Research on Manufacturing with Consideration of Environment and Risk Management for Timor Leste

（東ティモールのための環境とリスクマネージメントを考慮したものづくりの研究）

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Abstract

The 20th century was the most decisive transformation time; it was time where world societies faced enormous challenges due to the advancement of technology innovations, was time where maintaining product superior quality, time saving, low-cost production, less energy consumption and green cooling system became central attention of manufacturers, technologists, industries and scholars. These factors are essential and need to be managed in such to in-line with the principle of ecological modernization development approach. This means human can continue to develop for serving their needs without affecting the nature. However, the effectiveness of managing the related risks is still in concern. The question is to what extent the manufacturing related environmental and risk management issues are effectively managed and how important it is for Timor Leste? This study was therefore carried out to analyse and explore some related manufacturing environment and risk management aspects as starting point for Timor Leste's future manufacturing risk management development needs. Although, currently manufacture activities are still insignificant in the country, it will be more useful sector in near future when the country has run out from oil and gas. Perhaps, it requires high quality that meets world standards. It is no doubt to state that the 18 years old country may find hard to compete globally in manufacturing sector, but concepts, theories and ideas are essential and as reference for its human capacity development needs. Therefore, the influence of environment and risk management theory as well as the technology development evaluation platform concepts are very much needed. The results of the work thus will be important for the country. This work looked at several related topics which include risk at ordinary time and risk at non-ordinary time in manufacture.

Firstly, the environmental thermal fluctuation influences on machine tool performances accuracy as one of the risks at ordinary time was analysed by assessing both manufacture temperature and heat transfer coefficient changes at Nagaoka

University of Technology (NUT) machining shop. It then analysed machine tool accuracy due to the aforementioned aspects. Both experimental and Finite Element Machine (FEM) simulations were performed for the study. It concluded that temperature, heat transfer coefficient and heat radiation influenced machine thermal deformation and its cutting accuracy. It was able to observe that colouring machine tool surface can reduce its thermal deformation by one. This study reflects Timor Leste's general machine shop, specifically the machining shop of Universidade Nacional Timor Lorosa'e (UNTL) in Hera. The machine shop has no air conditioning and with significant large windows and ventilation for air circulations. Therefore, this study approach is more appropriate for the country.

Secondly, Timor Leste's electricity sector challenges and appropriate green energy options for the future manufacture development needs were reviewed and analysed. The current electricity generating system has both financial and environmental challenges. The study therefore evaluated the current electricity development challenges and identified the best energy options through Analytical Hierarchy Process (AHP) approach. It was able to highlight that reforming the current electric power system and promoting renewable energy options such as Hydropower and Solar power will not only reduce the country's annual operation and maintenance costs but also contribute significantly to the environmental protection efforts.

Thirdly, the environmental impact of using Strong Alkaline Water (SAW) for cooling during machining was assessed by using simple Life Cycle Assessment (LCA) approach and focused on transportation and machining impacts. It then compared the emissions from energy, fuel and oil consumptions for both SAW and conventional cooling methods. SAW cooling method offers significant environmental advantages compare with conventional cooling method. It reduces annual Carbon Dioxide (CO_2) equivalent potential impact by 72.95 %. The assessment approach of this study will be useful for teaching references and the SAW cooling method will be valuable for the future manufacturing needs in Timor Leste. It is one of the green countermeasures which are needed by all countries for addressing global environmental issues.

The earthquake impact on machine tool performance accuracy study was then conducted. It developed three mathematical models including parallel, rotational and falling down motions for machine tool physical movement behavior analysis. Three different real Japan large earthquake acceleration data were used for the study. It used a mock-up structure to mimic earthquake motion during experimentation. The study concluded that the developed models were appropriate for analyzing machine tool motion behavior at earthquake as it was able to perform with calculation accuracy up-to 60 %. These models are created to contribute to the machine tool design needs. The analytical and experimental approach which looked at the relationship between manufacture and earthquake events is important reference for the short, medium and long-term manufacturing development necessities in Timor Leste.

Lastly, the study discussed a multi-parameter analysis of Double-Eco (DE) technology model for promoting risk management in manufacture. The term Double-Eco was used to reflect dual function of a developed roller technology for machine tool lubrication evaluation. This work integrates risk for safety parameter to the current parameters that discussed in our previous study. Based on the multi-parameter (environmental, mechanical performances, economy and risk for safety) analysis, it was able to generate area of roller technology for the DE-Index concept. Approaches such as simple LCA and Mahalanobis Taguchi System (MTS) were used for the study. It was able to conclude that there is a significant improvement in all parameters with 87.5 % DE-Index opposed to 3.25 % conventional evaluation approach. This risk management approach is valuable for Timor Leste's future technology development needs. This is because; the technology development evaluation approach is more coherent and easier to be implemented in both academic and manufacturing sector in near future in Timor Leste.

Acknowledgement

I was fortunate to have enjoyed the support of a tremendous number of people throughout the course and the accomplishment of this work – the academic supervisor, donators, friends and families without whom this dissertation would have been impossible. They are the giants whose shoulders have borne me.

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I should not forget to thank my family specially my beloved Sonya Flor, Amelia Flor da Silva, Sierra Martins da Silva, my niece Marquita Pascoal, my cousin Flamino Pinto, my Father Tomas da Silva, my sisters Isaura and Petrolina who were tirelessly motivating me during the difficult times. Last but not least, I dedicate this achievement to my super mother who disappeared during Indonesian occupation in 1992.

“Nho’ku wali ulu eita’e hira susara ana”

-Amelia da Silva Freitas (†)-

August, 2020

PAULO DA SILVA

Declaration of manuscript publications

The contents of chapter (2), (4) and (5) were published in the form of articles and oral presentations in international conferences. Therefore, major ideas, figures, tables and writing style duplications may occur in respective chapters' content of this manuscript. The content of chapter (2) and (4) was presented in XXVIII CIRP International Conference in Karpacs, Poland on 12th – 16th March 2017 and published in Journal of Machine Engineering, the paper of chapter (2) manuscript is with ISSN 1895-795 (Print)/2391-8071 (Online) and DOI:10.5604/01.3001.0012.0921, and the paper of chapter (4) manuscript with ISSN: 1895-7595 (Print), ISSN2391-8071 (Online) and DOI:10.5604/013001.0010.8821. Meanwhile the content and the study results of the chapter (5) were published in International Journal of Safety and Security Engineering by WIT Press with ISSN:241-904X (Online) and DOI:10.2495/SAFE-V9-N2-121-136. In addition, the WIT Transactions re-published a slight improvement of chapter (5) with DOI: 10.2495/SUSI180181. In chapter (6), it referenced the content of ecology, economy and mechanical performances from previous work that published in Journal of Machining Engineering with ISSN 1895-7595 (Print), ISSN2391-8071 (Online) and DOI:10.5604/01.3001.0010.8812. In this part, it considered the risk for safety aspect parameter for technology evaluation platform. The content of chapter (6) was presented in International Scientific Conference on Engineering and Applied Sciences (ISCEAS) in Hong Kong on 4-6 June 2019. Here it needs to be asserted that the materials (contents, figures and tables) presented in the appendices (I, II and III) are obtained from literatures that indicated in each appendix and no additional new findings, and original materials are entitled to the papers` authors right. The related information from summary are presented as evident that various issues regarding risk management aspects are currently available. It presents various factors related to vibrations, flood disaster and its countermeasures per literature.

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Abbreviation

GDP	: Gross Domestic Product
GHG	: Green House Gas
CO_2	: Carbon Dioxide
N_2O	: Nitrous Oxide
CH_4	: Methane
Gt-eq/yr	: Giga ton equivalent per year
FEM	: Finite Element Method
AHP	: Analytical Hierarchy Process
LCA	: Lifecycle Assessment
SAW	: Strong Alkaline Water
NUT	: Nagaoka University of Technology
UNTL	: Universidade Nacional Timor Lorosae (National University of Timor Lorosae)
Lorosae	: East (in Tetum Language)
Leste	: East (in Portuguese Language)
CNC	: Computer Numerical Control
NC	: Numerical Control
V	: Volt
W	: Watt
F, C, R	: Fine day, Cloudy day and Rainy day
kW	: Kilowatt
kg	: Kilogram
µm	: Micro miter
W/m^2K	: Watt per meter square Kelvin
EIA	: Equine Infectious Anaemia (Environmental Investigation Agency)
MW	: Megawatt
TLEI	: Timor Leste Electricity Industry
PLN	: Perusahaan Listrik Negara (Indonesia national electricity firm)

UNTAET : United Nations Transitional Administration in East Timor

UN : United Nations

kVA : Kilo Volt Ampere

MVA : Mega Volt Ampere

EDTL : Electricidade de Timor Leste

URA : Utility regulatory authority

MTCPW : Ministry of transport, communication and public work

kWh : Kilowatt hour

PV : Photovoltaic

HFO : Heavy Fuel Oil

GovTL : Government of Timor Leste

OECD : Organisation for Economic Cooperation and Development

PPP : Public Private Partnership

IRENA : International Renewable Energy Agency

GW : Giga Watt

λ : Lambda

w : Weight

CR : Consistency Ratio

CI : Consistency index

RCI : Random consistency index

n : Total number of observations

K_2CO_3 : Potassium carbonate

IPCC : Intergovernmental Panel on Climate Change

NO_x : Nitrogen oxide

PM : Particulate matter

NMVOC : Non-Methane Volatile Organic Compound

ECF : Energy conversion factor

ℓ : Litter

CAD : Computer Aided Design

CAE : Computer Aided Engineering

F : Force

M	: Mass
t	: Time
α	: Acceleration
G	: Centre of gravity
g	: Acceleration of gravity
μ	: Coefficient of friction
M_s	: Mass for support No. S
L_{as}	: Length between a to s
I_G	: Inertia moment for centre of gravity
I_a	: Inertia moment for point a
DE	: Double-Eco
BASF	: Badiche Anilin-und Soda-Fabrik is one of the largest chemicals company in the world, it is based in Germany
ISO	: International Standard Organization
MTS	: Mahalanobis Taguchi System
MD	: Mahalanobis distance
OA	: Orthogonal array
S-N	: Signal-to-noise ratio
WBCSD	: World Business Council for Sustainable Development
TRIZ	: Teorya Resheniya Izobreatatelzkikh Zadatch: Theory of inventive problem solving, Russian Theory of Inventive Problem Solving.
GHGP	: Greenhouse gas potential
GWP	: Global warming potential
VAM	: Vibration Assisted Machining
AFS	: A1 foam sandwiches
ACS	: A1 corrugated sandwiches
CFRP	: Composite material reinforced by carbon fibres
IoT	: Internet of things
CIM	: Computer integrated manufacturing
CPS	: Cyber physical system
BDA	: Big data analytics

ICT	: Information and communication technology
AMT	: Advanced manufacturing technologies
USB	: Universal Serial Bus
NCSC	: National computer security centre
PC	: Personal computer
THB	: Thai Baht (Thailand currency)
LSCS	: Labyrinth Sharp Crest Spillway
CIMA	: Chartered Institute of Management Accounts

Chapter (1)

Introduction

1.1 Background

The advancement of industry and technology has dramatically changed the world. Since the beginning of 20th century societies in both developed and developing countries began to experience the change. The industrialization of the world is not only pushing the economic growth but also demolishing the isolation of societies in many parts of the globe. Technology continues to evolve and available for serving human needs. As the continuous increase of the world population that has reached over 7.6 billion [1.1], the demand for technology will continue to increase. Thus, both political and economy circumstances will continue to push the massive invention and production of technologies around the world. Concerning this, the societies will not only benefit from the technology developments but it will also detrimental to the environment. Here, as shown in Fig.1.1, increasing greenhouse gas emissions (GHGs) have led to concerns regarding climate change and representing the bulk of these emissions, CO_2 emission has been under the spotlight of environmentalists [1.2]. This needs a global consensus and collective efforts for tackling global warming from all segments of the societies from both developed and developing countries. All governments, private sectors, researchers and most importantly industries and technologists have very important role in this issue. This is because the consequences of global warming will not only be faced by a specific group of a society but it will equally be shared throughout the globe regardless developed or developing countries, poor or rich, emitters or not. Currently, industries and manufacturers are contributing significantly to the production of gas pollutants through massive energy and oil consumptions as well as manufacturing residues and wastes from cooling.

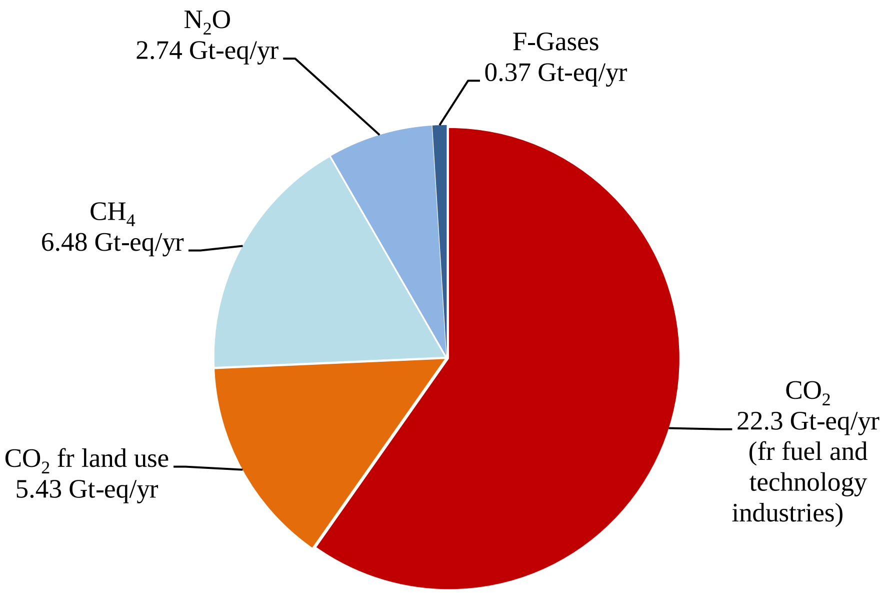

Fig.1.1 Average annual GHG emission by gases from 1970-2010 [1.2]

Thus, since the beginning of the 21st century, the importance of developing and managing technologies in an environmentally conscious way has become core discussion in the Paris Agreement and the agenda of the World Business Council for Sustainable Environment (WBCSE) for the next half-century. In this regard, technologists, entrepreneurs and manufacturers not only need to conserve and utilize energy in an efficient way but they also need to scrutinize to save resources and reduce emissions of environmentally harmful pollutants [1.3], [1.4].

Apart from the manufacturing emission risks, the thermal-induced error risk is another important aspect that often concerns manufacturers. It has been approached in various ways because of the influences that have over machine tools positional accuracy. Many studies are available and addressed wide aspect including thermo-mechanical analysis and error compensation [1.5]. It has been noticed that since 1960s, the thermal deformation issue has become one of the focus of scholars [1.6]; in fact, researcher [1.5] states that the thermal issue represents around 75 % of geometrical error during machining activities. As the industry evolves over the time the demand for superior quality products is high, therefore studies on designs as well as measures for reducing thermal error by considering temperature control system has become an essential focus of scholars [1.7] [1.8]. In addition, the advancement of current technologies has provided space for the development of thermal error behaviour predictions and analysis methods by using the finite element approach [1.9], [1.10] and neural networks [1.11]. This thermal error prediction analysis is also considering the transfer functions between temperatures surface that defined and a machining area relative displacement [1.12]. However, it is hard to put in action as many industries reluctant to conduct comprehensive machine tool testing. They instead shift testing responsibility to machine users to test and manage machine tool error performances through some procedures that force customers to consider such as warm-up times [1.5]. Although there are significant studies on environmental impacts on machine tool performances, the focus on detail analysis of heat transfer coefficient due to environmental thermal fluctuation as well as season and weather changes is minim. This aspect is very essential parameter that influences machine tool thermal deformation behaviour apart from temperature and heat radiation factors.

Another essential focus of current studies is the impact of natural disasters on industry and manufacture. Wide range of issues from common natural risk effects to set procedures and adaptations for minimizing consequences in industries are exist [1.13] [1.14]. In addition, manufacturers and industries shocked with large natural disasters and had huge destructions to both physical properties and industrial activities. For example, Japanese manufacturers were badly affected by several large earthquakes, including Hanshin & Awaji earthquake in 1995 [1.15], The Chuetsu earthquake in 2004 [1.16] and Higashi-Nippon earthquake in 2011 [1.17]. The study [24] reported that manufacturing production felt approximately 40 % as result of the Great East Japan Earthquake event. Manufactures and industries were struggling to recover after the seismic events. Also, significant small, medium and large manufacture firms in Thailand were affected by 2011 flood disaster [1.19] [1.20] [1.21]. The study reported that around 67 % of Thai manufacture sector was affected by the disaster and hardly to recover after the event [1.20]. Meanwhile, in Italy, the country faced serious hit by seismic in August 2017 [1.22], likewise in New Zealand, all sectors including manufacture and industries were heavily affected by February 2011 earthquake event. The country at least needs $30 to $40 billion to recover from the overall lost and re-stabilization of its economy [1.18].

As natural disasters often affect manufacture and industries, many scholars conduct various studies that cover a wide range of aspects for disaster adaptation and prevention. Here, it reviewed and highlighted several related works, and note some recommendations and measures that could be applicable for disaster prevention and adaptation especially in industry and manufacture environment. Advance disaster monitoring and forecasting systems [1.23] is viewed as an important aspect that needs to be highlighted, pre-disaster and post-disaster planning and actions [1.24] are an essential part of an overall disaster management issue. Meanwhile, in specific relation to the machining industries, the study [1.25] stated that anchoring design planning system for machine tools are very important for disaster prevention and vibration issues. Kono and other scholars [1.26] presented a method for stiffness tuning of machine tool supports by given significant consideration on contact stiffness. On the other hand, Möhring et al [1.27] looked at different characteristics and applications of different materials for machine tool structure from steel, cast iron to fibre reinforcement. Although significant researches on related natural disaster impacts, measures for seismic resistance are available, it was noted that specific study on machine tool motion behaviour for earthquake disaster adaptation design is minim.

The proper identification and management of mentioned risks will contribute to the achievement of manufacture`s overall objective. By identifying all potential risks and obtaining proper measures, will not only reduce energy consumption, costs and wastes minimizations but also help to maintain high-quality products and conserve the environment. However, the concern is to what extent and approach manufacture risk management and its related environmental impacts are addressed are left to question as most of the technologists, industries and entrepreneurs are profit-oriented and give less attention to the environmental issues. This study was therefore carried out to analyse and explore related manufacture environment and risk management issues as starting point for Timor Leste's future manufacturing development needs. Although, currently the manufacturing in Timor Leste is still not significant, it will be more useful sector in the near future when the country has run out from oil and gas. Perhaps, it requires high quality that meets world standards. This will make hard for the 18 years old country to compete globally in manufacturing sector but concepts, theories and standards are essential and as bases to build its own capacity that reflect the country's situation to move forward. Therefore, the influence of environment and risk management theory as well as the technology development evaluation platform concepts are very much needed. For this reason, the work was therefore carried out by studying the related manufacture environmental and risk management aspects.

The main coverage of this study includes; firstly, the environmental thermal fluctuation influence on machine tool performance accuracy as one of the risks at ordinary time was analysed by assessing both manufacture temperature and heat transfer coefficient changes at Nagaoka University of Technology (NUT) machining shop. It then analysed machine tool accuracy due to the aforementioned aspects. Both experimental and Finite Element Machine (FEM) simulations were performed for the study. It concluded that temperature, heat transfer coefficient and heat radiation influenced machine thermal deformation which ultimately affects machine tool performance accuracy. It was able to observe that colouring machine tool surface can reduce its thermal deformation by one. This work reflects Timor Leste's general machine shop, specifically the machining shop of Universidade Nacional Timor Lorosa'e (UNTL) in Hera. The machine shop has no air conditioning and with significant large windows and ventilation for air circulations. Therefore, this study approach is more appropriate and reflects the country's situation.

Secondly, Timor Leste's electricity sector challenges and appropriate green energy options for the future manufacture development needs were reviewed and analysed. The current electricity generating system is affecting both financial and environment. The study therefore evaluated the current electricity development challenges and identified the best energy options through Analytical Hierarchy Process

(AHP) approach. It was able to highlight that reforming the current electric power system and promoting renewable energy options such as Hydropower and Solar power will not only reduce the country's annual operation and maintenance costs but also contributing significantly to the environmental protection efforts.

Thirdly, the environmental impact of using Strong Alkaline Water (SAW) for cooling during machining was assessed by using simple Life Cycle Assessment (LCA) approach and focused on transportation and machining impacts. It then compared the emissions from energy, fuel and oil consumption for both SAW and conventional cooling methods. SAW cooling method offers significant environmental advantages compare with conventional cooling method. It reduces annual Carbon Dioxide (CO_2) equivalent potential impact by 72.95 %. The assessment approach will be useful for teaching references and the SAW cooling method will be valuable for the future manufacturing needs in Timor Leste. It is one of the environmental countermeasures for addressing the global environmental issue.

The earthquake impacts on machine tool performance accuracy study were then conducted. It developed three mathematical models including parallel, rotational and falling down motions for machine tool physical movement behavior analysis. Three different real Japan large earthquake acceleration data were used for the study. It used a mock-up structure to mimic earthquake motion during experimentation. The study concluded that the developed models were appropriate for analyzing machine tool motion behavior at earthquake as it was able to perform with calculation accuracy up-to 60 %. These models were created to contribute to machine tool designing purpose. The analytical and experimental approaches which looked at the relationship between manufacture and earthquake events are important reference point for the short, medium and long-term development needs in Timor Leste.

Lastly, the study discussed a multi-parameter analysis of Double-Eco technology model for promoting green management risk in manufacture. The term Double-Eco (DE) was used to reflect dual function of a developed roller technology for machine tool lubrication evaluation. This work integrates the risk for safety dimension into the other existing parameters that discussed in our previous study. Based on the multi-parameter (environmental, mechanical performances, economy and risk for safety) analysis, it was able to generate area of roller technology for the DE-Index concept. Approaches such as simple LCA and Mahalanobis Taguchi System (MTS) were used for the study. It was able to conclude that there is a significant improvement in all parameters with 87.5 % DE-Index as opposed to 3.25 % conventional evaluation approach. This risk management approach is valuable for Timor Leste's future technology development and manufacture risk management needs. This is because; the technology development evaluation approach is more coherent and easier to be implemented in both academic and manufacturing sector in near future.

Here, it needs to define some terminologies that used in some parts of the thesis. They are including; *Risk management*: this term reflects identifying, analysing and evaluating related manufacture issues that arise from both internal and external factors and presenting relevant countermeasures to obtain its overall performances. *Risk at ordinary time/non-ordinary time*: these means risks that arise in normal time and not normal time (due to man-made or natural disasters) in manufacture, *Double-Eco Technology* reflects a developed double roller lubricant technology for machine tool guide-way that perform dual function for collecting and adjusting grease thickness during a machine tool operation. *Double Eco (DE)-Index* is a dimensionless index from the comparison of a technology evaluation between the real and ideal implementation which is areas that generated through systematically defined ecology, performance, economy and risk for safety evaluation axes.

1.2 Objective of the research

The main objective of this research is to study some related manufacture environment and risk management issues in a comprehensive manner. These are associated with both risks at ordinary time and non-ordinary time in manufacture. One essential aim is reviewing the influence of weather and seasonal changes in manufacture that affects machining accuracy. Meanwhile, it discussed three specific objectives for both fabricated and natural disasters as part of the risk at the non-ordinary time. The first study related to man-made risk aims to research the current electricity industry impacts and analyse the green energy options for Timor Leste. The second is to study the impact of environmentally friendly cooling method in manufacture. On the other hand, the earthquake impact on machine tool motion behaviour study is part of risk due to natural disasters. From these manufacture risk explorations and identifications, a multi-dimensional consideration of Double-Eco technology model was analysed to reflect a Double-Roller lubricant technology for promoting risk management in manufacture.

The overall objective of this works is to obtain valuable concepts and references for Timor Leste's future development needs in manufacturing sector and also for teaching and learning references for schools and universities.

1.3 Scope and approaches of the study

The focus of this research is studying both manufacture related environment and risk management issues. Green energy, environmentally friendly cooling methods, and high precision finishing products are the main focus of the study. These related issues are often become challenges and need proper measures. Thus, this study discusses both aspects associated with risks that occur at the ordinary time and non-ordinary time that classified into two including fabricated risk and risk due to natural phenomenon. The study for risk at the ordinary time is chapter two which focuses on the influence of environmental thermal fluctuations on machining accuracy including room temperature change and change of heat transfer coefficient.

Both chapter three and chapter four focus on risk issues from man-made in manufacture, it looks at electrical energy impacts and challenges and explores green energy options for Timor Leste (chapter three) and the environmental impacts of using strong alkaline water for cooling during machining is discussed in chapter four.

Meanwhile, the chapter five researches the earthquake impact on machine tool structure motion behaviour as one of the risks associated with natural phenomena. It presented a multi-dimensional technology evaluation approach by proposing a Double-Eco Technology concept for green lubrication during machining as an effective consideration for an environmentally friendly technology development evaluation framework. This paper integrated previous studies and used its experimental results [1.5, 1.6, 1.7 and 1.8] for chapter 2, 4 and 6. The data of those experiments were for the discussions of the mentioned chapters.

The methods for this paper include both experiments and analytical approaches. In chapter two, it used machine tool experiments and Finite Element Machine (FEM). Historical data review, questionary, survey and Analytical Hierarchy Process (AHP) were used for reviewing and analysing the Timor Leste electricity industry topic (chapter three). Simple Life Cycle Assessment (LCA) was used for assessing the environmental impact of using Strong Alkaline Water (SAW) for cooling during machining (chapter four); experimental and analytical approaches were used for earthquake impacts on machine tool structure motion behaviour analysis (chapter five). Finally, in the chapter six, the study used simple LCA and Mahalanobis Taguchi System methods for evaluating multi-dimensional parameters of Double-Eco Technology for risk management promotion.

1.4 Composition of the paper

In this section, it presents the composition and outline of the paper. The Fig.1.2 shows the schematic view of the paper. The main coverage of the work including chapter one (1) is the introduction of the paper that presents the background, objective, methodology and significance of the research.

Chapter two (2), presents the surveyed temperature and heat transfer coefficient data of machining centre, experiments and FEM (Finite Element Machine) simulations results of machine tools, comparison of machining accuracy between Japan and World which represented by Morocco, it then provides the considerations.

In chapter three (3), it provides an overview of the current Timor Leste electricity industry development, its challenges and opportunities, the energy usage growth and demands, the green energy option considerations based on Analytical Hierarchy Process (AHP) analysis.

Meanwhile, in chapter four (4), it discusses the environmental impact of using Strong Alkaline Water (SAW) for cooling during machining from transportation, machining and oil disposal.

In chapter five (5), it discusses the historical Japan large earthquake acceleration data, highlights the developed models, and discusses the structural behaviour during experiments and calculations. It then presents the results of application of the developed models for real earthquake acceleration data.

In the chapter six (6) it presents a multi-parameter analysis of Double-Eco Roller Technology for green lubrication as an alternative for substituting the conventional technology. The multi-dimensional technology evaluation analyses including economy, ecology, mechanical performance and risk for safety aspects; it also presents the experimental results, which obtained from previous studies [1.5, 1.6, and 1.7]. It compares the efficiencies of the Double-Roller Technology lubrication model with the conventional model.

Finally, the last part of this paper is chapter seven (7), this chapter summarises all the results for each chapter as well as the important highlights and considerations for risk management promotion.

The specific coverage for all chapters of this paper follows:

Chapter (1), Introduction

- 1.1 Background
- 1.2 Objective of the research
- 1.3 Scope and approaches of studies
- 1.4 Composition of the paper

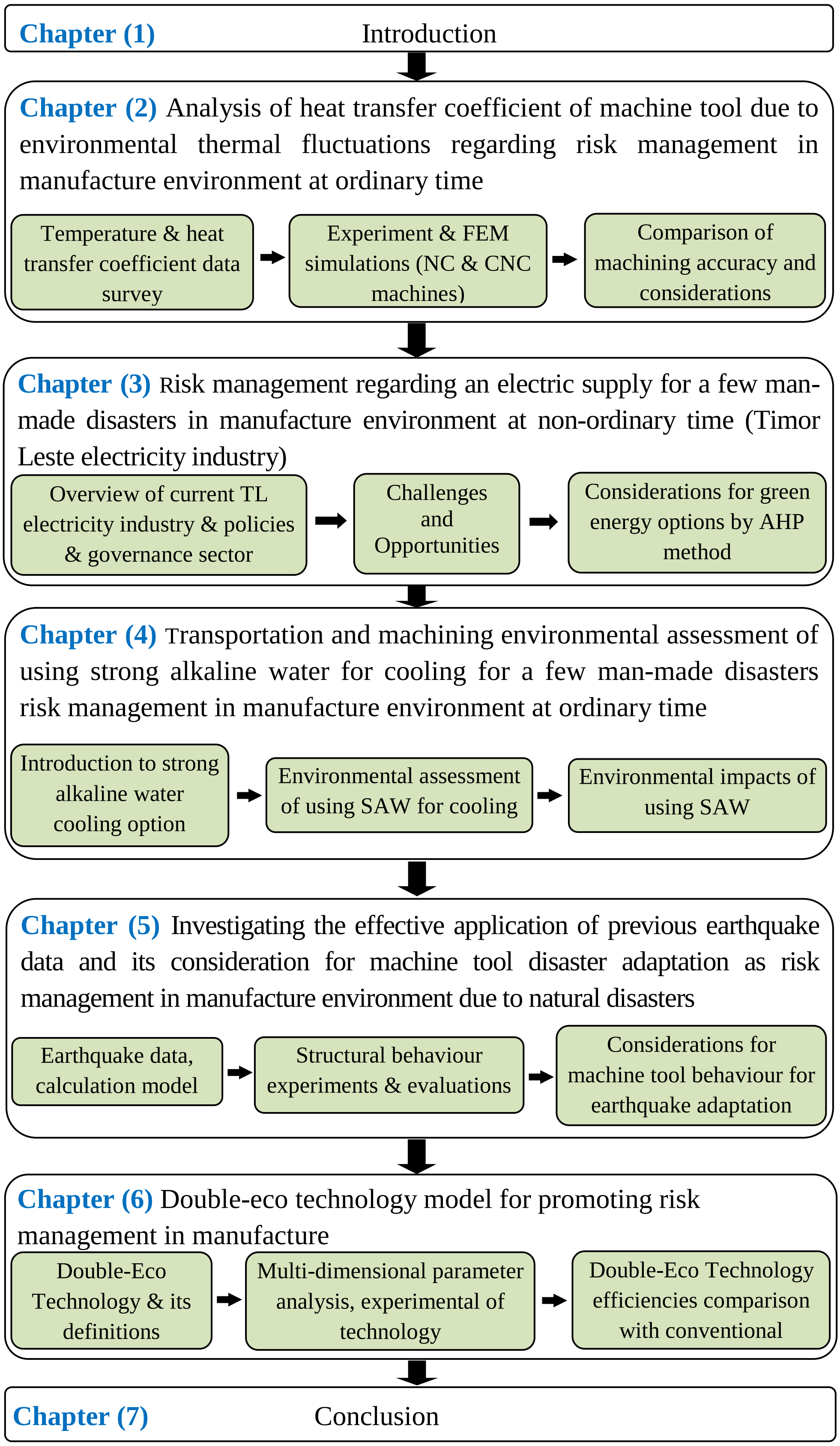

Fig.1.2 The schematic view of the research outline

5.7 Experimental of structure motion behaviour and its evaluation results

5.8 Application of developed models for real earthquake data

5.9 Summary

Chapter (6), Double-eco technology model for promoting risk management in manufacture

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6.2 Study objective and approaches

6.3 Double-eco discussions and eco-efficiency definition

6.3.1 Environmental conviviality dimension definition

6.3.2 Mechanical performance dimension definition

6.3.3 Economical dimension definition

6.3.4 Risk for safety dimension definition

6.4 Experimental of Double-roller technology

6.5 Multi-dimensional parameters evaluation of Double-roller technology

6.5.1 Environmental dimension evaluation

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6.5.3 Economical dimension evaluation

6.5.4 Risk for safety dimension evaluation

6.6 The Double-Eco Technology efficiency evaluation results

6.7 Summary

Chapter (7), Conclusion

This chapter presents the summary of the work.

