</i>	D-26
Anchored instruction ITS: a novel approach to make learning programming interesting and effective <i>B Hartanto, J Reye</i>	D-32
Requirements analysis for the disaster logistics inventory information system to improve the effectiveness and efficiency of handling emergency response periods <i>N U Handayani, D P Sari, Y Widharto, G Basyir</i>	D-39
Software verification and validation using statistical test: a systematic mapping study <i>S Arifiani<sup>1</sup>, F Handani, S Rochimah<sup>1</sup>, D Herumurti, I Kuswardatyan</i>	D-45
Usability of multimedia-based technology in situational judgment test: literature review and survey on millennial generation <i>F Handani, E Yuliandari, Elisabeth</i>	D-52
Employing game technology as positive influence on conveying positive message and train positive behavior: case study racism and tolerance issue <i>N M Angga, M F Suciadi, S Yuanita, M A Wiradarma</i>	D-59



FSM based virtual camera control for earthquake evacuation simulation <i>D A Prima</i>	D-64
Machine learning to predict rainfall at Deli Serdang Stasion in North Sumatra <i>I Fitriyaningsih, L R Bernando, S N Kwatri</i>	D-71
Rethinking third place in the digital era <i>R F P Hadi, E Ellisa</i>	D-78
Image based indonesian fruit recognition using MPEG-7 color structure descriptor and k-nearest neighbor <i>J Siswantoro, H Arwoko, M Wideasri</i>	D-84
The design of android-based application for museum guide information system using beacon technology <i>D Absari, D H Prasetyo, F Adinata</i>	D-90
Virtual reality app on Milky Way solar system, case study: Kebraon II Public Elementary School, Surabaya, East Java, Indonesia <i>M F Suciadi, Lisana, F Ramadhan</i>	D-96
Computer vision system in measurement of the volume and mass of egg using the disc method <i>M Wideasri, L P Santoso, J Siswantoro</i>	D-102
Fraud detection using process mining and analytical hierarchy process with verification rules on erp business process <i>M F Naufal</i>	D-108
Customer intention to use airbnb application: a case study <i>S Bellina, Laurence, N Hartono</i>	D-114

Evaluation of academic website using eye tracker and ueq: a case study in a website of xyz

*A H Kusumo, M Hartono*

D-119

A decision tree algorithm for predicting amount of batik tulis lasem production by decision support system to support financial feasibility

*T Khotimah, R Nindyasari, N Ermawati*

D-125

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

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**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

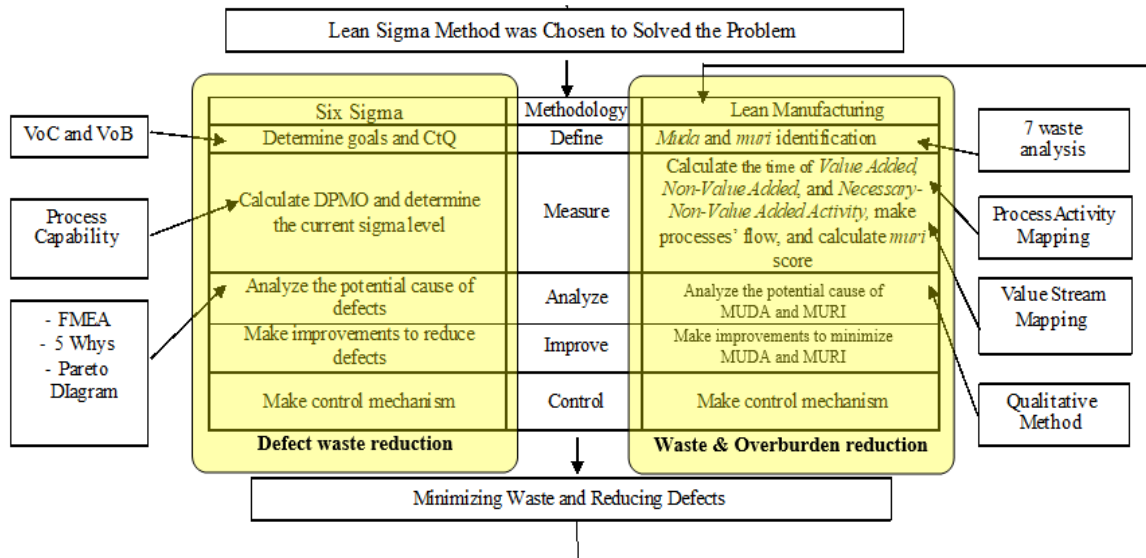
Data-driven life-cycle approach called as DMAIC methodology was used for problem exploration, data collection and analysis, problem solving and designing solutions. Lean activities are integrated into the steps of Six Sigma's DMAIC and the framework of DMAIC methodology (Figure 1) is briefly described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