Chapter (2)

Analysis of heat transfer coefficient of machine tool due to environmental thermal fluctuations for risk management in manufacture environment at ordinary time

2.1 Introduction

Nowadays, high-quality products of machining are significantly required. To obtain such products, industries and technologists are putting efforts to address related risks in the manufactures. One of the major concerns by industries is how to produce a product with very minim error. Various aspects cause errors of machine tools. One of the main causes is the thermal fluctuation of the manufacture environment. It has been addressed for some time and in multiple ways by industries and academics through various studies and findings. Mayr et.al (2012) analyzed the thermo-mechanical error and its compensations [2.1]. The thermal issues continue to be one of the major issues in machining field and it has been scholars focus since the 1960s, the researchers stated that around 75 % of overall machine tool geometric error is due to thermal issues [2.1] [2.2]. Researchers and scholars are not only focusing on designing but also give much attention on both durability and thermal stiffness factors [2.3]. Besides, the study done by Tanabe (1996) presents some alternative designs which given highlights and attention on temperature control mechanisms in manufacture [2.4]. Apart from these, the new technology concepts and development studies [2.5] [2.6] have looked at some thermal error behavior by using a computer program called finite element method (FEM) and neural networks [2.7]. Seto and other scholars (2014) present a thermal deformation prediction model for transfer functions between the surface temperatures that defined and the relative displacement of the area [2.8]. Meanwhile, the studies [2.5] and [2.9] highlighted that the finite element method is suitable for the thermal error prediction analysis and it consumes less time. The approaches regarding the manufacture environmental thermal changes and heat transfer coefficient influences are need to be considered. Neugebauer (2010) stated that it is hard to measure the heat transfer coefficient directly yet empirical methods are right way for the analyses [2.10]. In the mentioned study, it discussed the influential coefficient factors such as temperature on a structure, ambient temperature, and surface orientation about the heat transfer coefficient. Meanwhile, the thermal radiation of a machine shop walls and heat transfer coefficient [2.11], environmental perturbations concerning the seasonality and thermal changes are explored [2.12]. On the other hand, studies [2.5] [2.12] [2.111] pointed out that it is not a new issue for the thermal gradients in the shape of environmental temperature changes. However, they highlighted that the heat transfer coefficient in regard to the heat transfer coefficient of machine tools is considered as a constant thing and argue that it does not depend on the changes of seasons [2.5] [2.12]. It was noticed that the determination of thermally sensitive points of machine tools is important for future explorations specifically monitoring the machine tools' thermal changes [2.13].

This study presents an improved method for analyzing the variation of the heat transfer coefficient due to the machine tool environmental thermal fluctuations. It is thought that the environmental thermal variation could influence the machine tool thermal deformations. Therefore, the study explored and surveyed one-year data of machine shop temperature changes and its heat transfer coefficient in detail. The overall objective of this study was to understand the level of a machine tool error due to manufacture environment's thermal fluctuations. It was obtained by both experimental and FEM simulation analysis. The main coverage of this paper including, first, it discuses the surveyed machine shop temperature and heat transfer coefficient changes, second the experimental and simulations results, third it compares the machine tool calculation error results regarding Japan (Kumamoto) and Sahara Desert (Morocco) conditions. Then finally, it highlights consideration for minimizing machine tool thermal deformation. The full content of this work was published in the Journal of Machine Engineering in 2018 [2.24].

2.2 Objective of the study

The main objective of this study is to obtain an improved method that could be an alternative approach for reducing machine tool errors. This is to produce a high product quality. As it shows in the Fig.2.1, there are three specific aims of this study. It aims to understand the factory and its environmental relationship, analyze the thermal deformation of a machine tool due to weather and seasonal changes then investigate the room temperature change as well as the heat transfer coefficient.

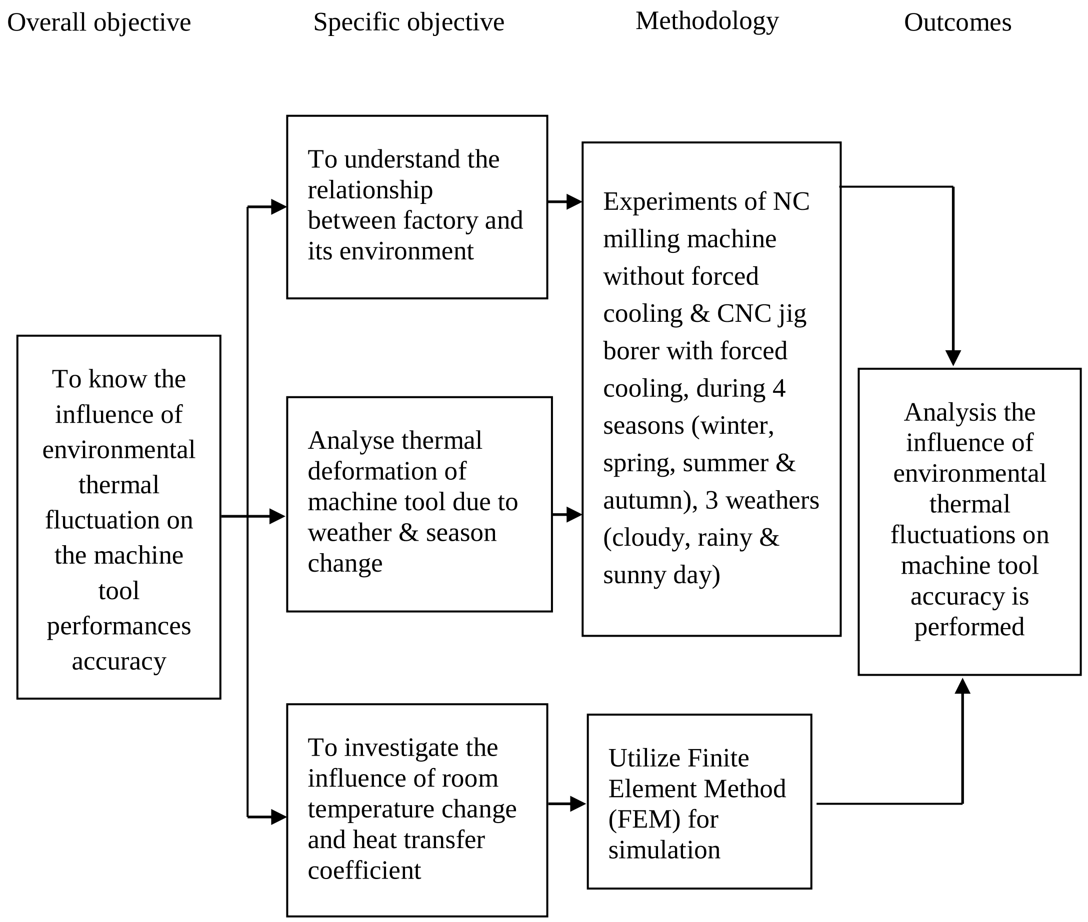


Fig.2.1 The schematic view of the study objective and its outcomes

Analysis the influence of environmental thermal fluctuation on machine tool performances accuracy due to the weather and seasonal changes, heat transfer coefficient fluctuations is the main outcome of this study.

2.3 The scope and method of study

There are several parts covered in this study; first, the study overviewed the machine shop conditions, measurement instruments and machine tool specifications that used for the experimental activities. It surveyed the room temperature and heat transfer coefficient of the machine shop for a yearlong. It then used the Finite Element Method (FEM) for the simulations by creating a model for both Numerical Control (NC) and Computer Numerical Control (CNC) jig borer machines. From this, it discusses the results of both experimental and FEM simulations obtained during the study. The machine tool comparison between Japan, in this case, represented by Kumamoto condition and the world represented by the Sahara Desert in Morocco conditions, is for validating the influence of the heat transfer coefficient on machine tool performances accuracy. Finally, the work also presented a consideration for addressing machine tool errors by looking at the relationship between thermal radiation and heat transfer coefficient for machine tool surface colors.

Fig.2.2 Photograph of NUT central machine shop [2.24]

These works are approximated through both experimental and simulation approaches. Two machine tools including NC milling machine and CNC jig borer machines in the Machine Shop of Nagaoka University of Technology (NUT), refer to Fig.2.2 were used for the experiments and FEM simulations. Models for both machines were created by using Solid-Work program for the simulations. It obtained the data (section 2.6) that surveyed during one year for whole seasons including spring, summer, autumn and winter, the weather conditions including fine, cloudy and rainy days. It used five fans and heaters during experiments in summer and winter respectively. Meanwhile, the study obtained the relationship and the comparison of room temperature and outside temperature for both Japan and the world represented, Morocco by using equation 2.1.

2.4 The experimental set-up and specifications

This section presents the visualization of the Nagaoka University of Technology (NUT) machine shop, equipment and the existing machine tools that used for the experiments, temperature and heat transfer coefficient measurements.

2.4.1 Machine shop condition

The Table 2.1 outlines the general condition and specifications of the central machine shop at Nagaoka University of Technology (NUT), and the Fig.2.2 in earlier section shows the actual condition of the machine shop. The machine shop is made from concrete walls with a surface area of length 26 m, width 14 m and the height of 7 m. The specific dimensions for walls in each direction are shown in Table 2.1. There are around 52 machine tools available and exist in the machine shop, and the average factory users are around 20 people per day. The conventional machine shop has completed with a central heater and several additional moveable heaters including few electrical fans.

Table 2.1 Specifications of the NUT central machine shop [2.24]

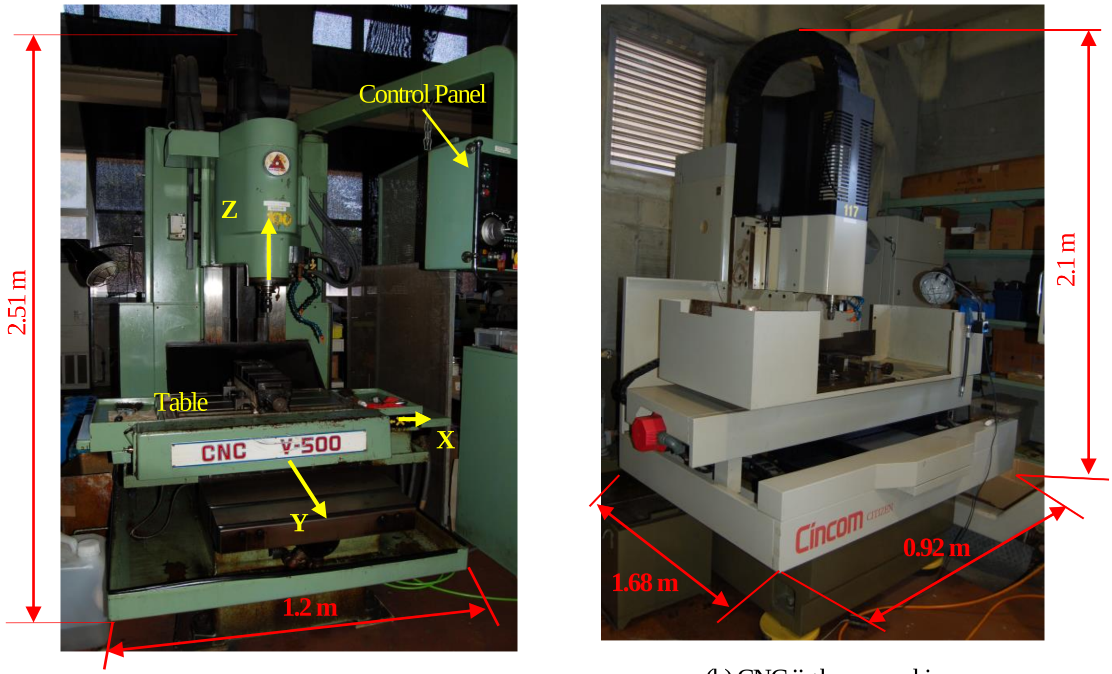
Dimensions	Surface area: 26m x 14 m Height: 7 m
Total machine tools (Machine tool occupied area rate)	52 (54 %)
Average factory users	20/day
East wall dimensions (Area occupied by windows)	28 m × 7 m (23 %)
South wall dimensions (Shutter dimensions)	14 m × 7 m (3.6 m × 3.6 m)
West wall dimensions (Entrance dimensions)	28 m × 7 m (2.4 m × 2.5 m)
North wall dimensions (Amount of ventilation units)	14 m × 7 m (2)

2.4.2 Machine tool specifications

This section presents the specification of machine tools which is used for the experiments and the FEM simulations during the study. The used machine tools for the experiments were one NC milling machine and one CNC jig borer machine. The Table 2.2 shows the details of the machine tools. Meanwhile, Fig.2.3a and Fig.2.3b present the actual photographs of both machine tools.

Table 2.2 Specifications of NC milling and CNC jig borer machines [2.24]

Parameters	Unit	NC milling machine	CNC jig borer
Table working surface	mm	610 × 381	620 × 320
Table loading weight	kg	250	150
Total table travel X-axis Y-axis Z-axis	mm	510 381 460	510 310 385
Distance from the table top face to the surface of the spindle nose	mm	100 – 560	110 – 495
Spindle speed	min^{-1}	180 – 7000	200 – 10000
Feed speed	mm/min	0 – 5000	1 – 3600
Motor output	kW	5	1.5
Machine weight	kg	2600	4500



(a) NC milling machine

(b) CNC jig borer machine

Fig.2.3 The photographs of NC milling and CNC jig borer machines

2.4.3 Measurement instruments

In the experiment, it used two instruments for the temperature of the central machine shop and heat transfer coefficient analysis measurements. It used a T-type thermocouple for the temperature fluctuation survey by connected to the temperature data recorder. Fig.2.4 shows the actual photograph of the temperature mobile recorder. Meanwhile, Fig.2.5 shows the developed T-type thermocouple.

Fig.2.4 Temperature data reader and recorder

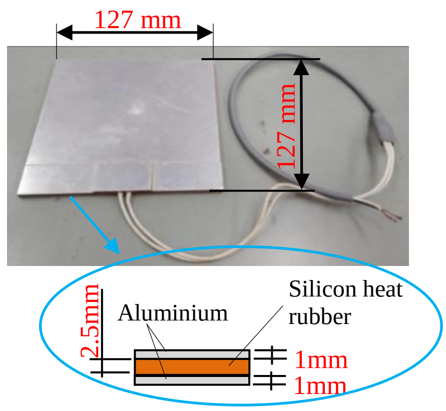


Fig.2.5 T-type developed thermocouple

The specifications of the developed device for measuring the heat transfer coefficient are following. It consists of a silicone rubber heater with a capacity of 120 Volts and 500 Watts with the physical dimensions of 127 mm × 127 mm × 1 mm. This silicon rubber is attached to two aluminum plates, the aluminum dimensions are 127 mm × 127 mm × 2.5 mm.

2.5 FEM simulations

Two machine tools were used for the simulation analysis. They are NC milling machine, and CNC jig borer machine. In simulation discussions, it covers FEM modeling, boundary conditions and meshing for the simulation analysis. Regarding this, the idealized models of both machine tools were created. As the literature [2.5], [2.12] explore the influence of manufacture environment temperature on relevant machine tool structure parts including rear and front bearings, carrier, table, spindle, and tool, were considered in the Solid-Works program analysis, the details of these aspects are explained in the following sections.

2.5.1 FEM Modeling of NC milling machine

The Fig.2.6 shows the photograph of the NC milling machine. Meanwhile, the Table 2.3 outlines its specifications. Based on the software default meshing techniques, it created the meshing model for the NC milling machine with around 2523 elements and 3121 nodes, it is shown in the Fig.2.7. The boundary condition for NC milling machine were two main heat sources, front bearing 28 W and rear bearing 14 W that obtained by inverse analysis based on the temperature representation. The measured environmental thermal fluctuations, temperature, and heat transfer coefficient applied to whole surface of the machine tool. For the FEM simulations, it is important to note here that the temperature variation measurement was considering the representation point that is located in the front of headstock of the machine; it shows in red color in

Fig.2.7. Meanwhile, it defined the relative displacement, the result of the thermal deformation between the spindle top surface and the table centre area as error of cut.

Table 2.3 The specification of NC milling machine [2.24]

Parameters	Units	Dimension
Table working surface	mm	610 ×381
Table loading weight	kg	250
Total table travel X-axis	mm	510
Y-axis		381
Distance from the table top face to the surface of the spindle nose	mm	100-560
Spindle speed	min^{-1}	180-7000
Feed speed	mm/min	0-5000
Motor output	kW	5
Machine weight	kg	2600

Fig.2.6 The used NC milling machine for FEM simulation

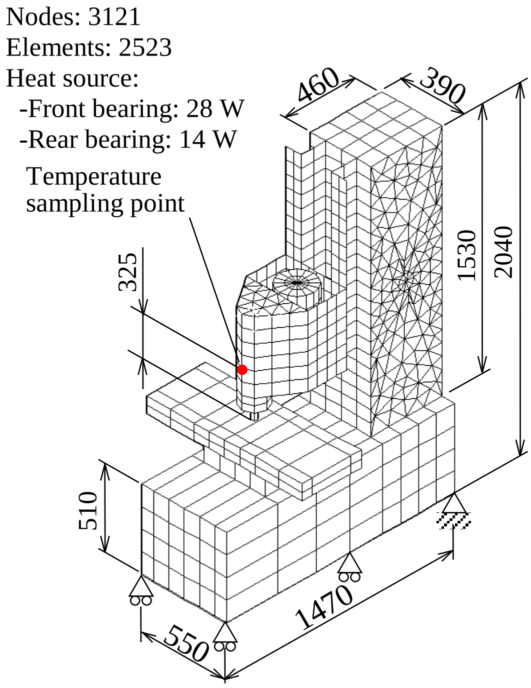


Fig.2.7 Meshed FEM model of NC milling machine [2.24]

2.5.2 FEM modeling of CNC jig borer machine

The Fig.2.8 shows the photograph of the CNC jig borer machine for the FEM simulations. The Table 2.4 outlines the specification of this machine. The Fig.2.9 depicts the meshing model of CNC jig borer machine. The meshing techniques were as same as the NC milling machine, it was based on software default meshing techniques and was able generated around 9990 nodes and 5827 elements for the model. There are two heat sources for the boundary condition analysis. These are front bearing with power of 25 W and rear bearing with power of 32 W. Similar to the NC milling machine, the measured environmental thermal fluctuations, temperature and heat transfer coefficient were applied to the machine tool surface. The temperature variation indicated in red point in Fig.2.9 was considered for the FEM simulation. The study used this temperature variation for machine error analysis. It defined the error of cut from the relative displacement of the machine tool between the table center and the spindle top surface. The CNC jig borer is with a compulsory cooling system, it utilized a ball screw with a room temperature of ±0°C and a grinding coolant for the spindle with a room temperature of -1°C that defined during the experimentation [2.24]. To approximate the grinding coolant thermal effects during the FEM simulations a specific representation area surrounding the table of CNC milling machine was defined to have a heat transfer coefficient of 500 W/m^2K [2.24].

Table 2.4 The specification of CNC milling machine [2.24]

Parameters	Units	Dimension
Table working surface	mm	620 ×320
Table loading weight	kg	150
Total table travel X-axis Y-axis Z-axis	mm	510 310 385
Distance from the table top face to the surface of the spindle nose	mm	110-495
Spindle speed	min^{-1}	200-10000
Feed speed	mm/min	1-3600
Motor output	kW	1.5
Machine weight	kg	4500

Fig.2.8 The used CNC jig borer machine for FEM simulation

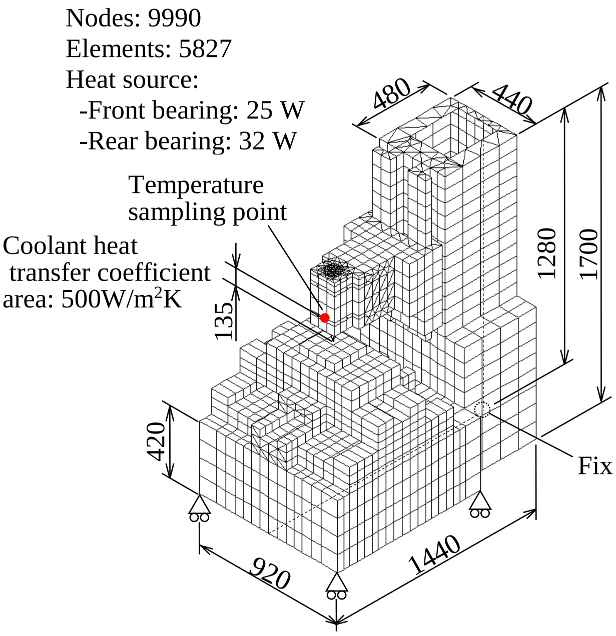
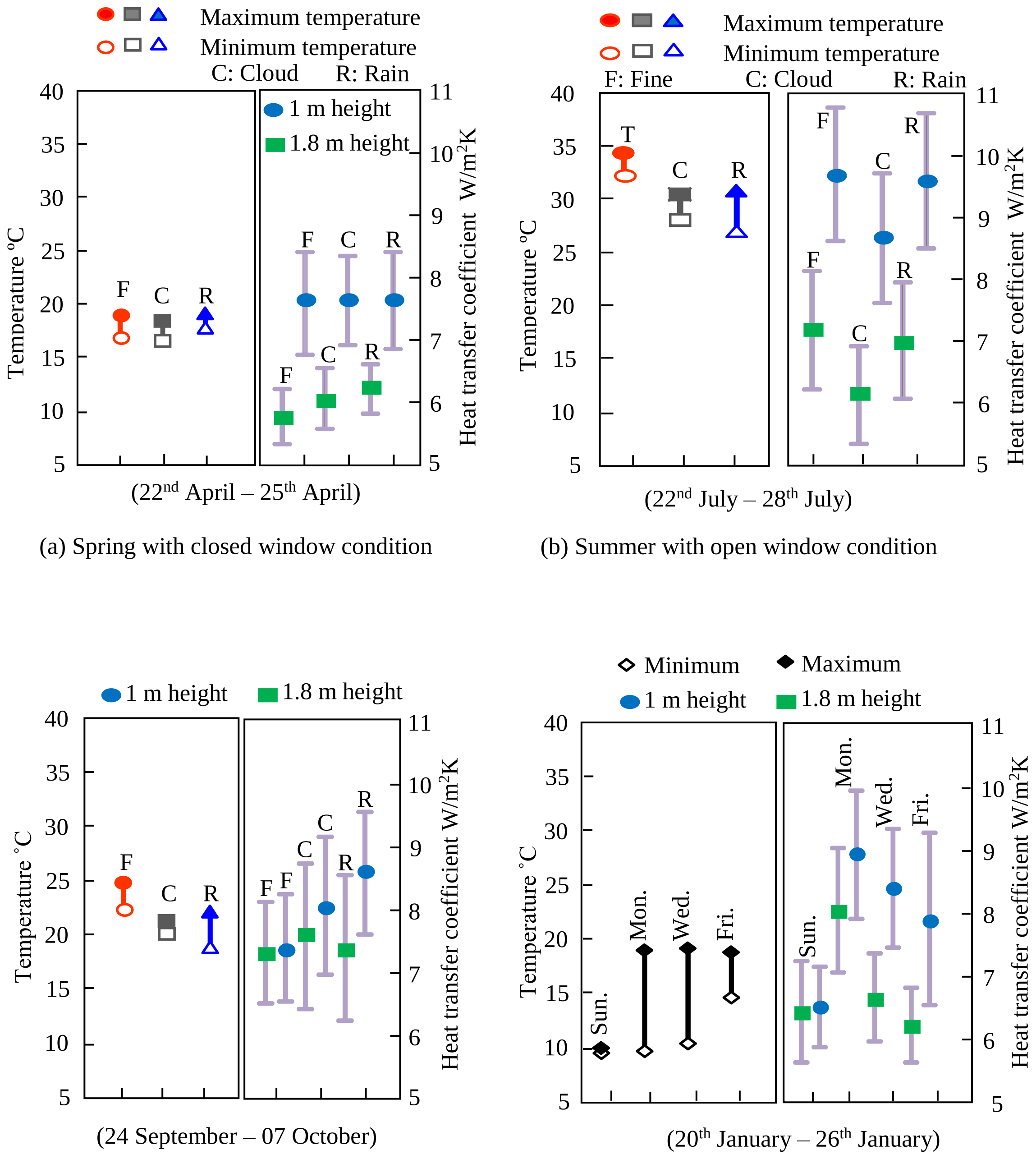


Fig.2.9 Meshed FEM model of CNC jig borer machine [2.24]

2.6 Temperature and heat transfer coefficient data recorded

In this section, it discusses the surveyed temperature and heat transfer coefficient results. It obtained the data at the conventional machining center at NUT during the one-year survey, started from spring 2014 to winter 2015 [2.24]. It is mentioned here that during the survey, windows were closed in spring, however, it was opened in autumn and summer, and 5 fans were used during the summer experiment and measurements. It is important to mention that it did not position the heaters and fans within a 5 m range of the machine tools. It positioned a T-Type thermocouple at the center of machine shop at two different heights 1 meter ● and 1.8 meter ■ for the temperature measurements. Meanwhile, the heat transfer coefficient data were measured by locating the developed measurement device vertically at two different heights as same as a thermocouple. As explained in the earlier section 2.3, the device of silicon rubber heater, T-Type thermocouple for measuring the temperatures of the plates were positioned at a 50 mm perpendicular distance from the center of the plates. The heat transfer coefficient of this device was considered as a device for the calculations. Meanwhile, the temperature differential and heat flux parameters are known [2.14], [2.15]. The Fig.2.10 shows the survey temperature result for the machining center. It reveals the heat transfer coefficient and temperature fluctuation for each season of the machine shop in a yearlong period.



(a) Spring with closed window condition

(b) Summer with open window condition

(c) Autumn with open window condition

(d) Winter with closed window condition

Fig.2.10 Temperature and heat transffer coefficient for 4 seasons

The temperature fluctuation and heat transfer coefficient for spring is shown in Fig.2.10a, summer in Fig.10.2b, autumn in Fig.2.10c and winter in Fig.2.10d. As depicted in the figures, the temperature for whole seasons and weather conditions such as fine (F), cloudy (C) and rainy (R) days are revealed. During the winter, the weather constraints made hard and gave un-satisfaction results; therefore, the measurements were set like days of the week. It conducted in four days, including Sunday, Monday, Wednesday and Friday as weather parameters. The experiment was only conducted in these four days during the winter season, as the influence of weather was not significant compared to the influence of the central heating and stoves' that very large on the environment of the machining center. The machine tools and workshop were not used on Saturday and Sunday, the room temperature on Monday morning was thus lower than on Friday.

The figure reveals the one-year survey results of the heat transfer coefficient of the central machine shop for whole seasons. It was observed that regimes with convection factors such as heating systems in winter and open windows in Summer, generated heat transfer coefficient values up to 3 $W/(m^2K)$, this is opposed to the spring season which generated the heat transfer coefficient of half or 1.5 $W/(m^2K)$. It was calculated by using the equation 2.1.

$$\alpha_e = \frac{Q}{A_s (T_s - T_\infty)} \quad (W/m^2.K) \tag{2.1}$$

Here, the α_e is the heat transfer coefficient, Q is the applied heat power, A_s is the surface area of T-type thermocouple, T_s is the surface temperature of thermocouple and T_∞ is the ambient temperature. The figure indicates that the experiment results for the heat transfer coefficient for both winter and summer season exhibit large values compare to the other two season's experiment results. This shows that the environmental (temperature and heat transfer coefficient) of machine shop indeed influence the thermal deformation of a machine tool, thus considering the manufacture environment influence on machining accuracy is essential for obtaining high superior product quality.

2.7 Validation of experimental and simulation results

To prove the accuracy, several experiments were considered for the validation of FEM simulation analysis. The Table 2.5 shows the cutting conditions for the experiments. It consisted of grooving machining of an S55C material.

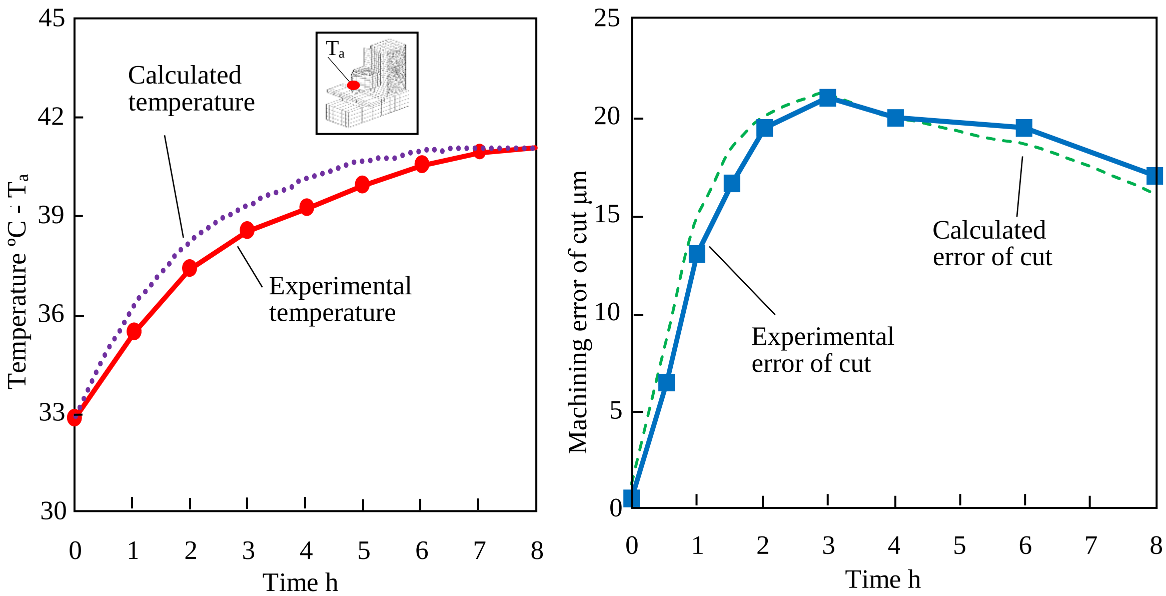
Table 2.5 The cutting conditions for the experiment [2.24]

Description	Unit	Dimensions
Material S55C (JIS) Width Length Thickness	mm	40 85 20
Tool used: End-mill	Ø	6
Defined time for the grooving	hours	0, 0.5, 1, 1.5, 2.0, 3.0, 4.0, 6.0, and 8.0
Spindle speed	min^{-1}	4700 (2000 min^{-1} for idle mode)
Cutting speed	m/min	89
Grooving conditions Depth Length Width	μm	40 40 6

The machining strategy consisted of cutting several grooves over the workpiece at different subsequent times to approximate thermal induced machining errors. In the experiment, it first machined the top surface of steel flat-wise on a test piece (Width 40 mm × Length 85 mm × Thickness 20 mm) by milling cutter of 6 mm diameter. It then machined 8 channels in which depth is 40 μm and width is 6 mm in every one hour. The time for the grooving was defined as shown in Table 2.5. The interval between the grooving times was considered as an idle time for the experiment. It kept the spindle of the machine in running with the speed of 2000 min^{-1}. This experiment was done during the environmental temperature and heat transfer coefficient survey of the general machine shop. After the machining performances, the workpiece was left in a controlled temperature room (air conditioning room) for 3 days. It then compared the measurements between each groove depth and the initial machined groove, the targeted value of the measurement was 40 μm. It measured 5 points on each cutted channel by using a digital micrometer. The average values were considered as the depth representation. The difference value was as the error of cut or machining tool precision value, for example, 10 μm, then the totsal depth of cut would be 50 μm.

2.7.1 NC milling machine simulation and experiment validations

For the observation of the relationship between machining time and the error of cut and temperature for both calculated and experimental is shown in the Fig.2.11, the example of surveyed data was randomly selected. It used the data from a fine day in the summer season for the 8 hours cycle. The Fig.2.12 shows the one-year experiment maximum error of cut values for the NC milling machine. It can note from the figure, the approximate results between experiment and FEM simulation values (calculated) are close. In the same way, the Fig.2.12 indicates that the onetime cycle, the FEM simulation values, and the experimental results are approximately close.



(a) Calculated and experimental temperature (b) Calculated and experimental error of cut

Fig.2.11 NC milling machine error of cut and temperature for a fine day in summer

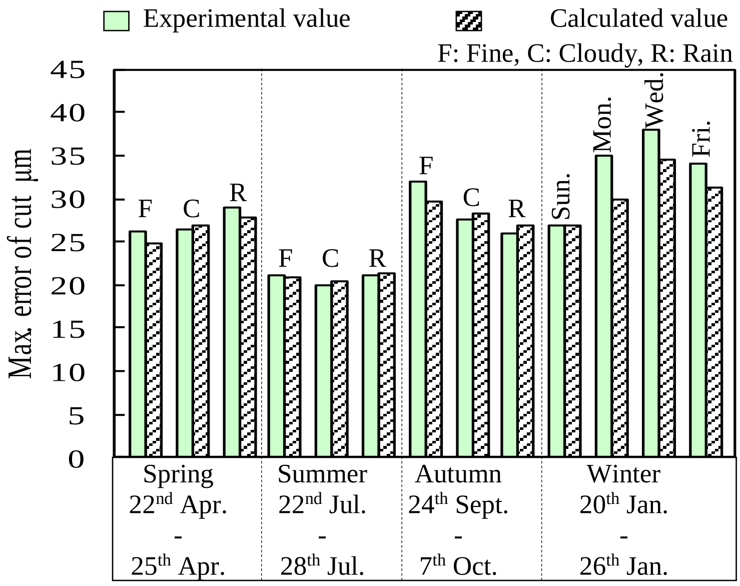


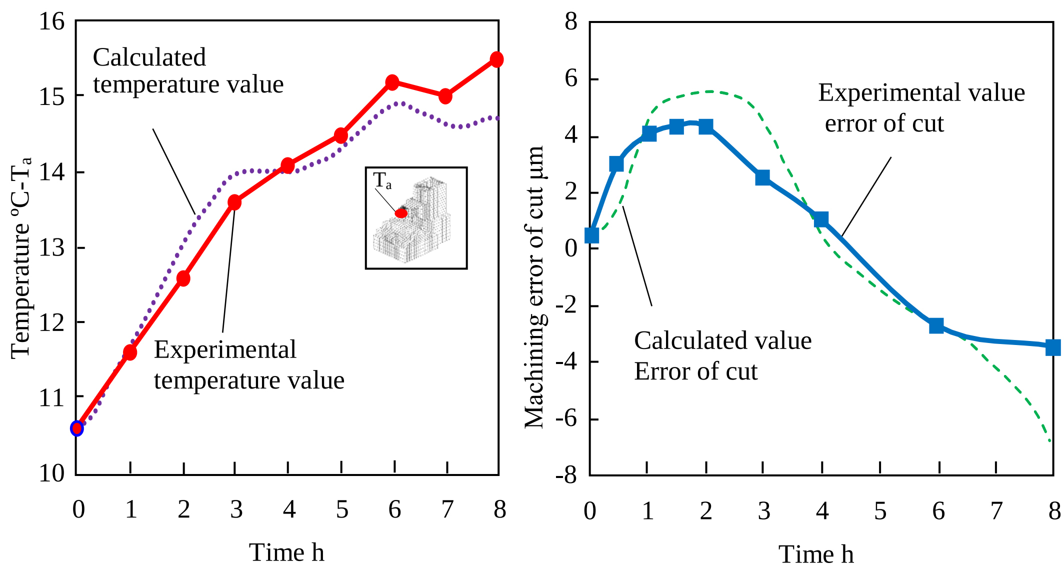
Fig.2.12 NC milling machine maximum error of cut values in a yearlong period [2.24]

This shows that the environmental thermal fluctuation, temperature changes, and heat transfer coefficient indeed influence machine tool thermal behavior. Therefore, it is worth to state that the FEM simulation model and the procedure are appropriate for the machine tool behavior prediction.

The Fig.2.12 shows that the error of cut in the summer season is smaller than other seasons. It is stated that the possible main reasons for this small value were the presence of large heat transfer coefficient, the machine tool headstock effective cooling because of the convection regimes; open window and it deployed five fans during the experiments. Contrarily, the error of cut for the winter season is significantly large due to their constraint regimes, windows were closed and an additional 4 heaters and the central heating at the machining centre were used. Therefore, as indicated in the figure, the difference maximum error of cut between the summer and winter seasons of 15 µm is due to the environmental thermal changes in the machining center. Regarding this, it must be highlighted that managing machining activities should pay attention specifically to seasons and weather situations. Here, as indicated in Fig.2.12, the heat transfer coefficient and temperature data used for the FEM analysis show that from spring to autumn the machine tool obtained higher precision or less error of cut compare to those in the winter season. This means the convection interactions; the heater system and closed windows regime that influenced the FEM simulation approximation affected the winter data. Therefore, the interactive procedures and monitoring the environmental thermal changes were important for the improvement of machine tool and machine center performances [12.15].

2.7.2 CNC jig borer machine simulation and experiment validations

The Fig.2.13 shows the compilation of CNC borer machine error of cut. It shows that the results of calculated and experimental are approximately close. Nevertheless, Fig.2.13 reveals the relationship between the error of cut and the working time. It depicts both calculated and simulation results of temperatures. In the study, it used a randomly selected Friday data of the winter season. Consequently, it was thought that the surveyed data of environmental thermal changes, heat transfer coefficient and temperature as well as the coolant thermal properties influenced significantly on the machine tool thermal behavior. Therefore, it is stated that the proposed method is appropriate for machine tool behavior prediction and analysis.



(a) Calculated and experimental temperature (b) Calculated and experimental error of cut

Fig.2.13 CNC jig borer error of cut and temperature for a winter Friday cycle

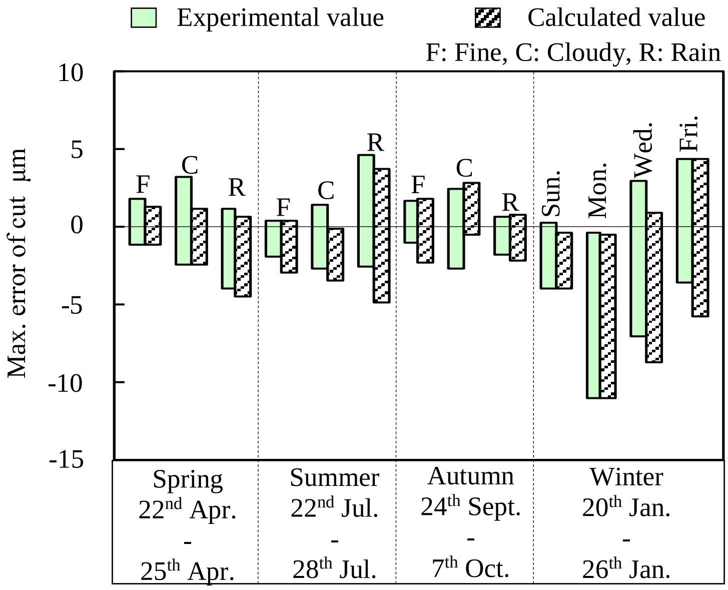


Fig.2.14 CNC jig borer maximum error of cut values in a yearlong period [2.24]

On the other hand, the Fig.2.14 presents the experimental and calculated FEM maximum error of cutting values of CNC jig borer machine for a yearlong period. The figure reveals that the experimental and simulation data analysis values are steady for all seasons from spring to autumn, however, it becomes significant large in the winter season. The error of cut in this has the same meaning in Fig.2.10. This section intends to discuss the difference between the NC milling machine that completely does not use cooling while the CNC jig borer with forced machining cooling, as the previous sections, already highlighted the change of convection regime for a yearlong period. The CNC jig borer is a high precision machine tool with a positioning accuracy of 0.1 μm. Although it is a high precision machine tool, the study result shows that the maximum error of cut of this machine at the conventional machine centre of NUT from spring, summer, and autumn ranged from 3.0 μm to 8.0 μm. Meanwhile, in the winter season, it is about 12 μm. It was noticed from the study that the error for the winter was due to the forced cooling during machining, room cooling temperature was around -1°C and the temperature of the ball screw, the room temperature was around ±0°C. In this way, the machine tool with the compulsory cooling system was having a large thermal deformation and less precision. However, if the synchronized control of the temperature on the machine structure for controlling the compulsory cooling system was applied then the error of cut would significantly be reduced. It is confirmed by the experimental results that the difference between the simulation and experimental of the cutting error ranged from 2.0 μm to 3.0 μm. In the FEM simulation, it did not consider the changes in room temperature and heat transfer coefficient for the machine centre environment and the thermal deformation of the spindle head as well as ball screw. However, due to the small differences, it uses FEM simulation for calculating the CNC jig borer machine accuracy. From the study, it was able to note that the changes in the room temperature and heat transfer coefficient was indeed influenced by seasons and weathers. The convection regimes and convection constraints such as open and shut windows and using fans and heaters were also influenced machining accuracy.

2.8 Consideration of the uncertainty of machining accuracy

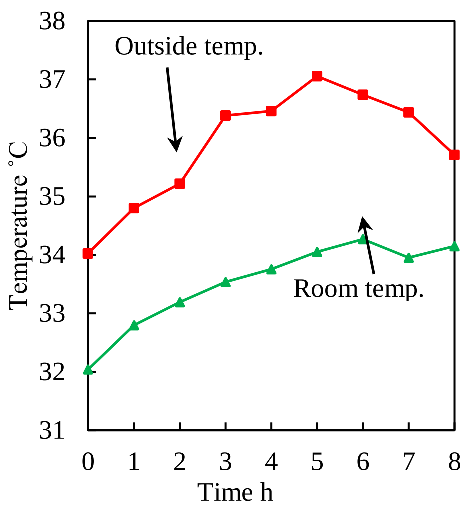
2.8.1 Room temperature calculation approach

Through the FEM simulation, an approximation of world machine shop environment influence on machine tool accuracy was able estimated regard the influence of heat transfer coefficient. Two machine tools at NUT were set and arranged for these experiments and calculations concerning manufacture risk handling. Equation (2.2) briefly depicts the relationship between room and the outside temperatures [2.16].

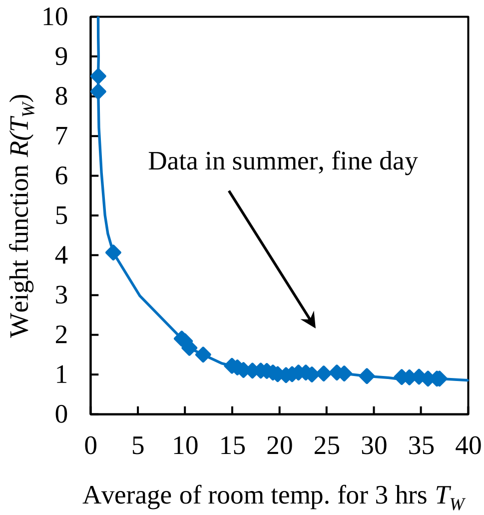
$$\int_{t_i}^{t_n} T_R(t)dt = R(T_W)\int_{t_i}^{t_n} T_A dt, \qquad T_W = \frac{\sum_{t_x=t_i}^{t_n} T_A(t_x)}{t_n - t_i} \tag{2.2}$$

Here: the t_i is the initial time, t_n is the passage time, $T_R(t)$ is the room temperature at the time t, $T_A(t)$ is the outside temperature at the time t and the $R(T_w)$ is the weight function [2.16]. Meanwhile, the T_w is the average of the outside temperature for the fixed time (=3 hours in this paper). This is civil engineering equation.

Meanwhile, the Fig.2.15a shows the outside and room temperature at a fine day in the summer season. By using the same equation, the weight function for the general machine shop was calculated. Weight function is the function of room temperature in relation to initial time and passes time during cutting period.



(a) Outside temperature and room temperature in Summer and fine day



(b) Weight functions

Fig.2.15 Weight function of general machine factory

On the other hand, the Fig.2.15b reveals the relationship between the weight function and average of the room temperature of 3 hours. The room temperature is set such that to reflect and represent several places in the world.

2.8.2 Machine tool accuracy comparisons

Table 2.6 shows the maximum change of room temperature in both Japan and the world, it was obtained from the internet [2.17]. Both Kumamoto and Sahara Desert data of maximum room temperature fluctuations were used for the calculation of both Japan and the world respectively. The maximum heat transfer coefficient which due to compulsory convection and the minimum heat transfer coefficient due to natural convection values are indicated in Table 2.6 [2.17] [2.18] [2.19] [2.20] [2.21] [2.22].

By using weight function, it calculated both room temperature change (NUT machine shop and the world) and the outside temperature (Table 2.6).

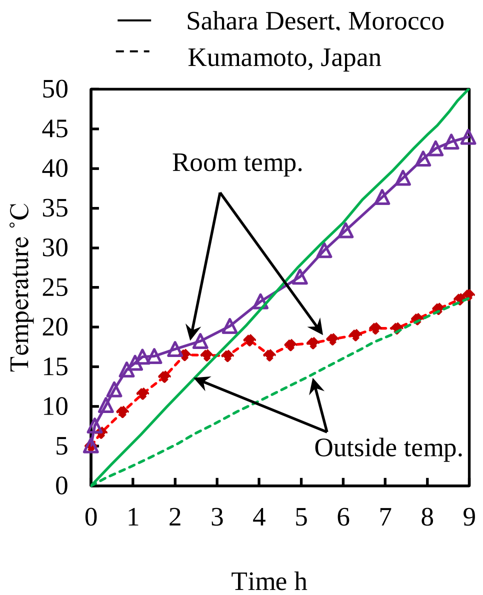


Fig.2.16 Temperature fluctuation of both outside and room temperature in general factory

Table 2.6 Boundary conditions for FEM thermalanalysis

Condition	Value
Maximum heat transfer coefficient (Forced convection)	48.8 W/m²K (Wind velocity:1.55/s) (Reference [2.17]-[2.22])
Minimum heat transfer coefficient (Natural convection)	7 W/m²K (Reference [2.17]-[2.22])
Maximum diurnal range of outside temperature (Morocco)	0 ⇒ 50˚C (Reference [2.17])
Maximum diurnal range of outside temperature (Japan)	0 ⇒ 24˚C (Reference [2.17])

Likewise, by using the heat transfer coefficient from Table 2.6, the error of cut for both machine tools were able calculated. The Fig.2.16 shows the calculation results of maximum room temperature change in the general machine shop for both Kumamoto and the Sahara Desert. From the figure, it indicates that the maximum room temperature changes for both the general machine shop of the Nagaoka University of Technology and the Sahara Desert are 20 ˚C and 40 ˚C respectively. It is important to highlight that the temperature changes are very essential to be considered as it has a significant influence on machine tool accuracies. The Fig.2.17 shows the errors of cut for the NC milling machine (no compulsory cooling). Regarding this, it was found that an approximation error of cut for the Sahara Desert from the grooving is 90 µm, from the target of 40 µm. Therefore, the total machining depths of cut values became 130 µm (= 40 µm＋90 µm). Likewise, the approximation error of cut from the grooving for the Kumamoto is 35 µm, and the target value is 40 µm. The machining depth values thus became 75 μm (= 40 μm + 35 μm). It was noticed from the study that if the room temperature change becomes large and the heat transfer coefficient becomes small.

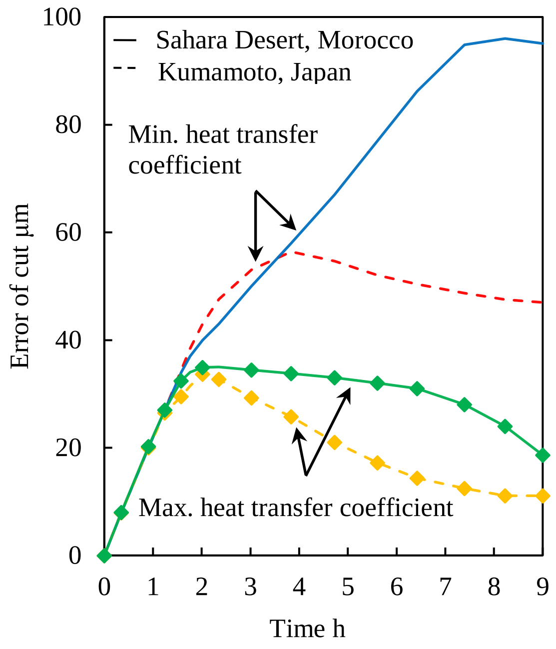


Fig.2.17 Machining accuracy using NC milling machine in general factory

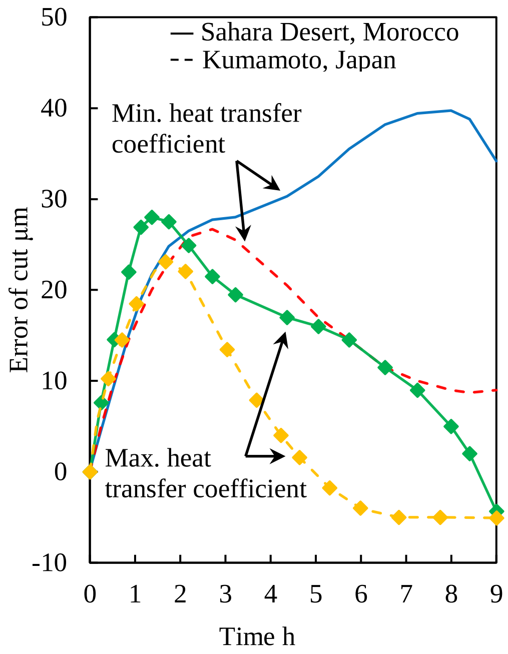


Fig.2.18 Machining accuracy using CNC jig borer machine in general factory

Thermal deformation for the outside heat generation becomes large and the cooling phenomenon for inside heat generation becomes small; this was due to the low heat transfer coefficient.

The Fig.2.18 shows the CNC jig borer compulsory cooling error of cut. Although it has a compulsory cooling system, the machine tool still generates maximum errors of cut from grooving for both Sahara Desert and Kumamoto were 40 μm and 25 μm respectively. From the results, it can be stated that if a general machine shop build in the Sahara Desert and deploying a compulsory cooling system machine for cutting then the machining accuracy would be inferior. Therefore, controlling room temperature and heat transfer coefficient are very important for machining to obtain superior product quality. It is noticed that the FEM simulation was very effective for machining accuracy risk management.

2.9 Coloring machine tool surfaces for reducing thermal deformation

In this last part of the work, the essence of the heat transfer coefficient that discussed in the section 2.6 and 2.7, and the significant error of cut differences are presented. It is asserted that the temperature material-dependent properties influence the heat transfer coefficient [2.10], painting the surface area of machine tool due to the thermal radiation influence is necessary. Therefore, by using the previous research data of machine tool builders, the study conducted the experiments for measuring the heat transfer coefficient of machine tool surface color.

It considered the relationship between apparent heat transfer coefficient, thermal radiation, and machine tool surface color. In this experiment, the surfaces of a previously developed device which discussed in the section 2.4.3 were painted with chosen available 8 Japanese company paint colors together with black and aluminum which presented in Table 2.7. The device was placed inside a 1,000 mm^3 container. The room temperature in which the container held was around 20 ˚C ± 1 ˚C. Meanwhile, the geometric factor and absorption coefficient set to 1.0 by painting the container walls with black oxide.

On the other hand, the air flux adjusted to 10 mm ventilation open. The experiment results show that coloring machine tool surface has great thermal behavior influence than painting the machine shop walls [2.23]. The Fig.2.19 and Fig.2.20 illustrate the mentioned results. The Fig.2.19 shows the apparent heat transfer coefficient and heat flux. On the other hand, the Fig.2.20 reveals the emissivity for 8 different colors which obtained from 6 different Japanese Companies and black and aluminum. It was observed that the emissivity for the black oxide device was 1 and for aluminum was 0.06. Meanwhile, the calculated distribution of emissivity for each company colors ranges from 0.68 to 0.93. The details of eight-machine tool maker company color emissivity are YA: Yasuda (Dar-gray) 0.93 with standard deviation 0.005. Oe: Okamura (Light-gray) 0.78 with standard deviation 0.02, Ou (Light-gray) 0.76 with standard deviation 0.09, YMb: Yamadaki Madaku (Blue) 0.71 with standard deviation 0.09, YMg (Green) 0.80 with standard deviation 0.05, T: Takamatsu (Orange) 0.78 with standard deviation of 0.005, U: Urawa (Ivory) 0.68 with standard deviation 0.06 and K: Kuraki (Light-green) 0.76 with standard deviation 0.04 [2.23]. It used equation 2.3 for the emissivity calculation.

Table 2.7 Machine tool surface color survey used for experimentation [2.23]

Company (Color)	Munsell number	Paint material	Foundation
YA (Dark-gray)	7.5BG 4/1.5	Urea formaldehyde	Urea formaldehyde
Oe (Light-gray)	5Y 6/1	Epoxy	Primer
Ou (Light-gray)	5Y 6/1	Urea formaldehyde	Primer
YMb (Blue)	4PB 4/10	Epoxy	Primer
YMg (Green)	8.5GY 3.7/6.3	Epoxy	Primer
T (Orange)	1.5YR 6/12	Urea formaldehyde	Primer
U (Ivory)	10YR 8/3	Urea formaldehyde	Primer
K (Light-green)	2.8GY 6.5/2.8	Epoxy	Primer
(Metallic)	-	Aluminum	-
(Black)	-	Black oxide	-

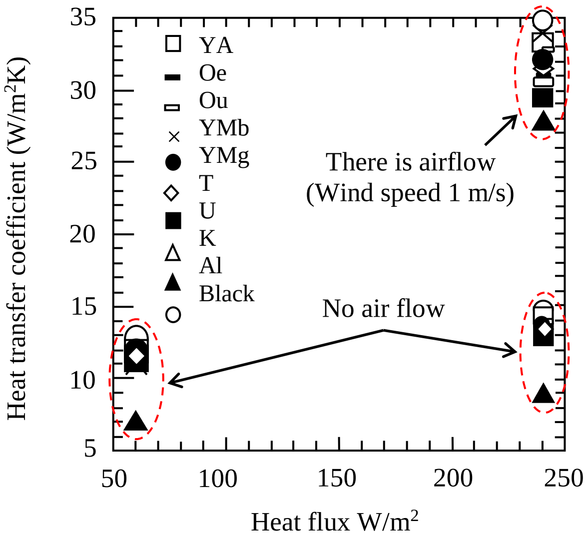


Fig.2.19 Thermal radiation and heat transfer coefficient relationship for multiple machine toolsurface colors [2.23]

$$\alpha_e A_s (T_s - T_\infty) = \alpha_R A_s (T_s - T_\infty) + 5.67\times10^{-8} A_s F_{ws}\boldsymbol{\varepsilon}_s X_w (T_s^4 - T_w^4) \qquad (2.3)$$

Here, the α_e is the apparent heat transfer coefficient due to colour painting, A_s is the surface area. T_s is surface temperature, T_∞ is the ambient temperature, α_R is the true heat transfer coefficient, F_{ws} is form factor (coefficient of relationship of heat source surface and wall) which was considered as 1, ε_s is the emissivity, X_w is number of the component or shapes of heat absorption, in this case, is 1, T_w is the wall temperature. Meanwhile, the 5.67×10^{-8} is the Stefan Constant.

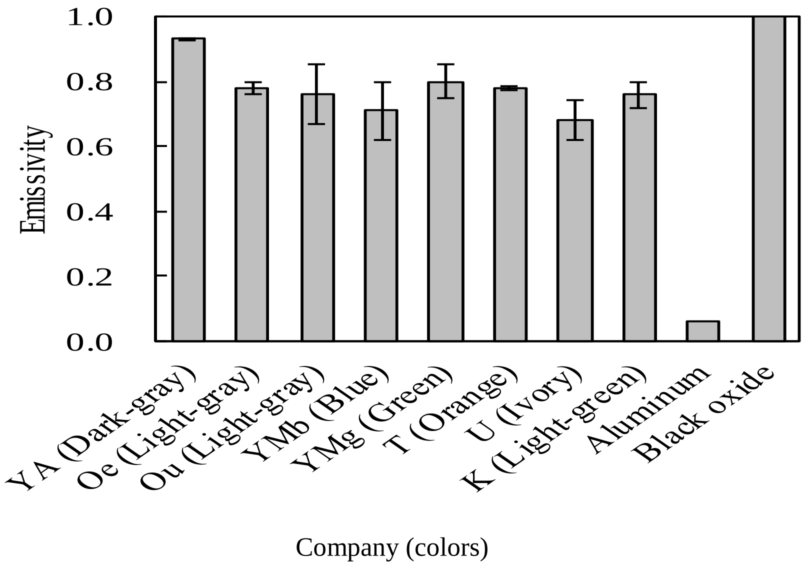


Fig.2.20 Emissivity of the selected machine tool surface colors [2.24]

The measured minimum and maximum heat transfer coefficients were black oxides and aluminum paints. The condition is that the aluminum measurement has only the heat transfer coefficient and no radiation produced. On the other hand, the blackbody measurement condition has both radiation and as well as the heat transfer coefficient. From the experiment, it was noted that convection occurred between the observed both blackening and aluminum color surfaces. From the Fig.2.19, for example, the observed heat transfer coefficient for a condition at which heat flux 60 W/m^2, is around 13 $W/m^2.K$ and the real heat transfer coefficient is 7 $W/m^2.K$. Here, it can be assured that there is an influence of thermal radiation of 6 $W/m^2.K$ or about 46 % influence. The result shows that thermal radiation was influenced about 20 % for one's color and the measurement accuracy was 10 % to 15 % due to 20 % changes of heat transfer coefficient [2.23]. Thus, the emissivity changes of 20 % will make around 9.2 % (20 % × 46 %) change in observed heat transfer coefficient, and the measurement accuracy change of 4.5 % - 7 % [2.23]. It was noticed from the experiment that the machine tool surface that painted with colors has a significant influence on the heat transfer coefficient compared with convection regimes. Thus, it is asserted that when considering the machine shop's environmental thermal factors, the material properties play an essential role in analyzing the thermal radiations, and when coloring an instrument will influence thermal deformation by one.