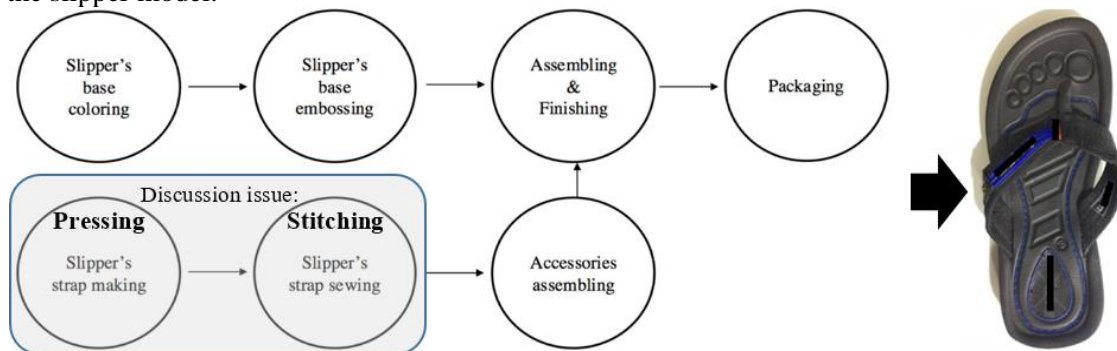


**Figure 1.** Framework of DMAIC Approach

### 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 ( $RPN = \text{Severity} \times \text{Occurrence} \times \text{Detection}$ ) 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
<b>Total</b>	<b>38183</b>	<b>160</b>	<b>385</b>	<b>321</b>
<b>Sigma Level</b>		<b>3.929</b>		

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
<b>Sigma Level</b>	<b>3.9</b>

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
<b>Total</b>			<b>129940.59</b>	<b>123600</b>	<b>6340.59</b>

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.

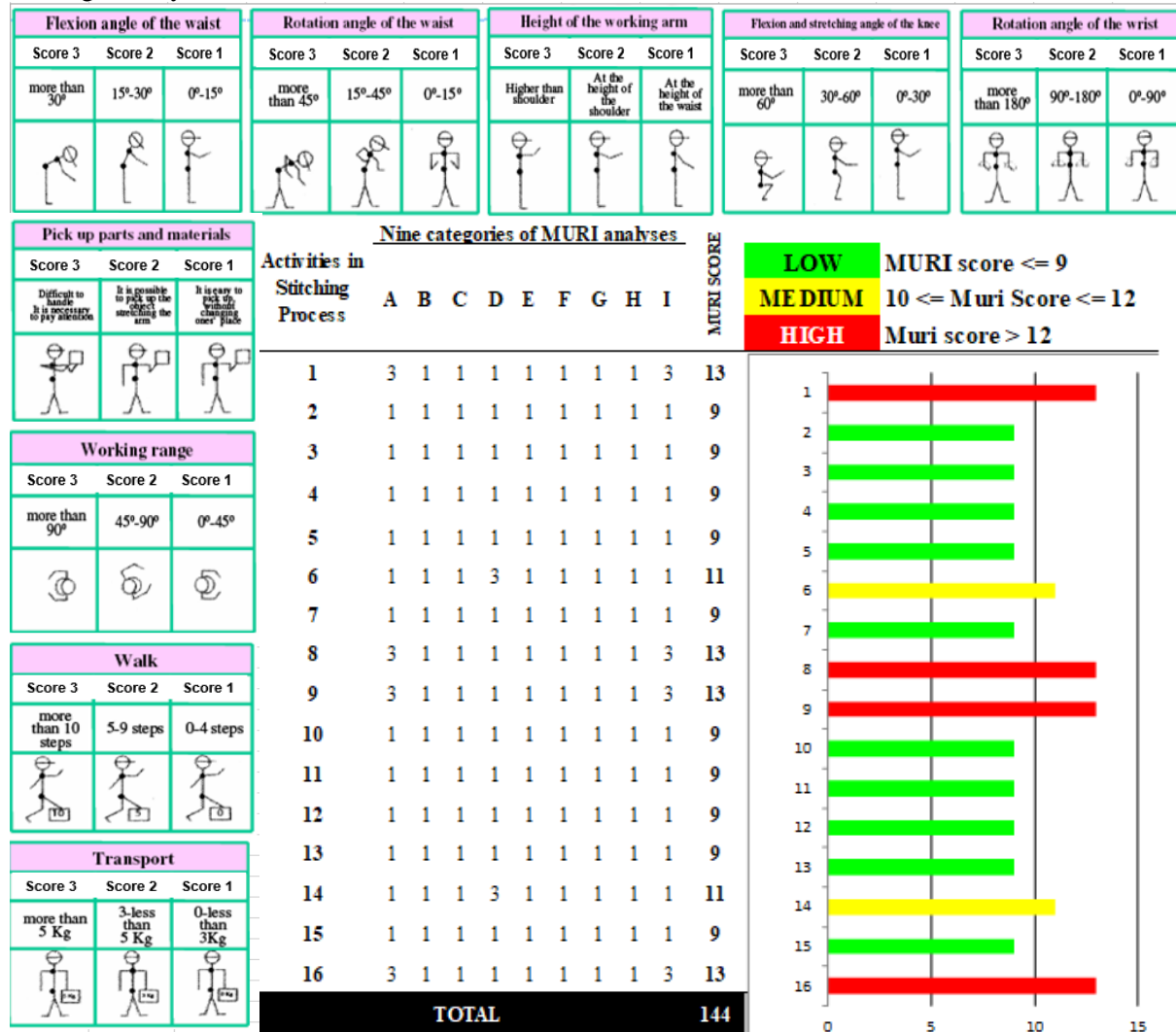


Figure 4. Muri analysis (for stitching process)

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