2.10 Summary

There are various approaches concerning thermally induced errors due to the influence that has over the positional accuracy of a machine tool. Therefore, the study explored the environmental thermal fluctuation influences on machine tool performance accuracy. It focuses on temperature, heat transfer coefficient and thermal radiation of the machine shop walls, as well as in terms of seasonality and varying thermal gradients.

Models for both NC and CNC FEM machine tools were created for FEM simulation needs. It then compared the simulation results with the experimental values. For the NC milling machine simulation results: in the summer the maximum error of cut was small due to large heat transfer coefficient at headstock cooling and convention regime such open window and running fans. In the winter the maximum error of cut was large due to constrained regime (windows were closed; central heating and other heaters were used). The maximum error of cut was around 15 μm difference between winter and summer due to environmental thermal fluctuations. The CNC jig borer machine has precision accuracy of 0.1 μm; however, it still generates the average maximum error of cut for spring, summer and autumn from 3 μm to 8 μm and 12 μm for winter. In winter, the error of cut was large due to forced cooling and temperature of headstock and ball screw. The results show that both experimental and simulation results of the CNC jig borer machine were significantly approximate. So, it is asserted that environmental thermal fluctuation, temperature, heat transfer coefficient, and coolant thermal properties influenced machine tool thermal behaviour. Regarding this, with the same experimental principle, an experiment device was painted with 8 different Japanese machine tool maker company colours together with black and aluminium. It then measured the heat transfer coefficient which was used to calculate the thermal radiation. It was noted that the convection between two heat transfer coefficients, blackening and aluminium was the influence of the thermal radiation. The overall summary of this study follows:

(1) Errors of cut for both NC and CNC jig borer machines were influenced by the different seasons and weathers, room temperature and heat transfer coefficient in the machining center.

(2) Through the FEM simulation approach, the uncertainty of machining accuracy for the environment representations of world machine shops was able highlighted and compared. It is very effective for machine tool thermal deformation analysis.

(3) It was noted that coloring the surface of a machine can reduce its thermal deformation by one.

(4) The study approach of FEM simulation and experiments for analyzing environmental thermal fluctuation influences on machine tool accuracy will be applicable for Timor Leste's general machine shop, specifically the machining shop of Universidade Nacional Timor Lorosa'e (UNTL), Mechanical Department in Hera. The machine shop has no Air Conditioning and with significant large windows and ventilation. Therefore, the approaches of this study will be applicable for Timor Leste situation.

Chapter (3)

Risk management of man-made disasters regard electrical supply in manufacture environment at non-ordinary time: Timor Leste electricity sector

3.1 Background

Electrical energy plays a very important role in today's lives. It is a main driving force for various sectors from economic, social to industry and manufacture. The industrial activities are including electrical and electronics, furniture, steel, and car manufacturing. Meanwhile, in the residential level, people use electricity for various needs including cooking, heating and lighting. Almost all activities including services are using electricity. The industrial and manufacturing sectors dominate electricity energy consumption in many parts of the world both developed and developing countries. For example, in the United States, the Environmental Investigtion Agency (EIA) data of 2011 [3.1] shows the industrial sector used 31 %, transport 28 %, residential 22 % and commercial 19 %. Meanwhile, in Australia, the electricity is used for the industrial sector is 38 % [3.2] in 2012. This usage of electrical energy is almost applicable to all countries both developed and developing. However, many countries are using non-renewable energy sources such as coal and natural gases for their electrical energy production. For example, in China, around 66 % [3.3] of energy is from coal. It is no doubt to state that using such sources of energy has a huge adverse impact on the environment as it produces high carbon emission. The [3.4] stated around 40 % of CO_2 emission that pumped to the atmosphere is from electricity usage. This is one of the current challenges, how to use electricity for economic growth but at the same time protecting the earth. This has been a serious concern for many countries in both industrialized and non-industrialized countries in the world.

Timor Leste as a poor and small state needs electricity for its economic growth and social developments. Although there is no large industry presence in the country, it needs energy for small and medium industrial activities. In household level, locals are using electrical energy for handicraft and coffee production activities besides kids use lights for study at night. Various local industrial activities such as concrete, food industry especially the coffee industry is running in the country. In 2015, one beverage company called Heineken started to produce different types of beers for domestic consumption needs. The government and an Australian cement industry company signed a contract in 2015 to build cement industry in Baucau Municipality. Meanwhile, the government has invested millions of dollars on basic infrastructure in the south coast of the country as the main supporting infrastructure for developing oil and gas processing centre in the next few years. According to the Timor Leste's national strategic development plan, the oil supply base will be built in Suai Municipality. Meanwhile, the Liquefied Natural Gas plant (LNG) will be built in Beaçu – Viqueque Municipality. These will require a stable power supply in the coming decades for supporting industrial activities. The government has invested over 300 MW of conventional power plants in the country. This investment has shown a positive sign for the country's move in the last few years. However, the current power source that provides power to the country is a big burden for the state. The sector is heavily relying on state financial subsidy over $100 million annually [3.5] for its fuel and oil costing. On the other hand, the sector has pumped over 560.6 million kg-CO_2 [3.6] annually as direct results from fossil fuel usage that consumed from 2012 to 2018. The small state will even face greater difficulties in the future if it continues relying on fossil fuel for its energy needs. It needs alternative energy options to minimize operational costs and carbon emissions. Therefore, this work aims to conduct a brief analysis on the current electricity industry development that has multi-dimensional impacts including social, economic and environmental. Although some studies have been done in the past, most of the papers were heavily focusing on basic technical and social issues and less acknowledgement is given to environmental dimension. It is no doubt to state that the existing conventional electrical plants are part of a fabricated disaster that has a significant impact on the environment for the future generation. Although electricity is important for industries and manufacturing activities, it has significant economic impact and environmental risks for the country. Thus, this work develops a broader perspective on the key issues that faced by the Timor Leste Electricity Industry (TLEI). It discusses the electricity development, electricity governance sector, constraints and makes energy forecast. It provides possible countermeasures as alternatives policies for the sector. The study then analyses various energy options by using Analytical Hierarchy Process (AHP) approach to recommend the most appropriate green energy options as a consideration that will serve the country's long-run electrical energy needs to support its industrial and manufacturing activities. All the related data and informations obtained from interview and questionnaries for this study are attached in the Appendix IV.

3.2 The objective, scope and method of study

The overall objective and method of the electricity-related study is shown in the Fig.3.1. Reviewing the existing Timor Leste electricity development and its challenges as well as identifying the potential green energy alternatives are the main overall focus of this study. The expected outcomes of this study are a better understanding of country's overall electricity development policy and implementation approaches are gained, the risks and challenges are identified and inventoried for the future policy setting needs, then measures are obtained and recommended to the related government institutions and key decision-makers based on its priority characteristics. These were achieved through historical data review, interviews with related electricity actors and policy makers in Timor Leste. The Analytical Hierarchy Process (AHP) was used for the various energy option analysis. It identified several important criteria and alternatives that reflect the country's situation. Over 40 energy experts and professionals provided their subjective judgment for criteria and alternative comparisons based on their experiences and expertise.

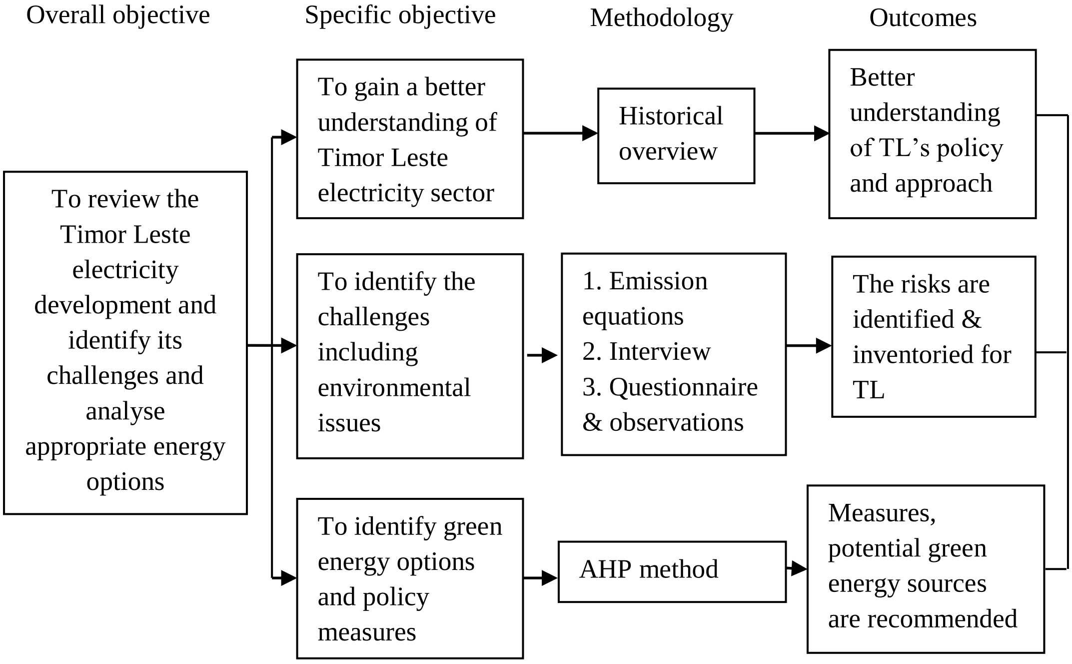


Fig.3.1 The schematic view of the study objective, methods and outcomes

3.3 Overview of Timor Leste electricity sector

Electricity was not known by the majority ordinary Timorese during Portuguese occupation. The study [3.6] reported that Dili was the only city had sealed roads in 1960s. Then Timor Leste did not access to electricity until 1962. There was no trace of electricity in the country. People rely mainly on biomass for their energy needs. It is believed that the Portuguese probably start introduced electricity in major cities, such as Dili, Baucau, and Ainaro between late 1963 and 1964. However, access to power was only limited to the important government residences and public buildings. There are no references about how big the supply power was. Despite the brutality, the Indonesian regime had given much attention on electricity, and introduced in most sub-district towns (*at least 2-3 villages located around sub-district town's access to electricity*) as early as 1980s. In 1998, the total power capacity was around 28 megawatts [3.3] and half of this was supplied to Dili customers. The electricity industry was under state responsibility and managed by a national electricity company called PLN (Pembangkit Listrik Negara).

When Timor Leste separated from Indonesia in 1999, all the power stations suffered enormous damage. The transmission and distribution lines were destroyed and wires were stolen. Power utility management capacity systems, computer-recording centres were removed and destroyed. The United Nations Transitional Authority in East Timor (UNTAET) was the United Nations (UN) body present in East Timor in 1999 started putting effort on the power sector. The UN initiated few emergency projects including restoration of power stations. The project covered at least 39 stations with a range capacity of 50 KW to 100 KW in major cities and towns. It also included upgrading Comoro power station and its supporting infrastructure after the country restored its independence in 2002. The Comoro generating station with a capacity of 19 MW supplied power to over 26,000 mainly in Dili and surroundings. The project at least costed over $100 million. So, the total power capacity until 2011 was 40 MW which served customers over 55,000 [3.6], [3.8].

To liberate the remaining majority of the population from darkness and poverty, in 2008 the government invested significant county's financial resource (over one billion dollars) on the power sector by building two diesel base power plants with a total capacity of 250 MW in the mainland of Timor Leste. Also, the government through the regional government built a 17.1 MW power plant in enclave Oe-Cusse that is separate by an Indonesian Province of Nusa Tengara Timur (NTT) from the country. The projects were also including transmission, distribution and sub-stations facilities throughout the country. This national electricity project was the largest infrastructure that the country ever built after it re-declared its independence in 2002 under the United Nations and other international community witnesses.

At least with the state investment in the power sector it did not only bringing light for the poor in rural areas that living without power during Portuguese and Indonesian occupations but also helping them to utilize the power for income-generating activities. The first power plant with capacity of 119 MW was accomplished in 2012; it is situated in Hera (Fig.3.2) about 15 to 20 minutes' drive from the main capital of Dili.

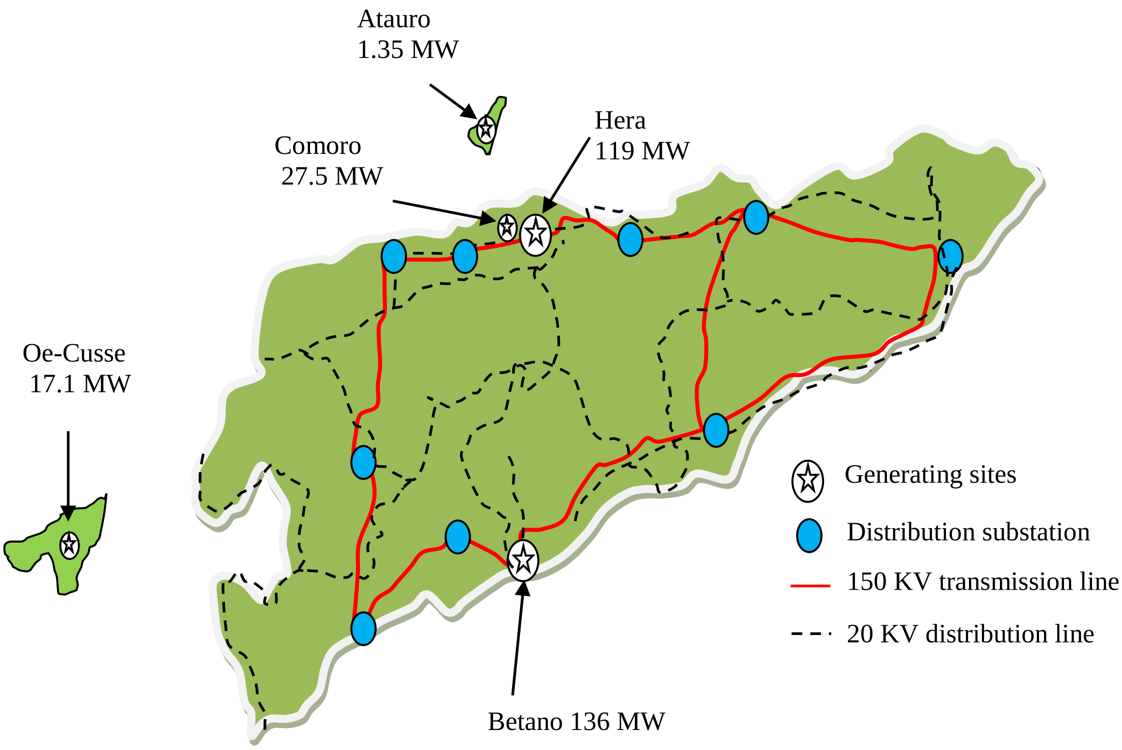


Fig.3.2 Timor Leste electricity coverage [3.6], [3.9]

Hera power plant generates an average of 7 x 17 MW for a total capacity of about 119 MW. The plant is completed with fuel storage facilities. It includes a sub-station that raises the voltage to 150 kVA for connecting with the transmission system [3.6]. The second power plant was built in Same – Betano on the south coast with an overall capacity of 136 MW [3.2]. This average generating capacity produced from 8 x 17 MW generators. These plants are completed with nine sub-stations (Table 3.1) which scattered throughout the country. The sub-stations are used to reduce power voltage that allows connection to the 20 kV distribution lines in the capital of 12 districts in Timor Leste. Fig.3.3 depicts that in 1997 the power capacity for whole country was around 28 MW. In 1999, there were almost no power supplies after infrastructure was destroyed and facilities were stolen. The government rehabilitated several stations and upgrading the main power stations in Dili, so the capacity reached 40 MW in 2010. Then in 2012, the 1st power plant in Hera was concluded and the second power station was accomplished in the following two years.

Table 3.1 Electricity power sub-stations

Sub-station	Capacity (MVA)
Dili	2 x 31.5
Liquica	10
Manatuto	10
Baucau	31.5
Lospalos	20
Viqueque	10
Casa	10
Suai	20
Maliana	20

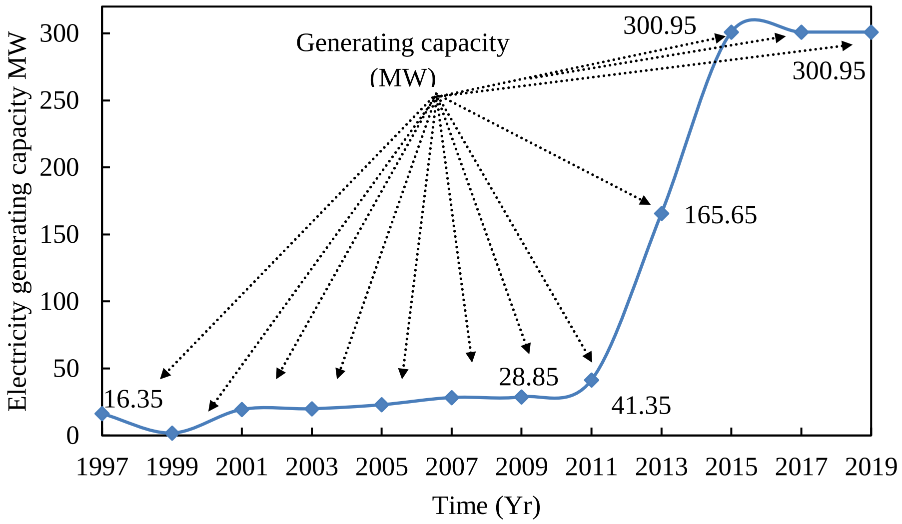


Fig.3.3 Timor Leste electricity generating capacity from 1997 - 2019

Meanwhile, the 17.1 MW Oe-Cusse Station was completed in 2016. Also, Atauro Island powered by two small stand-alone diesel generators with a capacity of 350 kVA and 1000 kVA. Therefore, currently the country has total generating power capacity of 300.95 MW. Table 3.2 shows the existing generating electric power plants. As a new and young country, the government invested in this essential sector for addressing energy needs. However, all the plants are relying on fossil fuel for generating electricity. It is no doubt to state that fossil fuel is a non-renewable energy in that it will not only shortage one day but also contributes significantly to global warming as the fuel produces huge amount of carbon dioxide [3.11]. To have a reflective policy option for the country, the governance aspect of the electricity industry becomes an essential element. Especially the body overseeing energy policy settings such as Utility Regulatory Authority (URA) and other related bodies should exist. Besides, laws and regulations are very important for allowing the mentioned institutions to undertake their activities in the best possible manner.

Table 3.2 Timor Leste's electric power plants

Location	Max. power rating (MW) [3.40]	System	Fuel
Hera	119	Internal combustion engine (dual function)	Diesel
Betano	136	Internal combustion engine (dual function)	Diesel
Oe-Cusse	17.1	Internal combustion engine (dual function)	Diesel
Comoro	27.5	Internal combustion engine	Diesel
Atauro	1.35	Internal combustion engine	Diesel

3.4 Electricity governance sector

Timor Leste electricity industry is a state-owned and run by a public firm called EDTL (Electricidade de Timor Leste). The government responsible for the TLEI and managed by EDTL. It was established based on the decree-law No.13/2003 to overseeing the basic operation and maintenance activities. The law allows EDTL to handle the daily operational activities to securing the power supply to customers. Even though EDTL is an independent body, it does not fully responsible for financial matters. All planning, budgeting, and decision that related to electricity industry are undertaken by the government, ministry of infrastructure's responsibility. It was found that in the current electricity management system, the business logic does not exist. This is because, aspects like, obligations of service to electricity users, have autonomy in managing industry, pricing, asset management, performance management, and human resource management are some of the business logic features which could provide enough room for EDTL to play its role wisely. The sector adapts a monopoly structure. This means, all components from generating, transmission and distributions are under a single firm. During the Indonesian regime, there was a process of electricity reform. Private electricity companies' participation in generating function was introduced in 1985 based on the government decree-law No.15/1985 [3.12]. Then in 1992, private electricity utilities had more opportunities for participating in transmission and distribution functions [3.12]. However, the reform was only conducted in major cities in Indonesia. Meanwhile, the electricity industry in other provinces including Timor Timur (another name of Timor Leste during Indonesian occupation) was continue to be managed by the vertical integrated government-owned company, Perusahaan Listrik Negara (PLN).

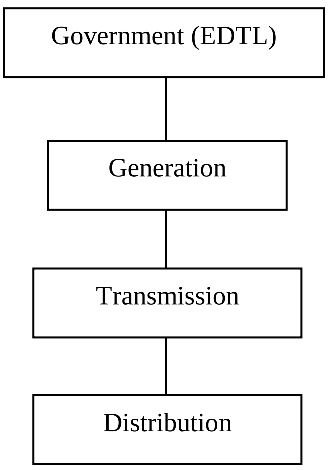


Fig.3.4 Timor Leste electricity structure

This model of the structure continued to remain unchanged by the Timor Leste electricity industry. However, in the last few years, the government gave opportunities for local private businesses, at least take part in the segment of fuel supply for generating and energy commercialization. By saying this, conditions for the private sector's participation in a bigger scale such as power generation is important. This will be secured by certain investment policy initiatives that enforced by laws.

Regulation is very important in the electricity industry sector, [3.9] states that "*regulation deals with the 'control' of the behaviour of the electricity industry following established principals, rules and laws to promote societal welfare"*. The reason why we need to regulate electric utilities is that private utilities and especially monopoly are profit maximisers and that if left on its own devices; they will misuse their powers and exploit customers. They may not supply safe electricity, not improve efficiency, pollute the environment and not commit to long term obligations.

In the case of Timor Leste, legal frameworks that used to regulate both electricity utility and customers are still very weak and far from best practices as other countries have. The process of restoring the electricity industry was very slow and considered as one of the big challenges that the transitional government faced when the country voted for independence in 1999. The process hampered by the in-existing legal frameworks. Thus, with Timorese entities, the United Nations Transitional Authority of Timor-Leste (UNTAET) established EDTL to handle basic electricity services in Timor Leste.

With very limited resources, both UNTAET and the Government of Timor Leste issued some basic laws which was used by EDTL and other related entities in dealing with electricity services. Below are the main laws [3.14] that have shaped the development of the electricity sector since 1999.

- *The initial Regulation 1999/1 of UNTAET, which sets the general legal principle that the laws that applied in East Timor prior to the 25th of October 1999 would continue to apply.*

• The UNTAET Tariff Directive effective on August 2001, giving EDTL the right to charge consumers for electricity services in Dili and including provisions for tariff setting, billing and collection, connection, and disconnection.

• The Basic Law for the National Power System enacted on May 2003, which defines the role of the Government in the power system and delegates most of its tasks to a Regulatory Authority, and favours outsourcing of the electricity services to the private sector through a long-term Concession Contract.

• Directive No. 7/2002 and the Ministerial Decree No.1/2003, which specifies electricity services, charges, and collection of fees [3.15].

Currently, the Timor Leste electricity industry is running without a proper Utility Regulatory Authority (URA) body. According to the basic law enacted in 2003, the government departments and ministries which directly dealing with the electricity sector are taking care of the regulatory authority role. The URA was under the responsibility of the Ministry of Transport, Communication and Public Works (MTCPW) in the first constitutional government. The power sector was under the responsibility of the National Directorate for Electricity Services. When the new government took place in late 2007, there was a change in government structure. A secretary of state was appointed to responsible for electricity, water, and urbanization. It was overseen by the vice ministry for electricity under the ministry of public works, transport, and communications in the VI constitutional government mandate. It again went back to the ministry for public work portfolio in the current VIII constitutional government. However, the government has approved a March 2020 act for allowing EDTL to become a public utility firm with its own autonomy management structure.

Electricity tariffs are to some extent very high for some residential customers. According to [3.6], the electricity charge for domestic customer in East Timor during the Indonesian Administration was $1.57 per 25 kWh including a 10 % tax. Meanwhile, there is no available data for industrial and commercial customers. Currently, the electricity tariff in Timor Leste is set based on decree-law No.1/2003 [3.15]. The social needs of Timor Leste are highly considered in structuring the current electricity rates, as shows in the present rates that charged to customers without tax. According to EDTL 2010 document, the initial monthly cost for residential customers for the first 20 kWh is 5 cents. The upper strata residential rate of 12 cents / kWh is a good compromise between the ability to pay and the cost of production. The rate that charged to business customers divided into three categories: small, medium and large consumers [3.16]. The rate details for charging the business customers are:

- Small customers (0000-1000 kWh / month) 15 cents / kWh
- Clients average (1000-3600 kWh / month) 20 cents / kWh
- Large customers (above 3600 kWh / month) 24 cents / kWh

According to this regulation, the public (state) buildings, embassies, and international non-governmental organizations are large customers. Meanwhile, the local non-governmental organizations and churches are domestic customers. Although these basic rules and regulations were set for facilitating the sector to perform its duties, many issues are still hindering the development of the sector in the future.

3.5 Emerging issues and fuel, oil and CO_2 emission forecast

3.5.1 Existing issues

Policy issues: the policy for electricity industry development is much emphasized in the national strategic development plan that the IV Constitutional Government formulated after having an intensive consultation with the wider community throughout the country. It is known as “Timor Leste Strategic Development Plan 2011 – 2030”, it was submitted to the national parliament for approval in late 2011. This work is continuation of the overall vision that initially developed in 2002, and was known as the 2020 vision. It asserted that people will no longer be isolated, production and employment will increase, the living standards will improve and the country will be prosperous. Therefore, the 2011-2030 plans formulated upon this vision. The plan covers three important areas; social capital, infrastructure, and economic development. The electricity sector is among the other six infrastructure areas namely road and bridges, water and sanitation, ports, airports and telecommunications that highlighted in the plan. Electricity is a very important sector that needs special attention from the government. It is not only a key driver for economic growth but also essential for liberating people from poverty and darkness. The government's overall electricity aim was access to electricity is a basic right and the foundation for the country's economic growth. The national electrification policy targets were that by 2020: at least half of Timor-Leste's energy needs responded with renewable energy sources and approximately 100,000 families would have access to solar-powered electric light. It also stated that by 2030 all households in Timor-Leste would have access to electricity either by the conventional expansion of the electricity system or by renewable energy sources. In mid-2019, over 83 % [3.5] villages have access to electricity. Meanwhile, others are still in progress and some of them will be electrified with standalone energy resources such as solar photovoltaic (PV). However, up until 2020, the country continues to rely on fossil fuel for serving its energy needs, as there are fewer efforts in reforming the current electrical energy policy. The country's political compromise on the electricity sector will reflect the country's social, financial, natural resources and environmental characteristics in the future.

Political issue: developing industry such as electricity for a fragile state like Timor Leste is challenging. Though the country's political climate has positively improved in the last few years, it is still unstable and fragile. The country politically remains vigilance after the civil unrest in 2006 – 2008, and political in harmonization in 2017 and 2020, many reasons why political challenges are the main constraints that dwarf the development of the electricity industry supply.

Firstly, the different government has different views and strategies when they come to the power issue. For example, in the first government (FRETILIN) administration, with international supports, an electrification development plan was established. One of the aims was to develop a safe and economically and technically viable generating power system that gradually developed to reflects both economic and energy growth. The Norway energy experts conducted an intensive study on Ira-Lalaro hydropower and planned to start construction in 2007.

However, when the new government took office in 2007, it was not considered due to some arguable reasons. The government then introduced a new policy by using HFO (Heavy Fuel Oil) technology, which believed economically viable to generate power for the country. However, the HFO later then shifted to diesel base due to wide protest from various institutions. Therefore, it overrides the core objective of providing electricity to improve societal welfare. This is very challenging for a small and fragile state to have an energy consensus policy. Apart from the mentioned political constraints, there are some major concerns affecting the sector.

First, in ministerial level, electricity issue is often ignored in their policy settings though it is essential for the normal operations of some services in the country such as schools, hotels, hospitals, domestic industries, agriculture, and fisheries. This is because the country is considered as not an energy-intensive country in present situation. Decision-makers solely focus on their department priorities without considering the importance of electricity. One thought that the electricity is as lesser importance by ministries since it is driven demand in itself, as cannot generate income thus not reflected in the majority annual plans of each ministry.

Second, most of the government departments have less coordination in developing and implementing policies, as a result, overlapping of energy activities among ministries often take place. The energy activities that under-secretary of state for energy policy and electricity, water and urbanization portfolio were implemented by different ministries without proper coordination [3.17]. Mercy corps' report says that in 2006, the Ministry of State Administration and National Territory that responsible for public administration executed solar PV projects that powered the 442 village offices throughout the country.

Institutional issues: both electricity and renewable energy sectors are under the Ministry of Public Works' responsibility and portfolio. Though EDTL is responsible for the overall functioning of the electricity sector, it is only limited to basic operational and maintenance aspects. The sector has no its proper institution such as Utility Regulatory Authority (URA). According to the Government 2003 act, the body is directly under the Ministry of Infrastructure, especially the Secretary of State for Electricity, Water and Urbanization. However, there was no sign of functioning of the body, all electricity-related rules and regulations seem directly implemented by ministry departments and EDTL.

Another institutional issue that may contribute to the future challenges is the lack of local authority and inadequate of professionals at the municipal level to handle the operational and maintenance aspects as well as renewable energy programs. Timor Leste does not have an autonomous body at both national and local levels for coordinating and implementing rural energy programs. As reported in a study done by Mercy-Corps in 2009, local communities do not know to whom they consult and seek advice when their solar home lighting systems are down. Therefore, having proper and adequate institutions in place will not only achieving targets and implementing the plan and policies but also overseeing the needs of the community in rural areas in general in a continuous manner. However, the VIII Government has issued and approved new law for allowing EDTL to be independent body as public utility firm, the law also considers the process of establishment of national authority for electricity sector that could effectively valid in early 2021.

Geography and community issues: the geographical constraint also contributes to the slowness of electricity industry development and leads to the very high cost of energy and transportation. Since some of the villages are far from the main roads, the transportation of goods and services to these communities could be very expensive though their energy needs are supplied with isolated renewable energy options such as PV. Meanwhile, the culture of "pay for use" is still far from the usual best practices among Timorese electricity customers. Some families even do not pay their bills and they continue access to power without any penalty from EDTL or government. GovTL (EDTL) indicates that the annual controlled energy that turned into revenue is less than

5 % [3.15]. These factors are very important and crucial for the sustainability development of the sector in future. To have better energy planning and sustaining long run services, it needs proper policy initiatives, a policy which is not only securing power supply for economic growth but also contributing positively to the environmental protection efforts.

Environmental issue: Timor Leste is one of the countries in the world that blessed with natural oil and gas resources. However, the oil and gas currently are not processed in its onshore; it is processed in Darwin, Australia. The country's electricity fuel needs are still relying on imported fossil fuel from overseas. Fossil fuel is a non-renewable energy source and has a huge impact on environment as it produces significant amount of carbon dioxide from diesel combustions. From 2012 to 2018, both Hera and Betano plants have consumed around 452,693,260 ℓ of diesel and 946,100 ℓ of oil [3.19]. According to [3.6] both plants have released around 3, 924.51 million kg-CO_2 into the atmosphere in the aforementioned period. As indicated in Table 3.3 the annual carbon emission from these plants is increasing. This figure will continue going up as the energy demand increases.

Table 3.3 Fuel & oil quantity and emission level

Date	Gross Production (MWh)*	Fuel consumption (ltr)*	Oil consumption (ltr)*	Fuel Emission (kg-CO_2)**	Oil Emission (kg-CO_2)**
2012	235,061,339	47,367,919	115,000	124,577,626.97	325,798,220.0
2013	323,734,824	65,089,488	180,300	171,185,353.44	510,794,948.4
2014	343,776,488	69,541,924	158,400	182,895,260.12	448,751,635.2
2015	326,997,520	65,833,352	126,200	173,141,715.76	357,528,133.6
2016	299,090,880	59,990,456	117,100	157,774,899.28	331,747,578.8
2017	304,597,616	60,907,624	117,700	160,187,051.12	333,447,395.6
2018	452,963,260	104,342,141	131,400	274,419,830.83	372,259,879.2

*EDTL Production directorate data: [3.14], [3.40] **CO_2 EF for Fuel and oil [3.41]

3.5.2 Fuel, oil and CO_2 emission forecast

This section briefly presents the annual fuel and oil consumption growth as well as the CO_2 emission forecast. The projection for the annual growth in the next 6 years (2026) is based on the historical energy data obtained from EDTL for the period of 2012 to 2018 as "Business As Usual (BAU) scenario approach. In this regard, annual fuel, oil consumption and the estimated CO_2 emission that pumped into the atmosphere because of diesel and oil consumption were obtained through the estimation of average periodic growth (*r*) and value at the desired time (V_2) for the projection. Using the following equations to estimate values:

$$r = (V_2/V_1)^{1/n} - 1 \tag{3.1}$$

$$V_2 = V_1 (1 + r)^n \tag{3.2}$$

Where V_2: value at time 2 with constant or average periodic growth rate from time 1, V_1: value at time 1, r: periodic annual growth rate as decimal rate and % rate equal R =100*r* and n: number of periods. Timor Leste fuel, oil and carbon dioxide emission forecasts show significant figures. Fig.3.5a reveals the annual diesel consumption and projection for the year 2026. It shows that in 2012, the sector consumed around 47.4 million ℓ of diesel for generating electricity. In the following five years, the annual diesel consumption increased to 60.91 million ℓ. From the estimation, it was able to observe that, the fuel average annual growth (r): about 0.1404 or approximately 14 % and as it shows in the Fig.3.4a, the expected annual fuel consumption in year 2026 will reach 298.51 million ℓ if the current annual fuel consumption is maintained. The figure shows the diesel consumption will increase by 186.2 % in the next 6 years.

On the other hand, Fig.3.5b and Fig.3.4c show both annual oil forecast and expected carbon dioxide emission produced in 2026 respectively. The Fig.3.5b shows that in the first year of power plant operation, it consumed at least 115 million ℓ and following five years increased to 117.1 million ℓ. The power plants will probably need over 156.9 million ℓ of oil for annual generator maintenance in 2026.

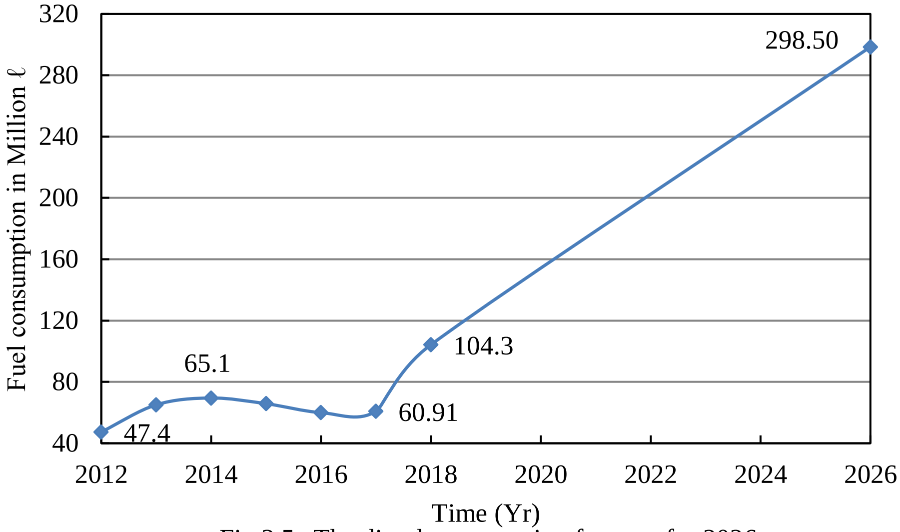


Fig.3.5a The diesel consumption forecast for 2026

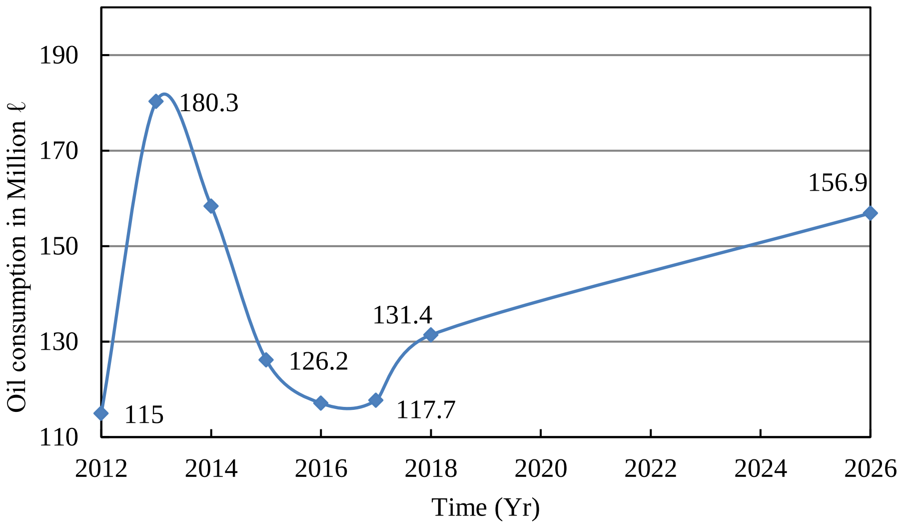


Fig.3.5b The oil consumption forecast for 2026

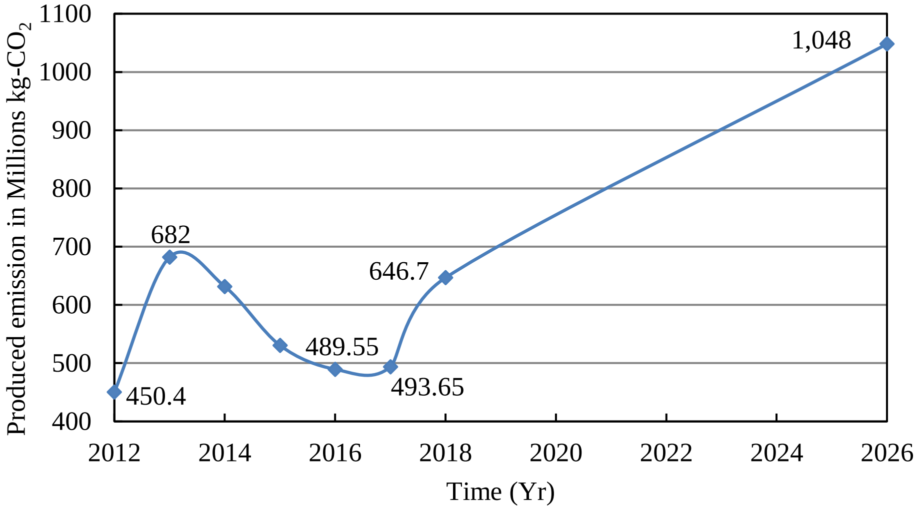


Fig.3.5c The carbon emission forecast for 2026

Meanwhile, Fig.3.5c reveals that the estimated CO_2 emission that pumped to the atmosphere as result of both fuel consumption and oil usage. Around 450.4 million kg-CO_2 was produced in 2012, and in 2018 it reached 646.7 million kg-CO_2. It is estimated that in 2026, the diesel power plants of Hera and Betano would at least increase its emission from fuel and oil consumption by around 1,048 million kg-CO_2.

The Fig.3.5b indicates that the average annual growth of lubricant oil for the power plants will be 0.02247 or approximately 2.2 % based on the current usage pattern. Moreover, the oil quantity in 2026 will reach around 576.71 million ℓ per annum that is over 19.5 %. Meanwhile, the calculation results indicated that if the current annual fuel and oil average consumption growth is maintained then the expected emissions that the power plants would inject to the atmosphere will be around 62 % (401 million kg-CO_2) (Fig.3.4c) in 2026. From these projections, it needs serious attention from key decision-makers in government. A green energy initiative is crucial, the policy will help to solve the sector's financial dependency, improve service quality and conserve the environment.

3.6 Measures for addressing the current electrical energy challenges

This section discuses some possible measures that can help to address Timor Leste electricity sector issues. It discusses policy measures including reshaping the current policies and presenting some of the potential renewable energy sources which the country can harness to full fill its electrical energy needs with less financial and environmental burdens. The energy source options are hydropower, solar power, and wind power.

In addition, this work presents and discusses a strategy for reforming the electricity sector. There are various components and issues for electricity reforming issues; here it presents several policy dimensions and its important features for consideration in regarding restructuring electricity sector in the next few years.

3.6.1 Restructure the electrical energy sector

Timor Leste's electrical energy sector has gone through several stages from colonialism to the independence period, from small and fragmented power generation to centralize. It is a public utility and controlled by the state government. The study [3.20] stated that the utility which under government portfolio, the management will heavily reflect its political priorities. Mostly, a government willing to have national and universal access to electricity to improve the standard of living, so all policies and regulations including electricity tariffs set by the government. Currently, there is only one electrical energy provider and the government issues all related laws, regulations, and policies. The most current concerns are including high operational and maintenance costs, environmentally unfriendly plants and in-affordability of electricity prices by lower-income families.

Table 3.4 Policy dimensions and key features for electricity reform [3.21], [3.22]

Policy Dimension	Key features
Corporation	Separate utility from ministry Create clear accounting framework Install private management
Commercialization	Cost recovery in pricing Reduce/eliminate subsidies Enforcement of collections
Law and regulation	Legally mandate restructuring Legally permit private participation/ownership Legally permit foreign participation/ownership/imports
Regulator	Remove regulatory function from ministry Create independent regulator Legally define scope, method and authority
Independent power producer	Create by privatizing state utility generation Greenfield development, Power purchase agreement
Restructuring	Vertical unbundling Create independent transmission authority/company Separate profitable parts for sale to private investors

Given these concerns, it is important to reshape the current policies that will minimize financial dependency, reducing environmental effects and providing more affordable electricity without ignoring the local context.

The Table 3.4 shows the most important components that the government needs to consider. It is important to restructure the sector based on outlined aspects that enable EDTL/other firms to stand on its own feet without relying on the government's financial support for the long run. Perhaps, not all these dimensions will be applied to Timor Leste's situation, it needs adjustment and locally reflected approach.

Some of the realistic and applicable measures that the country may need to consider for reorienting its electricity sector are:

- Identifying and initiating a green electrical option that will contribute positively to both environment and economy. The availability potential options of power sources discussed and presented in section 3.6.2 and 3.7.
- Regionalizing the generating power plants based on identified resources, therefore the power loss due to long transmission lines and high maintenance costs are minimized.
- Produce related acts/laws that will give possibility options for allowing the private sector to step in, specifically the generating segments through a Public Private Partnership concept. Also, establish related institutions for overseen the electricity policy issues and regulating sector performances.
- EDTL's internal management and financial ability should be strengthened. It will help to improve the revenue collection, operation and maintenance handling; before reforming its statute as a public firm.
- EDTL human resource mapping and provide specialist training on; power management, transmission engineering, hydropower engineering and other renewable energy engineering, energy planning and policy specialists, electrical and mechanical engineering skills are very much needed for handling EDTL in the long run.

3.6.2 Considering the availability of green energy options

The hydro, solar and wind power are the main available green energy options which could be harnessed for the future energy needs as it has not only less impact on the environment but also offers low operational cost. This section is presenting the aforementioned renewable energy options that are potentially attractive. The study obtained the data and information on the energy options from literature review and interview with relevant stakeholders who have been involved in the electricity development in Timor Leste or have comprehensive knowledge about the sector for a long time.

3.6.2.1 Hydro power

Hydropower is one of the promising sources that provide a very positive impact on economic activities and has less impact on the environment. It is by far the most established renewable resource for electricity generation and commercial investment, the early generation of electricity from about 1880 [3.19] often derived from hydro turbines. The International Renewable Energy Agency (IRENA) estimates that the worldwide hydropower installed capacity reached 936 GW in 2010, China, Brazil, and the USA invested more and have installed around 210 GW, 84 GW and 79 GW respectively [3.24].

Although some scholars give their concern on social and environmental aspects of hydropower during construction and operation phases, it is still the better option compared with fossil fuel. Hydro plants are long-lasting, for example, turbines could last for about 50 years, meanwhile, the diesel combustion generators could only last 10-15 years when continuing in operation. The good thing about the hydro is due to continues steady operation without high temperature or other stress. Consequently, established hydropower plant often produces electricity at very low prices with consequent of economic benefit. For example, Norway with 90 % of electricity coming from hydropower and the country receives a significant economic benefit

[3.23]. However, during the technical study period, it should consider factors like availability of water, water storage, geological investigation, water pollution, sedimentation, environment effect and access to sites.

Timor Leste is an island, which naturally blessed with some potential sites that suitable for hydropower development. Some studies from the last few years exist and indicate that hydropower could be a good option for the country. For example, [3.6], [3.25] indicate that Timor Leste has around 351 MW generating capacity in total. This generating capacity is from several sites (Table 3.5. potential hydropower sources in Timor Leste) that identified in the last couple of years by both EDTL and other international experts. Apart from these data of potential sites for generating hydropower, the average rainfall in some regions in Timor Lese is also depicting a positive sign.

Fig.3.6 shows that the annual average rainfall in some regions of Timor Leste including Ainaro, Ermera, Same, Covalima and Aileu including Viqueque Municipalities can reach around 2200 mm – 2800 mm.

Table 3.5 Potential hydropower capacity [3.6]

No	Sites	Estimated capacity (MW)
1	Ira-lalaro	27
2	Baucau	0.003
3	Gariuai	0.0035
4	Belulic	14
5	Laclo I	9
6	Laclo II & III	40
7	Gleno-Railaco	>40
8	Atsabe and Irabere	NA

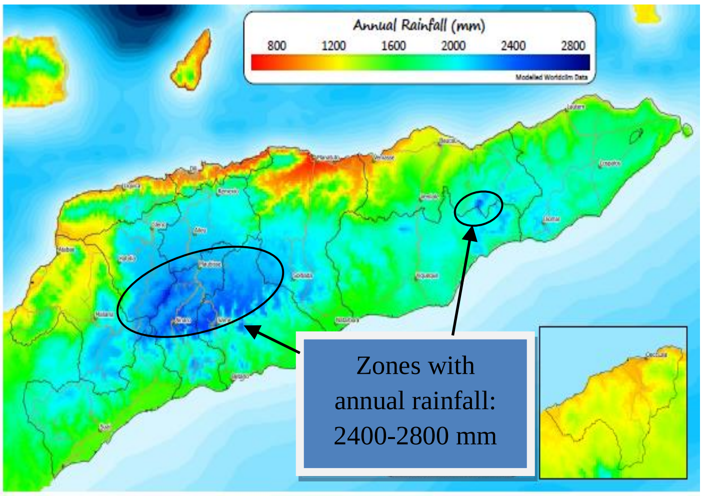


Fig.3.6 The annual rainfall in Timor Leste [3.26]

3.6.2.2 Solar power

Solar power is another renewable energy resource that many countries are harnessing; the free heat from the sun is converted into electricity for responding daily energy needs. This energy option has been an attractive option worldwide since 1970s. This is because environmentally friendly alternative and it is a right option for fossil fuel substitution in the future since the fuel is free from nature. As [3.23] points out that solar radiation arrives on the earth at a maximum flux density of about 1 kW/m^2. This means every m^2 receives an equal amount of energy from the sun and it is free of charge. Like other countries in the region, Timor Leste enjoys a significant period of sunshine. The country has two seasons namely rainy and dry seasons. In most of the coastal areas and north parts of the country, have up to180 to 217 cloudless days per year. The country's electrification master plan indicates that annual average sunlight around 14.8 and 22.33 MJ/m^2 [3.15]. There is no specific solar insulation data available for the whole country. The study [3.27], conducted in Hera, at Faculty of Engineering of UNTL shows that the average solar insulation ranges from 601.2 W/m^2 to 952.9 W/m^2. Meanwhile, some sources indicate that the country has the solar potential of 50,516,427 MWh/year [3.28]. The identified solar power potential is 7 MW according to the general directorate of electricity that presented the country's electricity policy during the 2013 Asia Pacific Energy Forum in Bangkok, Thailand. However, a specific study may be needed before hand of solar power projects, but given such information, Timor Leste has a great chance to harness solar power for its future energy needs. Although some scholars argue that the treatment cost after the solar module lifetime is high, research and technologies are continuing to evolve and it will be a very effective and efficient energy solution for substituting fossil fuel in the future.

3.6.2.3 Wind power

The extraction of power from the wind with modern turbines to generate electricity known is wind power. Some scholars define wind power as the use of airflow through wind turbines that changes mechanical power into electrical power. Like other renewable energy sources, it provides no emissions to the atmosphere and only needs a very small amount of land for constructing wind turbines. It does not need other resources such as water for its power generating needs. In 2017, the world wind power reached 546 GW [3.42]. Denmark produces its electricity from wind power around 40 %. Currently, China leads the wind power development in the world; the Gansu Wind Farm built around 6,000 MW. Meanwhile, India and United States have built 1,500 MW and 1,320 MW respectively. Perhaps, many important technical requirements are essential when developing a wind power. The most important aspect is how good the wind speed for the proposed wind turbine. The wind speed has at least in the range of 5 to 20 m/sec [3.19] to permit a wind turbine to operate.

Timor Leste consists of hills and valleys with some potential wind sources. It could be possible to make use of this free and environmentally friendly energy source for the country's energy needs. A source [3.29] indicates some potential sites including Baucau 8.5 MW, Bobonaro I and II 34 MW, Aileu 11.9 MW, Laleia 0.85 MW, and Lariguto I and II with 17 MW. On the other hand, EDTL indicates that the identified potential wind capacity in the country almost reaches 81 MW [3.25]. According to a study by Asian Development Bank in 2004 [3.43], it indicated several potential wind power sites and the study recommend to conduct a further detail technical assessment. It asserted Timor Leste has average 8.1-10.2 m/s of wind speed. Perhaps it needs an at least 5 to 7 years intensive study on collecting wind data before considering wind power policy. As [3.23] said, at least it needs 20 years of consecutive wind velocity data before developing wind power. From the overall discussions, it indicates that Timor Leste has some renewable energy resources; the country can consider for its future energy needs. To provide a good insight for future decisions, this study collected several inputs and ideas from different individuals, academic and private sectors as well as those who directly involved in power sector development in Timor Leste. The experts were consulted through a questionnaire for prioritizing and comparing the potential renewable energy sources including hydro, wind and solar to fossil fuel in Timor Leste. In the same way, they also compared the selected criteria including technical, financial, environmental, and resource usages that used for nominating the energy options priority, through a study method called the Analytical Hierarchy Process (AHP).

3.7 Energy consideration by AHP method

In this section, it discusses the different energy options by the AHP method. The discussion includes an introduction to AHP, criteria selections, energy options and discussions for overall priority option or alternative.

3.7.1 Introduction to AHP

AHP become popular tool for policy analysis after Professor Thomas L. Saaty introduced in 1970 [3.34]. It is suitable for solving a problem that involves multi-criteria. Other word, it is a tool for solving or organizing a complex decision with multi-objectives. Many scholars use this tool as one of the best methods for analysing complex issues. For example, Akash asserted that AHP is appropriate for analysing business decisions [3.31], selection of research area and development programs [3.32], resources policies such as water policy [3.33].

Table 3.6 Comparison scale for grading alternatives

Option	Numerical value (s)
Equal	1
Marginal strong	3
Strong	5
Very strong	7
Extremely strong	9
Intermediate value for reflecting fuzzy inputs	2, 4, 6 & 8

This tool provides a good reference for key decision-makers to evaluate a complex problem by breaking down into small components in the form of a hierarchy of references through a series of pair-wise comparisons of relative criteria. Experts and participants give their subjective judgment by giving a numerical value for each criteria or objective. They assigned numerical value based on Table 3.6.

The given numerical values then synthesized in the use of eigenvectors to determine which alternative or options are best that have the highest priority. The decision approach of this method is including calculation of priority vectors and checking the consistency ratio. The calculation of priority vectors is by applying the comparison matrixes; the vector weights (w) were done in two steps. First, the pair-wise comparison matrix $A.w = \lambda_{max}.w$ is normalized, and then the weights are calculated. It conducted the normalization process simply by dividing each element of a_{ij} by the column totals. Meanwhile, it can obtain the weight using the following equation.

$$W_i = \sum_{i=1}^{n} aij / n \quad (3.3)$$

On the other hand, the calculation of consistency index (CI), in the AHP, the pair-wise comparisons in a judgment matrix are consistent, if the corresponding CR is less than 10 %. It calculated the Consistency Index first before the consistency ratio (CR) coefficient. The CI result is obtained from equation 3.4.

$$CI = (\lambda_{max} - n)/(n-1) \tag{3.4}$$

Where: λ_{max} is the priority coefficient of matrix calculation and *n* is the number of criteria and alternatives that considered for AHP analysis. After that, divide the CI value by the random consistency index (RCI). The RCI values are decided based on the Table 3.7, it is taken based on the values of *n*.

Table 3.7 RCI values for different values of n [3.30] [3.31]

n	1	2	3	4	5	6	7	8	9
RCI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Using the following formula to obtain the CR value:

$$CR = CI / RI \tag{3.5}$$

The test of consistency is conducted when the CR (consistency ratio) is calculated and obtained. The important aspect that needs to be considered is when CR < 10 %, the data that obtained is consistent, however, if the CR > 10 %, it means the data that achieved is inconsistent. Another word, there is in consistent in judging or giving opinion, weighing. Therefore, it needs recalculation of the original from pair-wise comparison. Then, it continues with result compilation and formulation to obtain an acceptable result. The results can be valuable for decision-making process as an overall priority that based on the highest score.

3.7.2 Analysis and discussions

Based on the described methods and procedures, this section is outlining how the data was analysed and it presents the calculation process and the expected results for the selection of the best energy option for Timor Leste. This analysis of energy option selection is based on the modelled method of AHP is indicated in the Fig.3.7. The study compares all criteria and options according to the AHP procedure; likewise, the alternatives are also compared by using AHP. It was then decided the proposed criteria and the alternative energy options based on its importance and expert's inputs. The decision of selecting energy option is based on the alternatives and criteria with a direct method as the method that used to input quantitative data. Before conducting the AHP calculation, it is important to start with constructing the AHP hierarchy for the energy option selections. The study follows the AHP procedure and its calculation approach. The first step is deciding the criteria as a basis for the energy option selections.

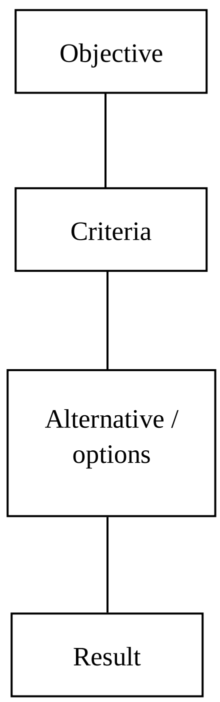


Fig.3.7 Hierarchy structure of AHP

After conducting several consultations, literature reviews and interviews with experts and academics, it selected and used four most important criteria such as technical, financial, environmental and resource usages for AHP analysis. The importance of each criterion was compared accordingly. The criteria are:

Technical criteria: The technical criteria is one of the most important criteria which need serious consideration in any decision-making process. A technical criterion is one of the sustainable criteria among environmental, social and economic. In this analysis the technical criteria is including aspects like reliability, efficiency, accessibility, and availability of energy options which are important for the country.

Financial criteria: A financial criterion is part of the economic criteria. The weighting judgment is not only considering both capital and expected operational and maintenance costs, but it also considers a cost that includes labour, profit for sub-contractors, legal and permit costs and compensation. It also includes costs for compensating land use and community reallocation. The experts have their breakdown financial criteria for each of the energy options, which is considered in this process and called alternatives.

Environmental criteria: An environmental criterion focuses on each alternative's contribution of pumping carbon dioxide emission into the atmosphere from transportation, land clearance, construction and until normal usage of energy. It includes emissions from fuel, oil consumptions during operation. It is also considering the destruction of the ecosystem, residual wastes to the surrounding areas and noisy levels as well as the final stage of disposal.

Resource usage criteria: in this part of the criteria, resource usage, it is mainly focusing on land usage for constructing infrastructure including generating and supporting facilities. In addition, the other important aspect of resource usage criteria that considered here is the water usage for each alternative (energy option) after full construction and during its operation for cooling.

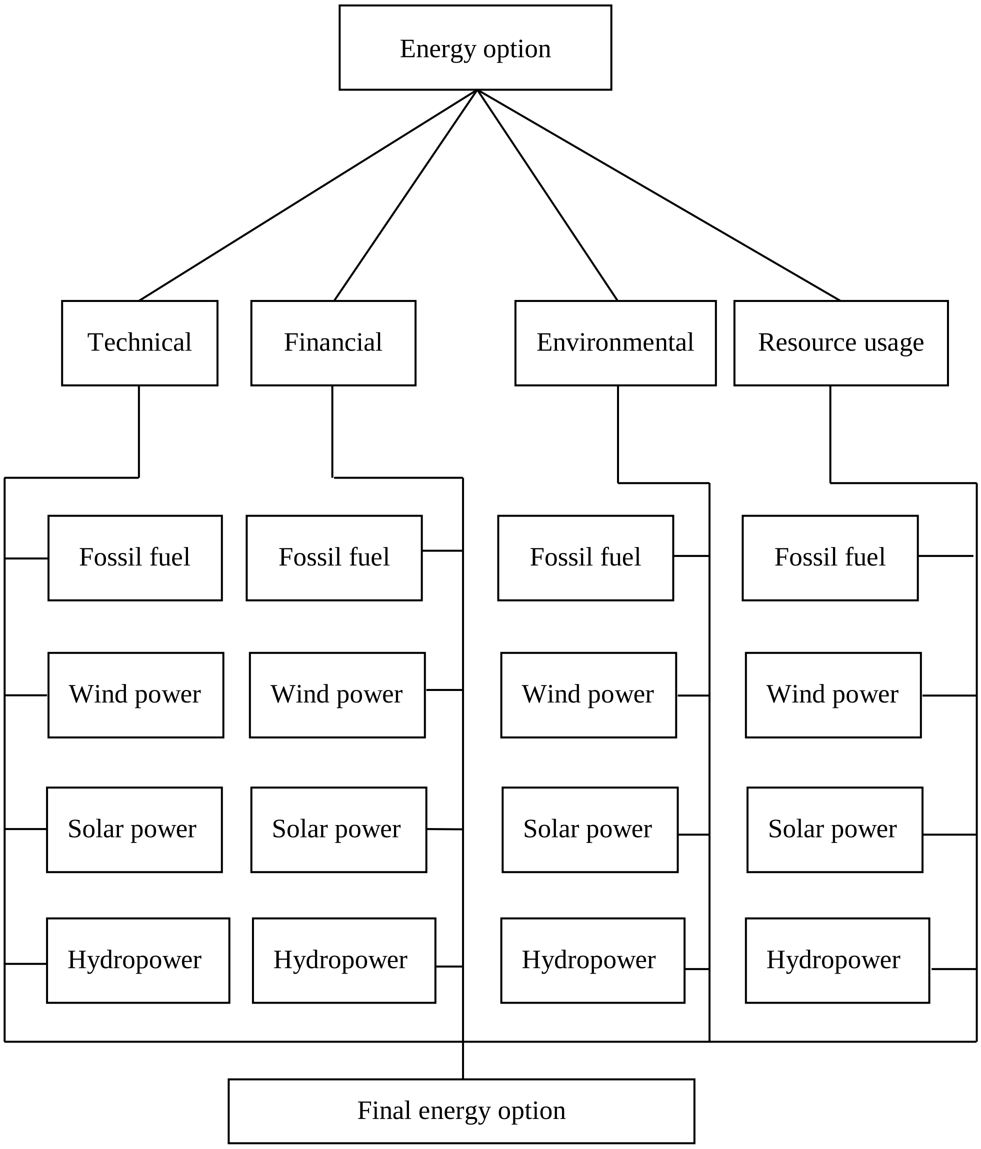


Fig.3.8 Hierarchy of criteria and alternatives of AHP

The alternatives or energy options are fossil fuel, wind power, solar power, and hydropower. The study considered them as potential alternatives after consultation with experts and professionals. In addition, it was decided based on the available information from literature. The Fig.3.8 depicts both criteria and alternatives. Now, the next step is to organize the criteria that has selected and weighted in numerical values into a pair-wise matrix form. After that summing all the matrix columns of each criteria and obtain its dividing value for the entire criterion in each column. The total of these values should be equal to 1 (one). After that, the summation of each criteria divided by a total number of criteria (n) to obtain priority vector (priority criteria). The result is shown in Table 3.8a.

Table 3.8a Criteria weighting matrix

Criteria	Technical	Financial	Environmental	Resource usage
Technical criteria	1	2	4	3
Financial criteria	0.33	1	2	2
Environmental criteria	0.25	0.5	1	3
Resource usage criteria	0.33	0.5	0.33	1
Total	1.9167	4	7.3333	9

Table 3.8b Criteria weighting matrix

Criteria	Technical	Financial	Environmental	Resource usage	Sum of Rows
Technical criteria	0.52173913	0.5	0.545454545	0.333333333	1.900527009
Financial criteria	0.173913043	0.25	0.272727273	0.222222222	0.918862538
Environmental criteria	0.130434783	0.125	0.136363636	0.333333333	0.725131752
Resource usage criteria	0.173913043	0.125	0.045454545	0.111111111	0.4554787
Total	1	1	1	1	4

Table 3.9 Priority vector

Criteria	Priority vector
Technical criteria	0.475131752
Financial criteria	0.229715635
Environmental criteria	0.181282938
Resource usage criteria	0.113869675

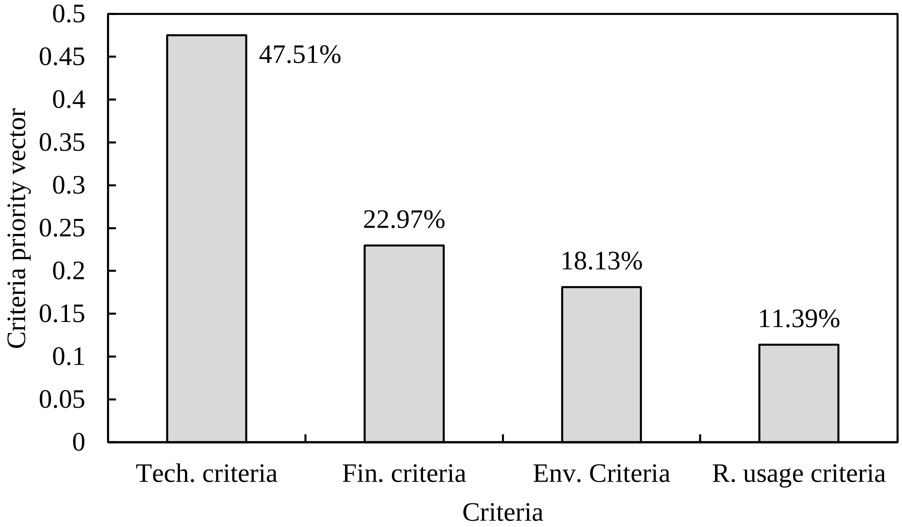


Fig.3.9 The Eigen priority vector

After calculating these weighting values, the priority vector of each criteria is obtained. These values are obtained by the sum of each criteria divided the total of the criteria itself and the results are shown in Table 3.9. Fig.3.9 shows that the experts and energy professionals consider and put the technical criteria aspect efficiency and reliability from power plants in the priority. Meanwhile, financial and environment criteria come to the second and third important criteria respectively.

After that, the alternatives need to be determined based on the above set criteria. Here, the study has come up with four alternatives namely fossil fuel, wind power, solar power, and hydropower.

- Alternative weighting matrix value concerning technical criteria

Table 3.10a Alternative weighting value with respect to technical criteria

No	Alternative	Priority vector	Percentage
1	Fossil fuel	0.074837269	7.5 %
2	Wind power	0.171088053	17.10 %
3	Solar Power	0.285486381	28.54 %
4	Hydropower	0.468588298	46.85 %
Total		1	100 %

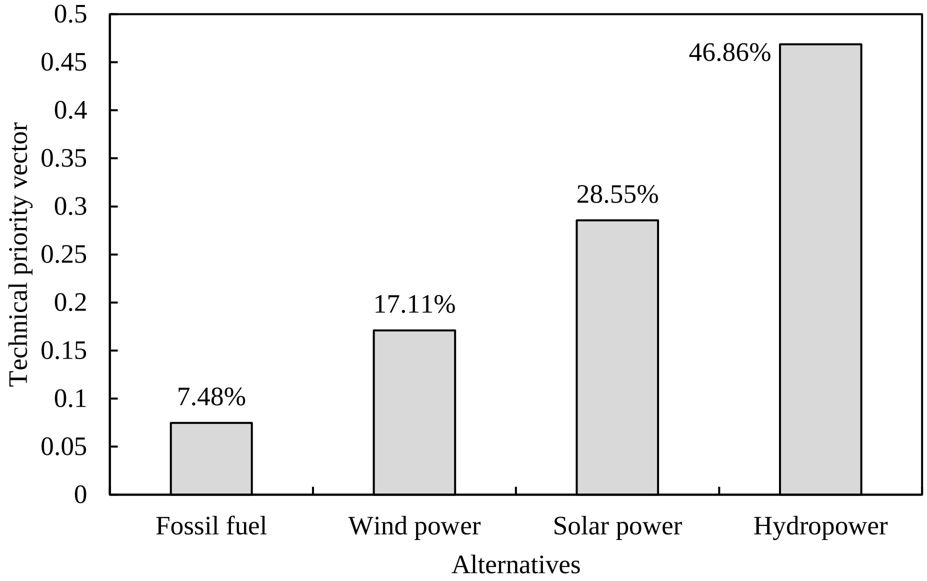


Fig.3.10 Technical criteria priority vector

These alternatives were then organized in a matrix form based on the set criteria. Therefore, there will be 8 matrixes that paring with its criteria. The process of obtaining the priority vector for each alternative regard to each criterion is the same method as the priority vector for criteria. So, the results are depicted in Table 3.10a, 3.10b, 3.10c, and 3.10d. Both Table 3.10a and Fig.3.10 show the priority vector of each alternative about technical criteria. The results indicate and depict that technically hydropower and solar power are the best alternatives that needed for the country. They hold 0.46858 and 0.28548 respectively. Meanwhile, wind power and fossil fuel come to the third and fourth places. They have 0.17108 and 0.07483 respectively. It is important to understand that this subjective judgment of technical criteria is based on factors such as reliability, efficiency, and availability of each alternative in Timor Leste. These factors were carefully analysed and equally considered when given its numerical value by the experts.

- Alternative weighting matrix value with respect to environmental criteria

In this section, Table 3.10b and Fig.3.11 show the environmental criteria specifically on emission aspect from each alternative. Again, the experts and energy professionals were giving their subjective judgment based on aspects including carbon emission wise that pumped to the atmosphere from each alternative. This emission judgment considers from the emission that produced by each alternative starting from material production stage, transporting, construction, usage of energy and waste that alternatives may have. As it shows in the Fig.3.11, the hydropower has a high ranking of green energy sources or in other word, it is one of the best alternatives with very low emission production compare with others.

Table 3.10b Alternative weighting value with respect to environmental criteria

No	Alternative	Priority vector	Percentage (%)
1	Fossil fuel	0.032155303	3.22 %
2	Wind power	0.24179996	24.18 %
3	Solar power	0.359272073	35.93 %
4	Hydropower	0.366772664	36.68 %
Total		1	100 %

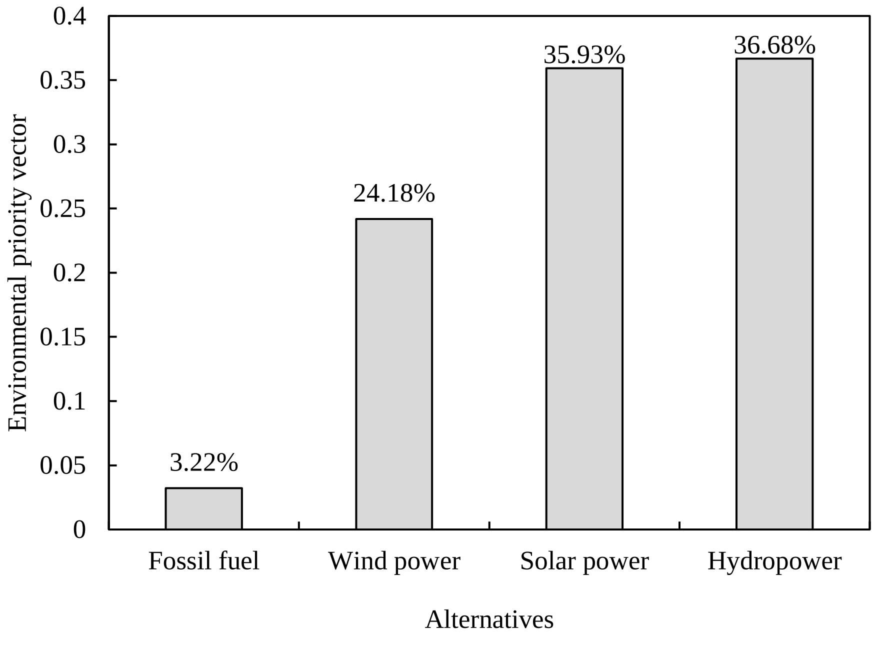


Fig.3.11 Emission criteria priority vector

It holds 36.68 % and solar power come to second with 35.9 %. On the other hand, fossil fuel option is the worst option as contributes high emissions to the atmosphere according to the experts.

- Alternative weighting matrix value concerning less resource usage criteria

Fig.3.12 indicates that the wind power option is using less significant amount of resources compare to other options, it is 30.41 %. It is important to be aware that regarding this resource usage means the alternative that needs minim area of land for plant constructing and water for cooling purposes. The second alternative power plant option that uses fewer resources is hydropower with around 29.10 %. Meanwhile, the third favourable alternative energy option that expert suggested is solar power. The result shows that it holds around 28.76 %.

On the other hand, fossil fuel needs significant resources, as it is not a favourable alternative according to experts. The figure shows that the non-renewable energy, fossil fuel is only with 11.73 %, this means, fossil fuel requires greater resources such as land for building power plants and water for cooling. It is about 17.37 % less favourable compare with hydropower and 18.68 % compare with wind power.

Table 3.10c Alternative weighting value with respect to less resource usage criteria

No	Alternative	Priority vector	Percentage (%)
1	Fossil fuel	0.117308171	11.73 %
2	Wind power	0.304054222	30.41 %
3	Solar Power	0.287625917	28.76 %
4	Hydropower	0.29101169	29.10 %
Total		1	100 %

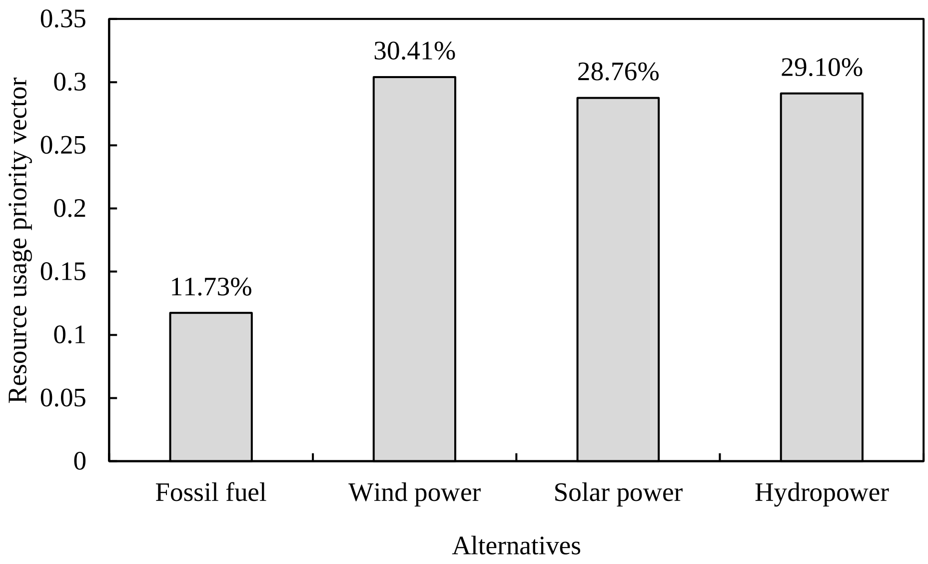


Fig.3.12 Resource usage criteria priority vector

- Alternative weighting matrix value with respect to financial criteria

Table 3.10d and Fig.3.12 show the financial resource criteria analyses. It is important to state that the financial judgment here considers all costing from research and design, construction, operation, and maintenance as well as waste-related treatment costs. The most favourable one will be alternative option that needs less financial resource.

Table 3.10d Alternative weighting value with respect to financial criteria

No	Alternative	Priority vector	Percentage (%)
1	Fossil fuel	0.146753247	14.67 %
2	Wind power	0.370779221	37.08 %
3	Solar Power	0.267532468	26.75 %
4	Hydropower	0.214935065	21.49 %
Total		1	100 %

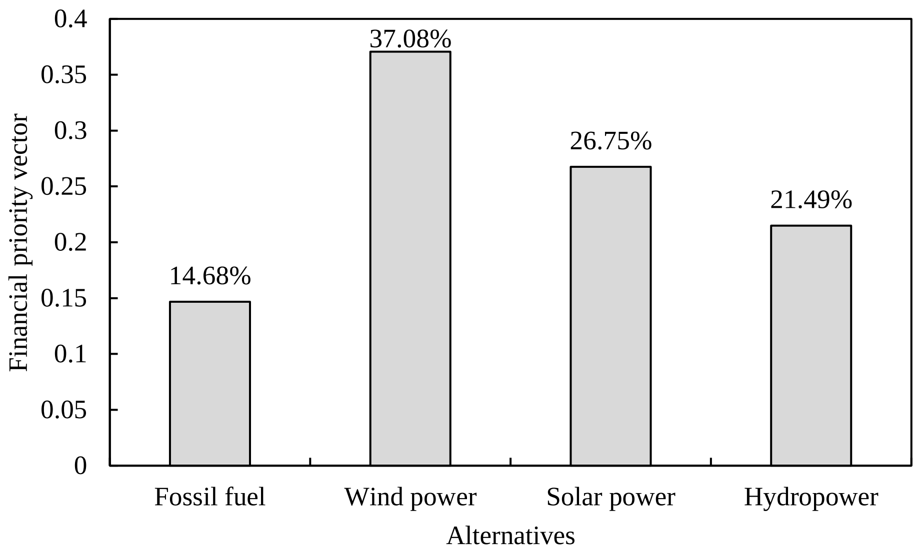


Fig.3.13 Financial Eigen priority vector

The Fig.3.13 shows the results of financial criteria consideration for all four alternative comparisons. It depicts that wind power requires less financial resource compare with other alternatives, as experts gave high scores for wind power with total 37.08 %. On the other hand, fossil fuel needs a significant financial resource as it holds 14.68 % that is about 12.07 % and 6.81 % compare with both solar power and hydropower respectively. From the above discussion and AHP processes, Table 3.11 presents the priority scores of all alternatives. Then, the next step is to calculate the maximum lambda and the consistency index of the AHP process.

Table 3.11 The weight of each alternative priority vector

Alternative	Technical	Environmental	Less resource usage	Financial
Fossil fuel	0.0748	0.0321	0.1173	0.1467
Wind power	0.1710	0.2417	0.3040	0.3707
Solar Power	0.2854	0.3592	0.2876	0.2675
Hydropower	0.4685	0.3667	0.2910	0.2149

Table 3.12 The lambda value of each criteria

Criteria	Priority x Lambda-λ	Priority vector**	Lambda-λ*
Technical criteria	0.7889	0.4751	1.9005
Environmental criteria	0.2110	0.2297	0.9188
Resource usage criteria	0.1314	0.1812	0.7251
Financial criteria	0.0518	0.1138	0.4554

*Table 3.8b. ** Table 3.9

The lambda value and calculated by the sum of priorities divided by priority criteria. The Table 3.12 shows the lambda values of all criteria. It used Eq.3.4 for the λ_{max}(-), it is coefficient of priority vectors, CI and CR values. Here, n is number of criteria and alternatives, CI is consistency index, CR is consistency ratio.

$$\lambda_{max} = \Sigma\lambda / n = 4.1837 \qquad CI = (\lambda_{max} - n) / (n - 1) = 0.061255 \qquad (CR) = CI / RI = 0.068 \text{ or } 6.8\ \%$$

The calculation result for criteria shows the CR is 6.8 % that is less than 10 %. As stated by [3.34], the pairing comparison of the given criteria matrix is consistent. With the same calculation approach, the CR for alternatives regarding technical, environmental, resource usages and financial are 9 %, 8 %, 7 % and 7 % respectively.

Table 3.13 Lambda and overall priority of alternatives

Criteria/ Alternative	Technical	Environmental	Resource usage	Financial	Overall priority
Fossil fuel	0.03556	0.00583	0.01336	0.03371	0.08846
Wind power	0.08129	0.04383	0.03462	0.08517	0.24492
Solar power	0.28549	0.06513	0.03275	0.06146	0.44482
Hydropower	0.22264	0.06649	0.03314	0.04937	0.37164

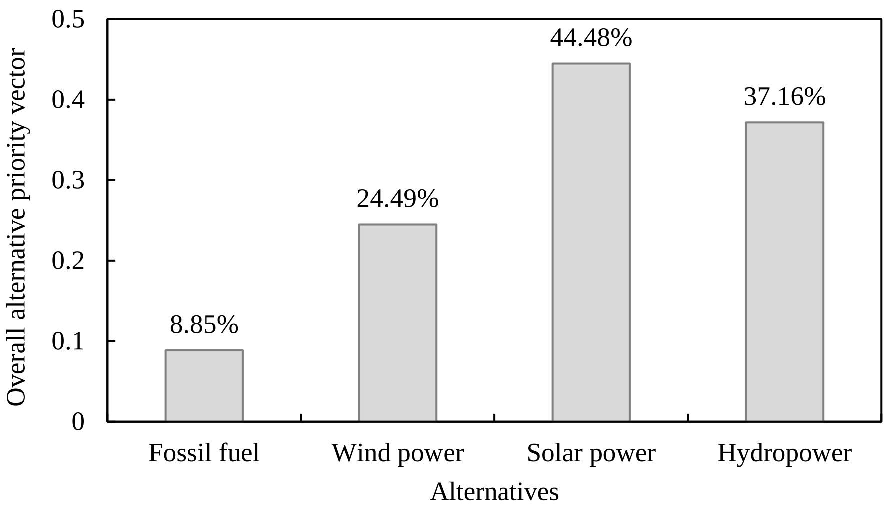


Fig.3.14 Overall priority vectors of energy options

The next step is to calculate the overall priority for every energy option (alternatives) for each criterion by multiplying the results from Table 3.9 with Table 3.10a, b, c, and d. So, the results of lambda value of each criterion are shown in Table 3.13. The overall priority results in Fig.3.14 show that solar power is the most preferred option among other alternatives. It holds 44.48 %, and hydropower comes to second place with 37.16 %. Meanwhile both fossil fuel and wind power are with 8.85 % and 24.49 % respectively. However, after considering all the priority results of four given criteria and the overall priority values including the consideration of multi-sectoral impacts, the hydropower has more points than other options. Recall the priority values of all the criteria and the overall priority by ranking each of them for example, 1 = 100, 2 = 50, 3 = 25 and 4 = 10. Therefore, the details are presented in Table 3. On the other hand, the consideration of multi-sectoral impacts is also ranked, for example, alternative that has 1 sector impact is 10, 2 sectors impact is 25, 3 sectors impact is 50 and 100 for over 4 sector impacts.

The AHP discussion results show that the technical criteria are more important compared with others. In respect to these criteria, hydropower alternatives gained the highest point, which means technically solar and hydropower is reliable, efficient and sustainable. Besides, both hydropower and solar power obtained the highest scores for the less emission contribution; the hydro is first preferred option then followed by solar power. In contrast, fossil fuel alternative dominated both resource usage and financial criteria. So, by considering all the criteria values and final overall priority that ranked, the hydropower option turns out as the most preferable energy option as it is shown in Fig.3.15.

Table 3.14 The final ranking scores

Criteria/ Alternatives	Technical criteria	Environmental criteria	Resource usage criteria	Financial criteria	Priority global	Multi-sectoral impact solution	Sum
Fossil fuel	10	10	10	10	10	25	75
Wind power	25	25	100	100	25	25	300
Solar power	50	50	25	50	100	50	325
Hydropower	100	100	50	25	50	100	425

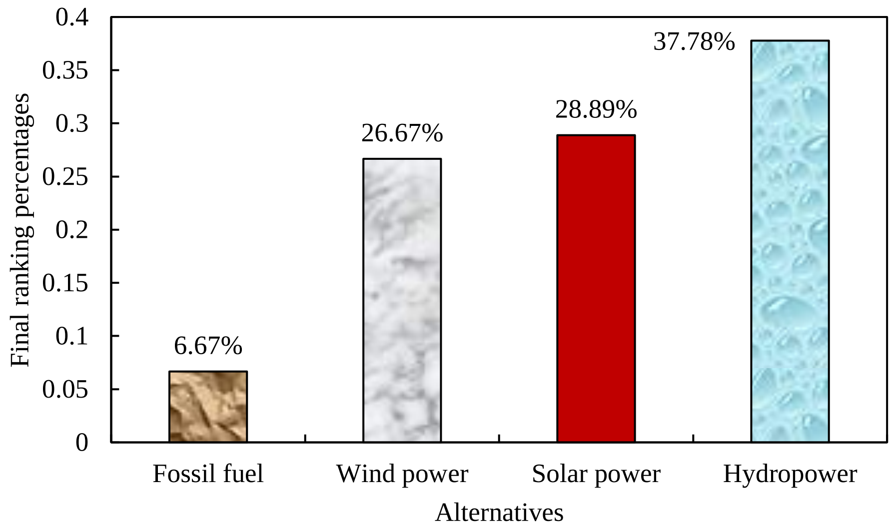


Fig.3.15 The overall results of alternatives based on criteria

3.8 Summary and recommendation

Timor Leste's electricity sector has undergone several changes and has improved significantly since the country regained its independence in 2002. However, many challenges are lying ahead, and huge tasks remain unsolved. The tiny island country is heavily relying on state subsidy to run its diesel power plants for supplying electricity to the people. The country spent over $100 million for both diesel and oil annually. Using fossil fuel for generating power is contributing to global warming as it pumps significant carbon dioxide into the atmosphere as result of combustion. The existing diesel power plants have released at least 3, 924.5 million kg-CO_2 from both diesel and oil consumption between 2012 and 2018.

Providing a reliable electricity service to over 1.3 million people is challenging. With very minim supporting logistics, facilities and other resources, it makes hard for EDTL to handle the basic operation and maintenance of electricity facilities. Currently, the country is hiring international experts and companies to manage both power plants and transmission operations. This will continue in some years to come as EDTL, still lack of qualified human resources to handle the developed electricity industry. As of early 2019, EDTL has only 520 staffs which including engineers and administrators, and 2 technical staffs assigned to each sub-district station throughout the country.

Although it is a very complex and high burden for the country in managing its current power sector, the country has several alternative resources that can be harnessed to substitute the current fossil fuel power plants to reduce financial dependency and minimize harmful pollutant gasses that released into the atmosphere. As indicated from the overall results of AHP analysis, hydropower (37.78 %), solar power (28.89 %) and wind power (26.67 %) technically, financially and environmentally are preferable options for substitution the existing source. To explore these promising resources, Timor Leste needs some concrete actions and policy settings. The actions and measures need to be organized and implemented periodically that reflects the EDTL and country’s conditions and categorized based on the urgency and executed periodically in short, medium and long term.

Some of the identified essential emerging issues that the country has and need to be considered are:

Most urgent:

(a) Review the EDTL internal management capacity and prepare for attributing more competencies to EDTL in handling the electricity sector without relying on government supervision. Prepare the necessary needs to transform EDTL to public utility firms per 11 March 2020 government's resolution.

(b) Conduct EDTL human resource and facilities mapping.

(c) Develop proper and reflected legal frameworks that will allow for future electricity development, issue a reflective electricity tariff regulation for low-income families in rural areas.

(d) Develop an effective and participative revenue collection strategy, especially in rural areas.

(e) Invest in EDTL human resource capacity building by focusing on more specialized areas including power engineering, power plant engineering, engineering management, hydropower engineering and other renewable energy engineering disciplines, transmission and distribution engineering, geothermal engineering, and energy planning and policy.

(f) Establish Utility Regulatory Authority (URA) to overseen the electricity sector including policy planning and setting, policy implementation and evaluation, related electricity laws and regulations, formulate standards and accommodate customer needs and provide protection when their rights are violated as March 2020 government decree law.

(g) Improve the distribution facilities, starting a more decentralized power distribution system to avoid massive power cuts in large areas.

(h) Evaluate the state firm, Timor Gap to take role in fuel supply to the existing power generations to reduce state expenditure.

(i) Establish a taskforce to conduct a detail visibility study on hydropower, solar and gas power options and developing proper action plans for its implementation.

(j) Reformulate the power sector policy that reflects local characteristics with multi-dimensional effects.

Not urgent:

(k) Reform the electricity sector, specifically the generating segment, to allow private sector participation through public-private partnership.

(l) Develop and design the execution of reform policy through regionalizing the power generating system to avoid power loss and reduce massive destruction due to natural disasters.

(m) Increase alternative energy initiatives through research and development.

The above measures shall be organised into three different periods for the effective implementation based on its priority. It was thought that the short-term measures are most urgent with the period of 2020-2022, medium-term 2023-2025 and long term is from 2026 onwards. Table 3.15 outlines the periodical actions. The government can redefine these actions based on country`s plan.

Table 3.15 The periodical electricity policy implementation

Short term (2020-2022)	Medium term (2023-2025)	Long term (2026 onward)
• Review EDTL internal management, attributes more competencies and transform to public utility firm as March 2020 GovTL approval. • EDTL HR and facilities mapping and pay attention on rural electricity revenue collection. • EDTL HR capacity building in various degree of skills • Accelerate and improve distribution maintenance system and decentralize the power distribution system	• Issue reflective frameworks and tariff regulations that consider lower income families • Establish URA for overseen policy planning, setting, implementation and evaluation including customer protection as March 2020 approval law. • Timor Gap takes fuel supply roles to avoid unnecessary state loss • Establish a task force for conducting technical visibility study on hydropower, gas and solar photovoltaic • Review and reformulate the state electricity national policy	• Reform the electricity sector specifically generating segment to allow private sector participation through public-private partnership • Develop and design the execution of reform policy through regionalizing the power generating system that avoid power loss and reduce massive destruction due to natural disasters • Increase alternative energy initiatives through research and development.

Chapter (4)

Transportation and machining environmental assessment of using strong alkaline water for cooling as a few man-made disaster risk managements in manufacture environment at ordinary time

4.1 Introduction

Environmental problem is world`s biggest concern nowadays. One of the main contributory factors for inducing global warming is the consumption of energy, oil disposal from both lubricants and cooling during machining in manufactures and transporting goods. This resulted in producing several gas harmful pollutants including Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Nitrogen Oxide (NO_x), and Non-Methane Volatile Organic Compounds (NMVOC). Regarding to this, technologists, manufacturers and entrepreneurs are paying significant attention to the issue as it has become major concerns in recent years [4.1] [4.2]. Scholars [4.3] [4.4] studied the mentioned maters which considering some useful ways to reduce carbon dioxide emission that resulted from machining activities. Papers [4.5] [4.6] [4.7] [4.8] looked at eco lubrication and cooling method for machining activities that contribute to the earth conservation efforts. Although many advantages are suggested in the mentioned studies, more green measures are needed. To contribute to these, this study assessed the environmental impact of using Strong Alkaline Water (SAW) for cooling by focusing on both machining activities and transportation. The study used simple Life Cycle Assessment approach for assessing both proposed and the conventional cooling methods. The assessment results revealed that using SAW for cooling during machining has great environmental benefits as it reduces annual GWP by 72.93 %, acidification 98.18 %, ozone depletion 99.62 %, smog formation 85.69 %, eutrophication 50.0 % and human toxicity potential by 44.83 % compared to the conventional wet cutting method. The full content of this work was published in the Journal of Machine Engineering in 2018 [4.23]. This valuable assessment tools and SAW cooling system will be utilized by Timor Leste in near future for its academic and manufacturing activity needs.

4.2 The objective of the study

The overall objective of this study is to assess the environmental impacts of using SAW cooling method, which can enhance machine tool performances for the improvement of product quality, time saving, reducing energy consumption and low-cost production. This will contribute to the environmental protection efforts.

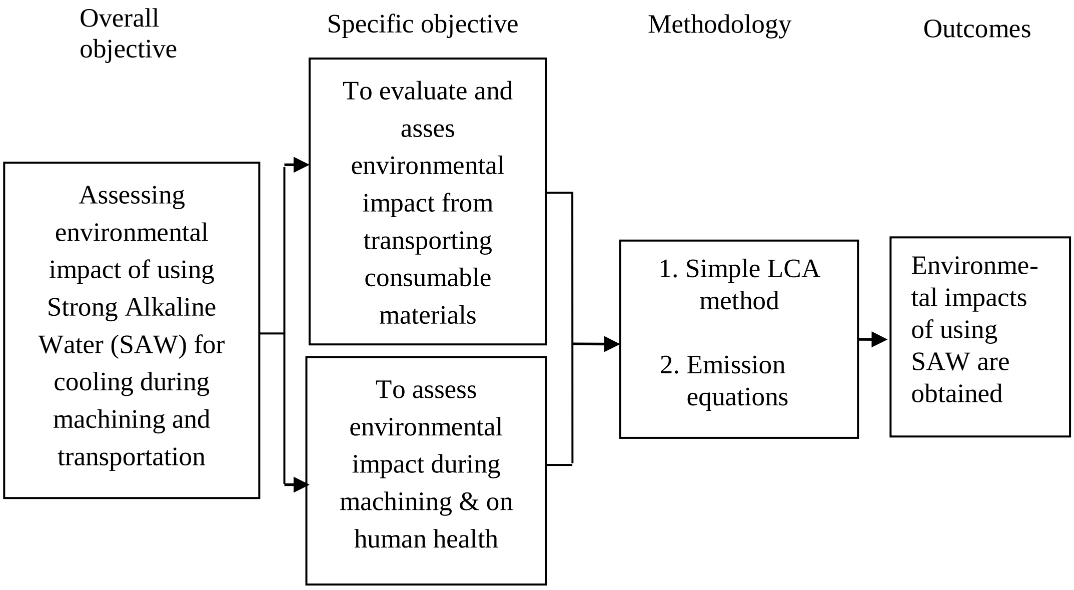
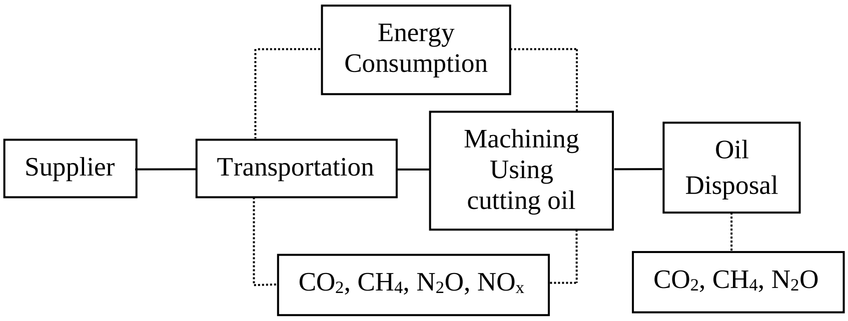


Fig.4.1 The schematic view of study coverage

Two main (Fig.4.1) objectives will be accomplished in this study; first to assess the environmental impact from transportation, second to assess the environmental impact during machining and compare with the conventional method. In addition, the assessment concept will be a reference point for Timor Leste, specifically teaching and learning activities at Universidade Nacional Timor Lorosae (UNTL).

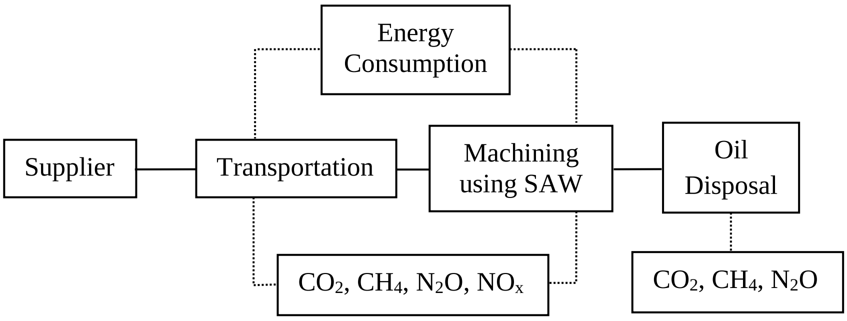
4.3 The scope and method of the study

Assessing the environmental impacts of using strong alkaline water was the focus of this study. Fig.4.2 shows a brief flowchart of the Life Cycle Assessment for both SAW and conventional cooling methods.



Note: Conventional supply: Cutting oil, Lubrication oil, Workpiece, Tools

(a) LCA for conventional cutting



Note: SAW supply: POCCA, Workpiece, Tools

(b) LCA for SAW cutting

Fig.4.2 The simple LCA approach for both conventional and SAW cooling methods

The transportation of cutting fluid and other consumable materials and machining activities are the focus of this study. However, it did not consider the original raw material extractions and workpiece and consumable materials production. It also does not consider the end waste and other environmental burdens after material lifetime. This simple LCA work is built based on the previous studies [4.9] [4.10] [4.11] which looks at the utilization of SAW for milling, drilling and turning cooling processes.

The assessment of environmental impact for this study focuses on the Green House Gas (GHG) emissions that resulted from transportation and machining activities. The emissions from pollutant gases of both conventional cooling and cooling assisted with SAW methods were calculated, it includes the used of lubricants for machining. The main functional unit for the calculations based on 1 km for transportation of cooling items and a 1-year period of machining.

4.4 Emission equations for environmental impact calculations

The environmental impact calculations were focusing on several gas pollutants and their potential impacts including global warming, acidification, ozone depletion, smog formation, eutrophication, and human toxicity. The first calculation was about the emissions that resulted from the transportation of SAW compounds and other related consumable materials from the supplier to machining centre at NUT, second the emissions that resulted from energy consumption of machining activities and finally it calculated the emissions from oil disposals.

By using the Eq.4.1, it calculated the emissions of CO_2, CH_4, N_2O, NO_x, and NMVOC based on fuel consumption for transportation. Meanwhile, Eq.4.2 was used for calculating the emissions for energy consumption during machining. On the other hand, the Eq.4.3 and Eq.4.4 were used for calculating oil disposal emissions. Specifically, CO_2 emission from cutting oil consumptions during machining used Eq.4.3 and CH_4 and N_2O emission as oil consumption was calculated by using Eq.4.4.

$$EG\ (kg\text{-}i) = L\ (km) \times EF\ (kg/km) \tag{4.1}$$

Here, EG is the Emitted Gases, which is symbolized with *i*. These gases are Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Nitrogen Oxide (NO_x), and Non-Metallic Volatile Compound (NMVOC). Meanwhile, the L is denoted for distance traveled in kilometer and EF is the emission factor per kilometer. Based on the fuel consumption per kilometer, petrol: 32.7 MJ/KM and diesel: 35.9 MJ/KM) [4.17], it calculated the emissions.

$$EC_i = \text{EF (kg-}i\text{/kWh)} \times W_E \text{ (kWh)} \tag{4.2}$$

Here, the EC denotes the energy consumption emissions, which indicated in previous and symbolized with *i*. Meanwhile, the EF is the emissions factor for each respective gas per kilo what hour energy. On the other hand, W_E is the total amount of consumed energy in kWh. Therefore, it calculates the machining activities and the emission based on per kWh consumption.

$$CO_2\text{ E (kg-}CO_2\text{)} = \text{DO (k}\ell\text{)} \times \text{CV (GJ/k}\ell\text{)} \times \text{EF(t-C/TJ)} \times (44 \div 12) \tag{4.3}$$

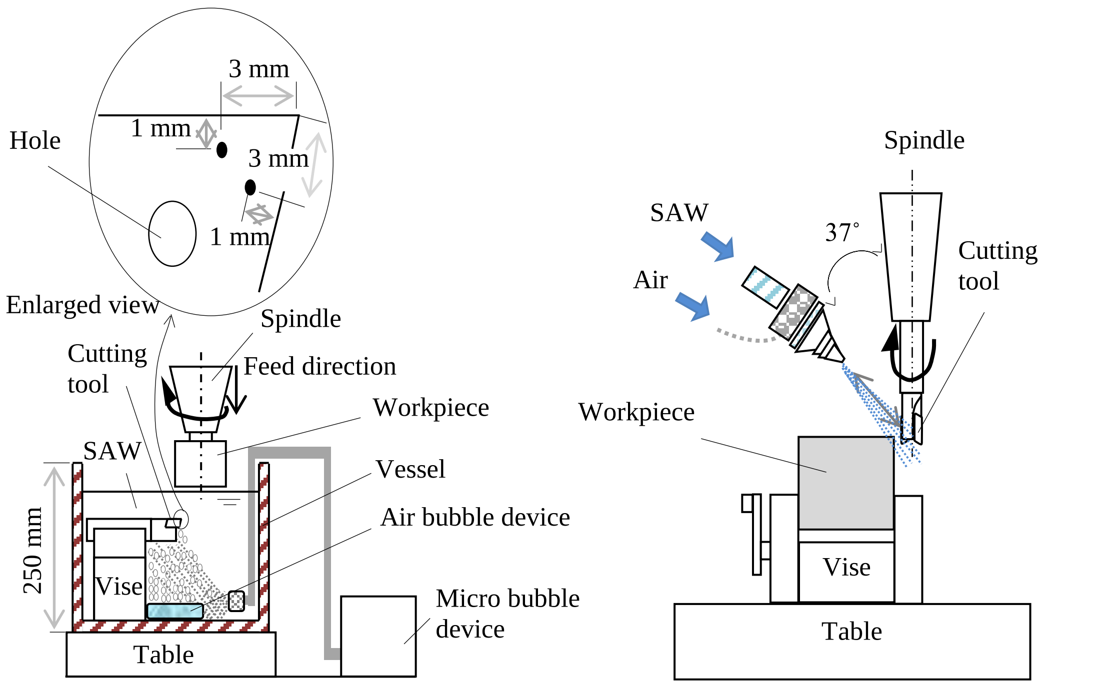
The application of this calculation is for carbon dioxide emission from oil disposal during transporting consumable goods and oil for lubrication for machining. Here, E is the emission for CO_2 in kilogram, DO is the disposal oil in kiloliter, CV is oil calorific value in Giga joule per kiloliter and EF is the emission factor for oil.

$$E_i = \text{Oil (k}\ell\text{)} \times \text{Calorific value (GJ/k}\ell\text{)} \times \text{EF (kg-}CH_4\text{/TJ, kg-}N_2O\text{ /TJ)} \tag{4.4}$$

As stated in the [4.23], the related amount of produced gases during incineration was used for oil disposal emission calculations. For the potential impacts, it calculated the global warming, acidification, ozone depletion, and photochemical smog formation based on the total emissions from transportation, machining and oil disposal. However, in this calculation, it did not consider the disposal oil at the end of life.

4.5 Machining assisted with strong alkaline water cooling

There are some cooling methods exist, strong alkaline water however is an innovative method as it has less environmental and human health impacts [4.9]. Although this cooling method has not widely used in industries, some are showing their interest in applying the SAW as a new cooling method. This is because it offers significant advantages. As revealed in Table 4.1 the property of strong alkaline water consists of 99.9 % water and only 0.1 % of Potassium Carbonate (K_2CO_3), it has a high specific heating value and best for medium cooling purposes. Strong alkaline water is colourless with a pH of 12.5, the dynamic viscosity of 1.002×10^{-3}Pa.s, and 4.184 J/g ˚C of specific heat. The Fig.4.3 illustrates the process of applying the SAW on cutting during machining. This visualization process of SAW application during machining was covered in the previous study [4.23].



a.Experimental set-up for measuring tool temperature [4.2] [4.10] [4.11]

b. Experimental set-up for measuring tool life and surface roughness [4.12]

Fig.4.3 Practical application of SAW for machining

Both workpiece and cutting tool are immersed in SAW as shown in the Fig.4.3a, on the other hand the Fig.4.3b depicts that with support of air the cooling is supplied to the cutting zone with nozzle angle of 37˚ from the centre of spindle and 225 mm between cutting tool and nozzle [4.10] - [4.12]. The usage of SAW will give enormous benefits to machining activities. The researches [4.9] [4.10] stated that the mixture of SAW with air can result high heat transfer coefficient than cooling using lubricant oil; hence the evaporation cooling will be much better when applying SAW. Researchers found that with high specific heat, large heat would be necessary for the changes of SAW temperature and micro bubble; this helps to reduce the heat that presents on the workpiece and tooltip. A previous experiment [4.10] on immersed bench lathe machine indicated that using strong alkaline water not only increases cooling efficiency and tool life but also improves the surface roughness of a workpiece.

In addition, the inhibitions of corrosion, less heat on the workpiece as well as gives superior final quality products are among the benefits of deploying SAW. With the pH concentration of 12.5, SAW could able to inhibit the corrosion of materials used for the machine tool needs. In Table 4.2 [4.10] it shows the corrosion properties of used machine tool materials that tested for two months at the NUT machining centre. The used for testing pH for normal water, common alkaline water and SAW were 7.0, 10.0 and 12.5 respectively. The two months tested results show that all materials were not corrode when submerged in the SAW except aluminium. However, it corrodes when in normal water and alkaline water (Table 4.2).

Table 4.1 Properties of strong akaline water

Description	Content
Assistant compound	Potassium carbonate (K_2CO_3)
Concentration	99.9 % water, 0.1 % K_2CO_3
pH	12.5
Dynamic viscosity	1.002 x10^{-3} kg/m.s
Specific heat	4.184 J/g˚C
Color	Colorless
Oiliness aspect	None

Table 4.2 Corrosion properties of the materials tested in various pH of water [4.10]

	Materials	Water (pH 7.0)	Alkaline water (pH 10.0)	Strong alkaline water (pH 12.5)
○ = No change × = Corrode	Titanium	○	○	○
	Ti6Al4V	○	○	○
	Inconel718	○	○	○
	Carbide	○	○	○
	S45C	×	×	○
	Aluminum	×	×	×
Changed color	Copper 	Light brown 	Brown 	Dark brown 
	Brass 	Light green 	Yellowish gray 	Dark green 

Hence, it is considered that strong alkaline water is better at inhibiting corrosion compared to normal water with pH 7.0 and common alkaline water with pH 10.0. In addition, both copper and brass showed discoloration. Consequently, precaution is required during machining of both copper and brass. The previous research reported that tool life increases by 2.4 times compared to conventional cooling when using SAW [4.11]. Meanwhile, the studies [4.10], [4.12] indicated that tool life is prolonged by 2.5 times when immerse bench lathe and 2.6 times with optimum air quantity.

4.6 The assessment of strong alkaline water impacts

In this part of the study, it presents the assessment results of SAW impacts on the environment. The emission calculations are based on the transportation of consumable aspects such as Pocca, cutting tools, lubricant oils, energy consumption during machining and oil disposals for machine tools operation needs including milling machine, turning machine and drilling machine and SAW machine producer. The study does not consider the end disposal of SAW as well as the extraction of raw material related energy usages and disposals at the initial stage.

4.6.1 Environmental impact assessment

The section 4.6.1.1 and 4.6.1.2 present the specific discussion for environmental impact assessment. It elaborates both emissions from energy consumption of both petrol and diesel and the brief discussion on human effects respectively.

4.6.1.1 Transportation assessment

Transportation is a sector where greatly contributes to human activities and economic growth, yet it has huge environmental impacts due to the large fuel consumption and release significant gas pollutants into the atmosphere annually. From the IPCC fifth report, it highlighted that the transportation sector itself pumps emissions around 10.2 % globally [4.13]. Generally, both petrol and diesel are the common fuels for the transportation consumption needs; therefore, the emission calculation for this section was based on the amount of mentioned fuel consumption during transporting consumable materials and strong alkaline water compound from supplier (Tokyo) to the site, Nagaoka University of Technology machine shop in Nagaoka, Niigata Prefecture. Table 4.3a shows the emission factor for different fuel consumption (petrol and diesel) as well as the total emissions produced from six different pollutant gases. It indicates that the majority emission resulted from transporting the consumable materials and tools is from pollutant gas of Carbon Dioxide, petrol 90.4 kg-CO_2, and diesel 80.9 kg-CO_2. Meanwhile, the emission for the methane gas is 0.0045 kg, N_2O is 0.0145 kg, NO_x is 1.15 kg, which is in the second place of gas pollutants. On the other hand, Particulate Matter and Non-Metallic Volatile Compounds are 1.47×10^{-5} kg and 0.0826 kg respectively. Here it needs to state that emissions were calculated for traveled distance of 413 km, which is from the goods supplier sites in Tokyo to the study sites of Nagaoka University of Technology (NUT) in Niigata Prefecture. On the other hand, Table 4.3b reveals the energy conversion factor and total energy consumed for the mentioned distance. The study shows that the energy used as result of both petrol and diesel consumptions are 13,505 MJ and 14,827 MJ respectively.

Table 4.3 Emission factor for fuel consumption from Tokyo to NUT [4.23]
(a) Emitted emission for 413 km

Pollutant Gases	Emission factor (EF)*		Total emission (For 413 km)	
	Petrol kg/km	Diesel kg/km	Petrol kg	Diesel kg
CO_2	0.219	0.196	90.4	80.9
CH_4	3.50×10^{-5}	1.10×10^{-5}	0.0145	0.0045
N_2O	3.60×10^{-5}	3.50×10^{-5}	0.0149	0.0145
NO_x	2.20×10^{-5}	2.78×10^{-3}	9.09×10^{-3}	1.15
PM	0.50×10^{-8}	3.56×10^{-8}	2.07×10^{-6}	1.47×10^{-5}
NMVOC	0.80×10^{-5}	2.00×10^{-4}	3.3×10^{-3}	0.0826

*EF of CO_2 [4.14]; CH_4, N_2O, NO_x, and NMVOC [4.15] and PM [4.16]

(b) Energy consumed for 413 km [4.23]

Fuel	Energy conversion factor, (ECF) MJ/km*	Total energy consumption for 413 km MJ
Petrol	32.7	13,505
Diesel	35.9	14,827

* ECF: Energy Conversion Factor [4.17]

The study calculated and inventoried the exhausted emissions of environmentally harmful pollutant gases such as CO_2, CH_4, N_2O, NO_x, Particulates and Non-Methane Volatile Organic Compounds (NMVOC) from both petrol and diesel consumption per kilometer. It obtained the emissions from these gases by using Eq.4.1. The Table 4.3a outlines and presents the quantity of fuel consumed, and emitted emissions. It represents the values for 413 km one-way trip distance from the supplier in Tokyo to machining center in Nagaoka. From these values, it calculated the annual emissions by multiplying these values with order frequency of consumable items and workpiece materials. It was assumed that transportation is shared by companies that exist in

Nagaoka. According to the Nagaoka city there are around 217 companies [4.23] in the area that involve in metalworking operation. It was assumed that 50 % of the companies are using conventional method cooling and other half are utilizing the SAW cooling method. It estimated that at least around 10 companies share per order and similarly emitted emissions from the shipping actions. The Table 4.4 shows the annual order frequencies of machine tool consumable materials and SAW compounds. The tools and consumables order for the conventional method are including cutting oil 12 times, grease 3 times, cutting tools 2 times and workpiece 12 times annually. Meanwhile, for the proposed SAW option, the order frequencies are cutting tools 2 times, workpiece 12 times and POCCA (Potassium Carbonate K_2CO_3 that ionized with water to produce SAW) is 2 times. Therefore, as indicated in the table, the total annual order frequencies for one company for both conventional cooling method and strong alkaline cooling method are 87 times and 48 times respectively. It must be asserted here that the mentioned total annual order frequency is assumed for the needs of 3 machine tools per company. With these considerations and assumptions, the energy required and emitted emissions from transporting goods for the machine tools are calculated and shown in Table 4.5.

Table 4.4 Annual tools and consumable order frequencies per company [4.23]

Cooling type	Tools and consumables	Order frequency for 1 machine (times/year)	Total order frequency for 1 company and 3 machines(times/year)
Conventional wet cutting	Cutting oil	12	87
	Grease	3	
	Cutting tools	2	
	Workpiece	12	
Cutting assisted with SAW	Cutting tools	2	48
	Workpiece	12	
	POCCA	2	

Table 4.5 Total emission and energy consumption during transportation [4.23]

(a) Total shared emission for 10 companies [4.23]

Pollutant gases	Conventional cooling method			SAW cooling method		
	Petrol* kg/year	Diesel* kg/year	Exhaust quantity ** kg/year	Petrol* kg/year	Diesel* kg/year	Exhaust quantity ** kg/year
CO_2	1574	1409	1524	868	777	841
CH_4	0.250	0.079	0.20	0.139	0.04	0.11
N_2O	0.260	0.25	0.26	0.143	0.14	0.14
NO_x	0.160	20.0	6.11	0.087	11.0	3.37
PM	3.59×10^{-5}	2.56×10^{-4}	0.00010	1.98×10^{-5}	1.4×10^{-4}	0.00006
NMVOC	0.0570	1.44	0.47	0.032	0.79	0.26
Total shared emission kg			1,531			845

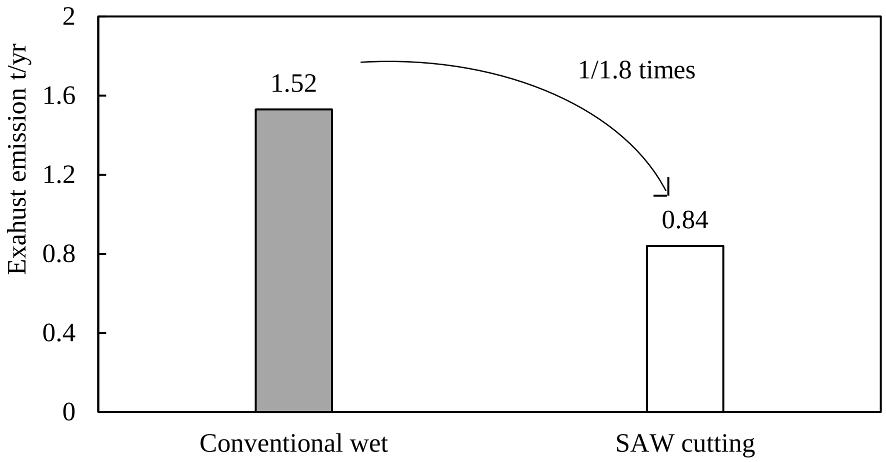
*Emission= EF × Distance travelled × 2 × Order frequency / 10 companies
** This quantity is obtained based on the ratio of fuel type in Japan. Petrol and diesel are 70 to Number of automobiles by fuel type [4.18].

(b) Total shared energy consumption for 10 companies [4.23]

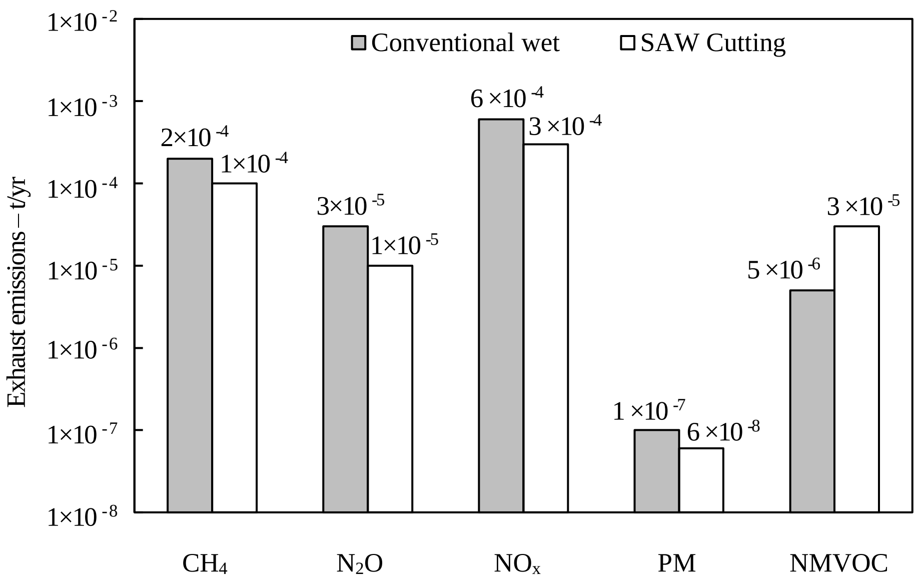
Description	Transportation for conventional		Transportation for SAW	
	Petrol#	Diesel#	Petrol#	Diesel#
Energy MJ/year	234989	257985	129649	142336
Total shared energy MJ/year ##	241887		133455	

#Energy usage = ECF × Distance travelled × 2 × Order frequency / 10 companies
This quantity is obtained based on the ratio of fuel type in Japan. Petrol: 70 and diesel: 30. Number of automobiles by fuel type [4.18].

The Table 4.5(a) shows the one-year emission sharing among 10 companies. The presented emission estimation from the transportation that shared among 10 companies shows that CO_2, CH_4, N_2O, NO_x, PM, and NMVOC pollutant emissions exhausted annual amount of emissions 1524 kg, 0.20 kg, 0.26 kg, 6.11 kg, 0.00010 kg and 0.47 kg respectively. On the other hand, the emission generated from these gases for the proposed cooling method are 841 kg, 0.11 kg, 0.14 kg, 3.37 kg, 0.00006 kg and 0.26 kg respectively. The total annual transportation amount of emission shared by companies for conventional cooling method is 1,531 kg and SAW cooling is 845 kg. Meanwhile, Table 4.5(b) presents the calculated results of shared annual energy between 10 companies. It shows that the energy consumed during transportation for the conventional cooling method is 241,887 MJ/year. On the other hand, it reveals that the SAW option consumed 44.8 % less than the conventional cooling method or 133,455 MJ/year. In other words, the energy consumed during transportation can be reduced by 108,432 MJ when using the strong alkaline water-cooling method. By using the Japanese automobile fuel type ratio, petrol and diesel 70 to 30, it obtained energy consumption and gas emission figures from the transportation analysis [4.18].



a. CO_2 exhaust emission [4.23]



b. Exhaust emission of other gases

Fig.4.4 Emission of different gas contents per year for transportation [4.23]

The CH_4, N_2O, NO_x, PM, and NMVOC pollutant gases are essential. The Fig.4.4a and Fig.4.4b show the comparison of exhaust emissions for consumable materials for both cooling methods. The Fig.4.4a reveals the carbon dioxide emissions for both. It depicts that the produced annual CO_2 emission from transportation for conventional wet cutting is about 1.53 tons. Meanwhile, the proposed cooling method of SAW is 0.84 tons, which is about 1/1.8 times less. According to the Fig.4.4a, the CO_2 emission from transportation could reduce up to 0.69 tons when using strong alkaline water for cooling. On the other hand, Fig.4.4b reveals the emitted emissions from other gases including CH_4, N_2O, NO_x, PM and NMVOC for both SAW and conventional methods.

Both figures show that using the proposed cooling method, the emission from all pollutant gases decrease by 44.8 %. This is because of the fewer order frequencies of consumable items and SAW compound materials. It is important to note that the exhaust emissions for transportation depends on order frequencies and the sharing emission loads depend on the number of companies involved in material ordering.

4.6.1.2 Machining assessment

This section discusses the emitted emissions as result from electricity consumption during machining for both cooling methods. It used the recorded energy for milling machine, drilling machine, and turning machine for emission calculations. The Eq.4.2 was used to calculate the pollutant gas emissions level of the CO_2, CH_4, and N_2O. The Table 4.6a and 4.6b show the emission calculation results for both options during machining.

For the conventional cooling method, the used emission factor for the calculation was based on hourly energy consumption (CO_2: [4.19], CH_4 and N_2O: [4.20]), the working condition was assumed 8 hour working days and 250 days in a year. It obtained the emission factor of 0.600 kg-CO_2 for carbon dioxide from a Tokyo electric company [4.19]. Meanwhile, the 7.09×10^{-6} kg-CH_4 and 3.96×10^{-6} kg-N_2O

emission factors for both CH_4 and N_2O were adapted based on an energy/kWh that used in Japan [4.20]. As shown in Table 4.6a, the 3.6 kW machine and 1.2 kW oil pumps power capacities were used for the milling operations. Meanwhile, the pumps with a power capacity of 1.2 kW, cooling device with a power capacity of 2.2 kW and 0.75 kW were utilized for the drilling operations. On the other hand, the 0.75 kW bench lathe machine, 1.2 kW oil pump and 2.2 kW oil cooling device were used for turning operations.

Table 4.6 Emission from electricity usage for both cooling methods [4.23]

(a) Electricity usage emissions for conventional cooling

Exhaust emission	Emission factor kg-i/kWh	Milling (4.8 kW)		Drilling (4.15 kW)		Turning (4.15 kW)	
		Total power kWh/year	Annual emission kg	Total power kWh/year	Annual emission kg	Total power kWh	Annual emission kg
CO_2	0.600	9600	5760	8300	4980	8300	4980
CH_4	7.09×10^{-6}		0.068		0.059		0.059
N_2O	3.96×10^{-6}		0.038		0.033		0.033
Total emission kg		5760		4980		4980	

(b) Electricity usage emissions for SAW cooling [4.23]

Exhaust emission	Emission factor Kg/kWh	Milling (5.66 kW)		Drilling (2.81 kW)		Turning (2.0732 kW)	
		Total power kWh/year	Annual emission kg	Total power kWh	Annual emission kg	Total power kWh/year	Annual emission kg
CO_2	0.600	9839	5903	4139	2483	2706	1624
CH_4	7.09×10^{-6}		0.069		0.0294		0.0192
N_2O	3.96×10^{-6}		0.039		0.0164		0.0107
Total emission kg		5903.11		2483.05		1624.1	

EF: CO_2 [4.19]; CH_4 and N_2O [4.20].

Note: work condition, working days: 8 hr × 250 days
SAW generator operates 25 hr/ yr

The total power consumed for milling, drilling and turning were 9,600 kWh/year 8,300 kWh/year and 8,300 kWh/year respectively. These were obtained based on the calculations, for example, for milling machine: ((3.6 kW + 1.2 kW) × 8 hr × 250 days). Meanwhile, for the proposed cooling method, the total annual electric used for milling machine, drilling machine, and turning machine were 9,839 kWh, 4,139 kWh and 2,706 kWh respectively. For the SAW emission calculations, it considers the total annual electric used for machine tools, oil pump, and the micro-bubble device. This was based on the 8 hour per day and 250 days in one-year assumption, however, the SAW device was only operated 25 hr/yr, this is because the SAW producer device generates 20 ℓ of SAW, it needs 2 hours and 10 minutes and water changed once a month. The machine tool capacities for the SAW option were 3.6 kW milling machine and 0.75 kW drilling and bench lathe machines. It was used together with 0.56 kW micro-bubble devices and 0.75 kW water pumps as well as 0.75 kW of the strong alkaline water device. Also, for the turning process, a 0.0132 kW chip removal pump was used during the operation.

The SAW device can able to produce 20 ℓ in 2 hours and 10 minutes, the water changed every month, so overall the annual duration for producing SAW is around 25 hours. Based on the above-outlined parameters and machine capacities, the total emissions for both the cooling systems during the machining were calculated and obtained. The results reveal that total annual emission from the conventional cooling methods for three machine tool operations is 15,720 kg. Meanwhile for the proposed SAW cooling is around 10,010 kg. From these results, it shows that by using SAW water will emit less emission to the atmosphere by around 5,710 kg annually or 36.32 %. On the other hand, Table 4.7 presents the emission calculation results of used oil for lubrication and oil that disposed annually for the conventional cooling methods. Again, in this part it considers three different machine tool operations including milling, drilling, and turning. The table shows that the total used and disposed oil from these machines were 1,040 ℓ for milling, 1,040 ℓ for drilling and 230 ℓ for turning.

Table 4.7 Emission from oil usage and disposal for conventional cooling [4.23]

Pollutant gases	Emission factor t-C/TJ, kg-CH_4/TJ,	Calorific value MJ/ℓ	Milling		Drilling		Turning	
			Total disposed oil ℓ/year	Annual emission kg	Total disposed oil ℓ/year	Annual emission kg	Total disposed oil ℓ/year	Annual emission kg
CO_2	19.2	40.2	1040	2943	1040	2943	230	651
CH_4	0.83			34.7		34.7		7.67
N_2O	0.58			24.3		24.3		5.36
Total emission kg			3002		3002		664	

Emission factor [4.15].

It calculated three different gases including CO_2, CH_4 and N_2O. It used Eq.4.3 to obtain the emission for carbon dioxide and for both CH_4, and N_2O were using Eq.4.4. It is important to be noted that the SAW cutting does not require oil, therefore the oil emission calculation for this, was not applicable and it was only for the conventional method. The emission factor for the calculation was obtained from the Japan Ministry of Environment report. It used 40.2 MJ/ℓ for oil calorific value for the calculations [4.14]. It was assumed that the process usages at least 680 ℓ of cutting oil for both milling and drilling operations. Meanwhile, the turning operation roughly requires at least 170 ℓ in one year. The amount of cutting oil for refilling the milling, drilling and turning machines were around 360 ℓ, 360 ℓ and 60 ℓ respectively. It was estimated that the total disposal oil for both milling and drilling around 1040 ℓ and turning 230 ℓ. The study shows that the annual total emissions for three machine operations that resulted from used and disposal oil were 3002 kg for milling, 3002 kg for drilling and 664 kg for turning. Fig.4.5 reveals the emissions comparison for both conventional cooling method and cutting assisted with strong alkaline water regarding the transportation, machining and lubrication and disposal oil. The figure shows that for the transportation, the greenhouse gas emission that shared by 10 companies regarding both conventional cooling and SAW are 24 t/year and 11 t/year respectively.

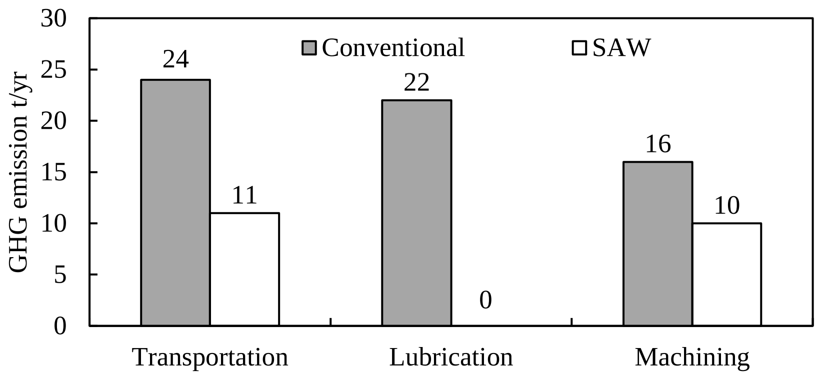


Fig.4.5 Overall GHG emission comparison for both cooling methods

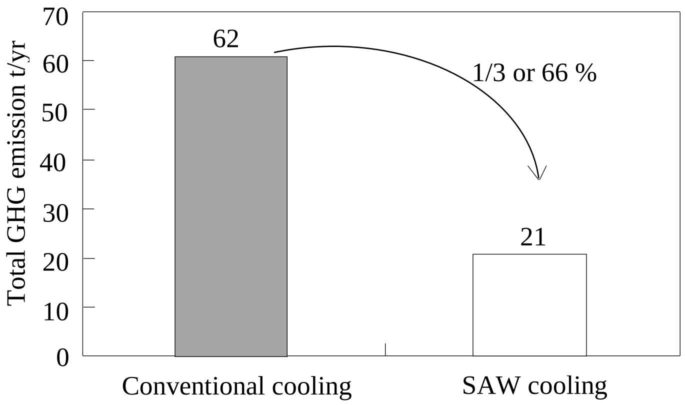
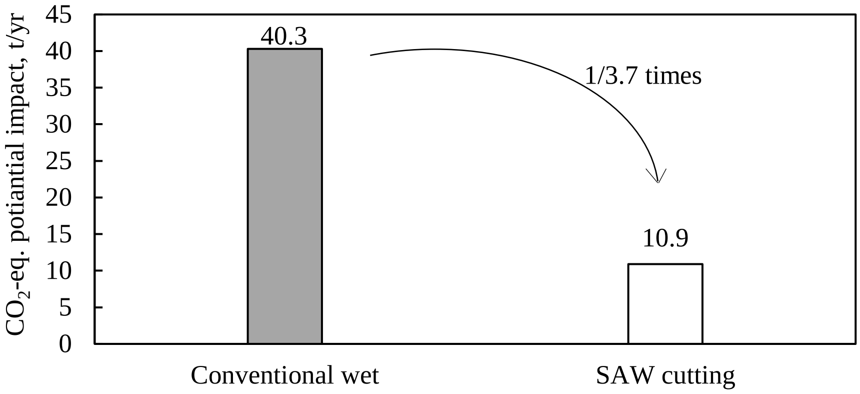
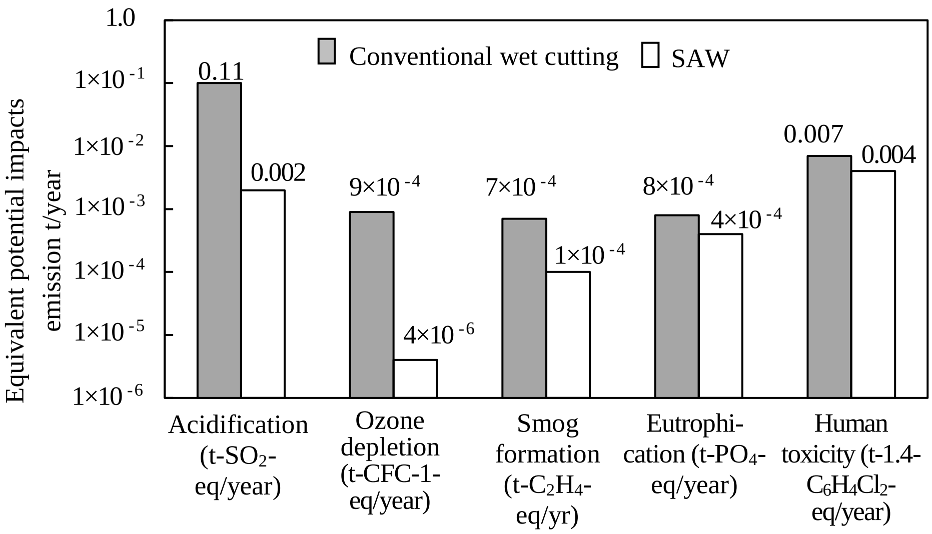


Fig.4.6 Total GHG emissions from both cooling methods

On the other hand, the Fig.4.5 reveals the overall emission results for the machining, it shows that the total Green House Gas emission for conventional cooling is 16 t/year and for strong alkaline water-cooling method is 10 t/year, which is around 62.5 % reduction. Meanwhile, the Green House Gas emission in regard to the disposal and used oil during the machining as lubricant, the conventional cooling method holds 22 t/year. In contrast, zero emissions for proposed SAW cooling method, as it does not required oil during machining. Therefore, it is 100 % emission-free for oil usage. The total greenhouse gas emissions were estimated for all activities, transportation, machining and cutting oil and oil disposals. The Fig.4.6 reveals the total emission of both cooling methods. It shows that the total greenhouse gas emission resulted from the conventional cooling method is 62 tons per year. Meanwhile, the total greenhouse gas emissions obtained from the proposed cooling method of strong alkaline water is 21 t/year.



(a) CO_2 equivalent potential impact



(b) Other gases potential impacts

Fig.4.7 Impact potential of emissions from both conventional and SAW cooling

The Fig.4.7a and Fig.4.7b reveal the calculation results of the impact equivalent potentials of emissions from the mentioned three different categories. Here, it describes both impact potentials of the conventional method and SAW method. The Fig.4.7a shows the global warming potential equivalent impacts for both cooling methods for CO_2. It depicts that for the conventional cutting method; the global warming potential equivalent impact is 40.3 t-CO_2-eq/year. Meanwhile, the proposed SAW cooling is 10 t-CO_2-eq/year, which is around 75.2 % less, compared with the conventional method. On the other hand, the Fig.4.7b shows that for the acidification impacts, the equivalent emission for SAW reduced by 98.18 %, which is 0.108 t-SO_2-eq/year. While the Ozone depletion impact reduced by 0.894 t-CFC-1-eq/year and the smog formation impacts are 0.6 t-C_2H_4-eq/year. On the other hand, the impact potential for eutrophication is 0.4 t-PO_4-eq/year and human toxicity reduced to around 48.2 %.

4.6.2 Human impact highlights

It needs to assert that, there was no specific work done on these related human health impacts. The related cancer risk aspects as well as total exposure risk are not specifically considered and calculated as the used compound for SAW has no specific chemical content as suggested by Mines (2014) [4.24]. It simply highlighted some important aspects in regard to human effects of using strong alkaline water when having contact with the compounds during machining activities. As it was noted from study [4.23], the compound which was used for producing SAW is Potassium Carbonate (K_2CO_3) of 0.1 % and diluted into water with a portion of about 99.9 % (Table 4.1).

Table 4.8 Effect of SAW to human health

Action	Risk level				Possible causes	Measures
	None	Low	Medium	High		
Skin contact or touch (Hand and face)	O				Minor irritation for some people	Cleaning and washing with proper detergent or soup is needed after long exposure with SAW
Eye contact		Δ			Minor irritation may occur	Wearing mask is highly recommended when encounter with SAW
Drink		×			Minor stomach problems may occur	Should avoid drinking SAW and strongly prohibited
Inhale	O				No problem	-
Smell	O				No indication of smell causes	-

O: No problem Δ: Avoid × : Prohibited

This indicates that the chance of having a health problem will be very minim when inhaling and skin contact during encountering SAW. However, it needs to note that irritation to skin may occur for some individuals. Regarding this, it is strongly recommended to use masks and gloves when exposing to SAW during machining activities, and not recommended to taste or drink SAW. It is not safe and can cause some stomach problems. By saying these, it is necessary to have a depth investigation on human health impacts in the near future.

4.7 Summary

The conventional cooling method of using oil has significant environmental impacts due to large emissions that produced. This is serious issue which has become global problem that need proper measures and solutions. There are several measures and ways for addressing cooling system in manufactures, using strong alkaline water is one of them which is considered as a most suitable and sustainable method for industry needs. The demand for using such environmentally friendly cooling alternative is significant. Regarding this, the study was conducted to explore the impacts of mentioned cooling option specifically on both environment and humans. It sought to compare both cuttings using strong alkaline water and using conventional wet cutting. The results from this study proved that the use of strong alkaline water as a coolant has positive impacts on both environment and human health compared with conventional cutting method. However, it recognized that further investigation regarding the impact of SAW on human health is required. Some specific summary from the study are:

(1) The strong alkaline water-cooling method uses less resource for machining activities.

(2) Most emissions are resulted from transportation aspect. This indicates that fuel alternatives, travel route, and better shipping planning are needed.

(3) Using SAW for cooling reduces annual global warming potential by 72.93 %, acidification potential by 98.18 %, ozone depletion potential by 99.62 %,

smog formation potential by 85.69 %, by eutrophication potential 50.0 % and human toxicity potential by 44.83 % compared to the conventional cooling.

(4) The assessment approach and the application of SAW for manufacture cooling are relevant and can be applicable in Timor Leste. This cooling method is one of the global warming countermeasures that needed by the country in near future.

Chapter (5)

Investigating the effective application of previous earthquake data and its consideration for machine tool disaster adaptation as risk management in manufacture environment due to natural disasters

5.1 Introduction

A natural disaster is an event that occurs beyond human capacity. It is a big negative event that resulting from the natural process of the earth. There are many different types of natural disasters related to geophysical, hydrological, meteorological and climatologically [5.1] [5.2]. According to [5.2] the natural disaster from geophysical aspects includes earthquakes, volcano and mass movements such as rock-fall, landslide, avalanche, and subsidence. The natural disaster from a hydrological perspective is flooding (general flood and storm surge or coastal flood). Meanwhile, storm such as tropical cyclone, extra-tropical cyclones, and local storms are part of the meteorological natural disasters. In addition, the extreme temperature (heatwave, cold wave, and extreme winter condition) and drought or wildfire such as forest fire and land fire are categorized as climatologically natural disasters.

The most frequent natural disasters that occurred in many parts of the world are including flooding, earthquake, forest fire, landslide, tsunami and cyclones. These natural disasters have huge negative impacts on various aspects from economic to social, from the environment to properties. For example, in India, a devastating flood in North India in June 2013 has resulted in more than 5, 700 people [5.3] lost their lives. Meanwhile, in May 2016, flood disasters occurred in Sri Lanka and have resulted in 92 fatalities, destroyed 502 buildings and over 319 thousand people displaced from their homes [5.4]. It repeated in May 2017, at least 180 deaths, 99 were missing and around 122 were injured [5.4].

In memories, several large earthquakes have affected many countries including Japan. The country was shocked by three large earthquake disasters several years ago and it brought serious problems for the country. These earthquakes were including Hanshin & Awaji earthquake in 1995 [5.5], the Chuetsu earthquake in 2004 [5.6] and the Higashi-Nippon earthquake in 2011 [5.7]. Many people lost their lives and serious damages to their properties by disasters. The damages that caused by these earthquakes were highlighted and reported [5.8], active measures and plans for the revival of countries' economy and social wellbeing were performed [5.9], and recently Japan is gradually recovering from the lost and destructions. Now disaster measures for the future is continually performed by using previous experiences. On the other hand, immediately after the earthquake disasters, it was very difficult to manufacture products in the actual place of each earthquake site; this then has seriously affected the Japanese economy [5.9]. Therefore, many people feel and think that the Japanese industry and economy with the patience of an earthquake are necessary for the future of Japan [5.11], [5.12].

In this study, a specific focus was given to earthquake disasters in Japan. It investigated the effective application of previous earthquake data and support regarding a machine tool during earthquake time. Earthquake data for Hanshin & Awaji large earthquake disaster in 1995, Chuetsu large earthquake disaster in 2004 and Higashi-Nippon large earthquake disaster in 2011 were firstly gathered and considered. Study then proposed several methods for analysis regarding the behavior of machine tool structure during an earthquake through a mathematical analytical model for calculating its' motion behaviors including parallel motion, rotational motion and overturn motion. The impact of the earthquake on machine tool regarding the mentioned motions was then evaluated from developed a mock-up structure. The analysis model based on the dynamic forces due to the parallel and rotational motions experienced by machine tool during an earthquake was essential. It deployed the 2004 Chuetsu earthquake data for the mock-up vibration study; this was due to its large vector acceleration, which is 2 times higher than the other two earthquake data.

Therefore, a set of reliable risk assessment criteria for machine tools become available. The detail of this work has published in WIT Press and WIT Transactions [5.17] and [5.18]. The concept of analyzing machine tool motion behavior is very important for teaching and learning activities, as well as research needs in Timor Leste. Also, the relationship between earthquake and manufacture is essential for the country in future.

5.2 The study objective and methodology

The main objective of this study was to set risk assessment criteria for machine tool prevention from displacement and overturning during an earthquake occurrence. The specific aim of the study was to analyze machine tool sliding behavior in parallel, rotational and overturning motions through both mathematical models and structure vibration experimental evaluation. The Fig.5.1 shows the brief overview of the study objective and its approaches.

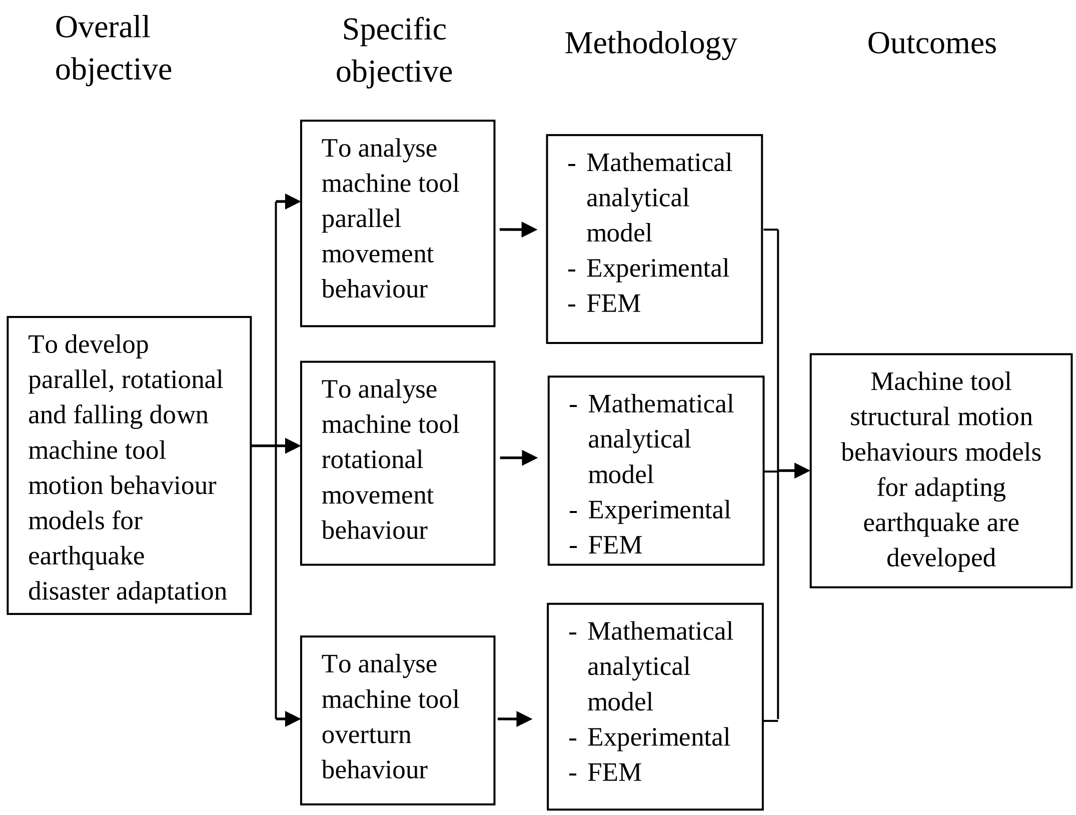


Fig.5.1 The schematic view of study objective and approaches

5.3 Review Japan real large earthquakes data

Here it is important to assert that there are many significant large earthquakes occurred in Japan. However, due to the data accessibility constraints, this study considered and utilized three Japan real earthquake data. The aforementioned large earthquake data are the Hanshin & Awaji large earthquake data, the disaster occurred in 1995 [5.13], the Chuetsu large earthquake data, this large and unforgettable disaster occurred in 2004 [5.13], and the last large earthquake data that used is the Higashi-Nippon large earthquake data, this unfriendly disaster occurred in 2011 [5.13]. It is clear that acceleration is the most important dimension in analyzing characteristics or behavior of any seismic activities. Therefore, this study used the acceleration data for mentioned earthquakes. The relationship between the earthquake acceleration and time for the large earthquakes is shown in Fig.5.2a, Fig.5.2b and Fig.5.2c. Here, Fig.5.2a shows the relationship between the three-earthquake acceleration and time in the North-South direction. It shows in the figure, the relationship for Higashi-Nippon large earthquake, which occurred in Ibaraki, reveals in light blue color, the Chuetsu large earthquake that occurred in Niigata is in pink color. Meanwhile, the Hanshin and Awaji large earthquake, which occurred in Hyougo is depicted in black color.

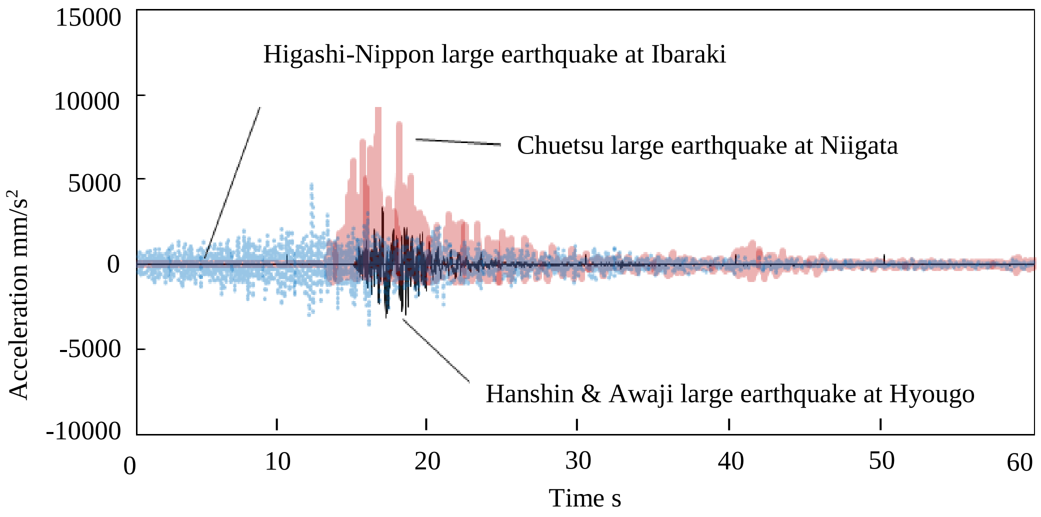


Fig.5.2a Relationship between acceleration and time in North-South direction

Fig.5.2a shows that the maximum acceleration of Chuetsu large earthquake at time 22.5 s reaches 9237.0 mm/s^2 which are almost double compared with the maximum acceleration of Hanshin and Awaji large earthquake that is around 5789.7 mm/s^2 at 18.0 s. Meanwhile, the maximum acceleration for Higashi-Nippon large earthquake in North-South direction is 8558.9 mm/s^2.

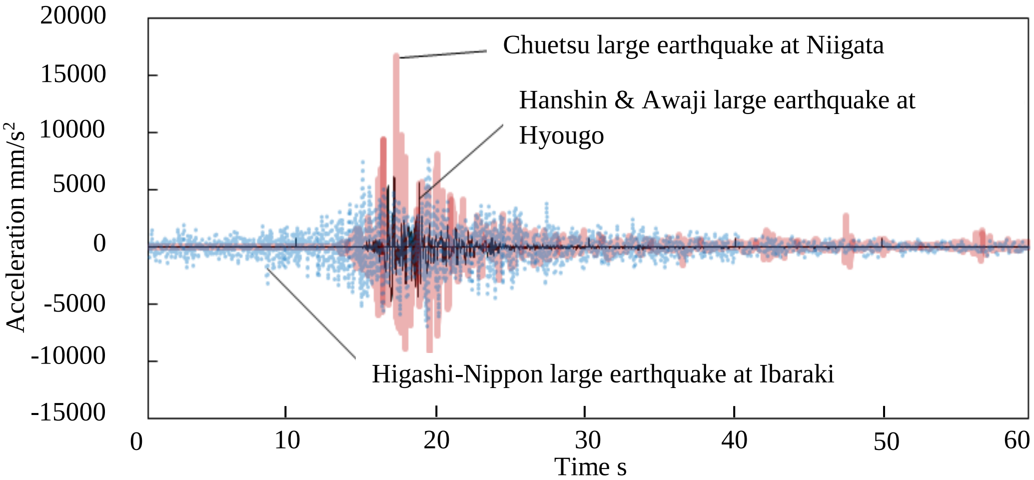


Fig.5.2b Relationship between acceleration and time in East-West direction

Fig.5.2b shows the relationship between acceleration and time for the three large earthquakes in East-West direction. It indicates that the motion of the Chuetsu large earthquake is very intense, and its maximum acceleration is double compare with the other two earthquakes. The figure depicts that at time 16.9 s, the maximum acceleration reached 16758.3 mm/s^2. On the other hand, both Hanshin and Awaji large earthquake and Higashi-Nippon large earthquake's maximum accelerations are 6172.8 mm/s^2 at 16.7 s and 7920.0 mm/s^2 at 19.1 s respectively.

Fig.5.2c shows the relationship between the acceleration and time of three large earthquakes in the Up-Down direction. The figure reveals that the maximum acceleration at time 16.1 s is 9550.0 mm/s^2 for Chuetsu. Then, for the Higashi Nippon large earthquake is around 4809.0 mm/s^2 at 11.7 s. Meanwhile for the Hanshin and Awaji large earthquake is 3322.4 mm/s^2 at 16.4 s. It indicates that Chuetsu has around 98.6 % and 187.4 % larger than Higashi and Hanshin and Awaji earthquakes.

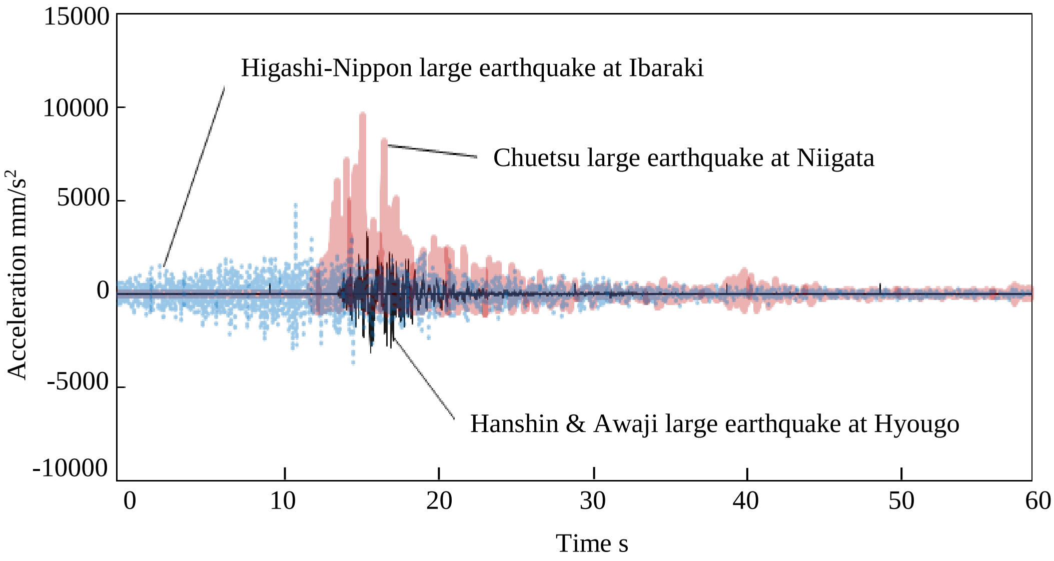


Fig.5.2c Relationship between the acceleration and the time in up-down directions

It needs to be noted that generally the unit of acceleration for an earthquake is Gal (1 Gal=0.01 m/s^2). However, the used acceleration unit in this study is mm/s^2. Each earthquake has own property such as vibration time, period and amplitude. If the same structures are set up for each actual earthquake site, the stress distribution and the behavior of its structure are completely different. It can be stated that if several structures with the same specifications are set up in the same place at an earthquake, they have different behavior due to either different direction or different support. It thought that more large vibrations at each earthquake might occur in the local area and with the soft ground or the neighborhood of the hypocenter. However, the data in the Fig.5.2 was used for the consideration of this paper. The table 5.1 shows the maximum values regarding the vector of the acceleration for each earthquake disaster. It also shows the times at maximum values.

The vector of the acceleration at Chuetsu large earthquake disaster is 2 times larger than the other 2 earthquake disasters; this is very violent vibration as it is equivalent to 1.5 times of earth gravitational acceleration. The occurrence times regarding the maximum values of the acceleration in each direction for each earthquake are different. The behavior of the structure in each earthquake disaster becomes very complex. Therefore, the data in the Fig.5.2 and Table 5.1 are important for this study.

Table 5.1 Maximum vector acceleration for three earthquakes

Earthquake sites	Motion directions			Plane Bases	
	North-South	East-West	Up-Down	Horizontal plane	On 3D space
Hanshin & Awaji large earthquake	5789.7 [18.0 s]	6172.8 [16.7 s]	3322.4 [16.4 s]	8478.6, [16.8 s] Direction: 142.8°	8910.1, [16.7 s] Angle of declination: -18.6° Direction: 315.5°
Chuetsu large earthquake	9237.0 [22.5 s]	16758.3 [16.9 s]	9550.0 [16.1 s]	16758.4, [16.9 s] Direction: 90.2°	16818.8, [16.88s] Angle of elevation: 4.9° Direction: 359.8°
Higashi-nippon large earthquake	8558.9 [16.1 s]	7920.0 [19.1 s]	4809.1 [11.7 s]	8807.9, [16.1s] Direction: 340.7°	8819.5, [16.1s] Angle of elevation: 2.9° Direction: 103.7°

※Unit is mm/s², [] is the time from the start of earthquake to the time at maximum acceleration and Direction: North=90°, South= 270°, East =0°, West= 180°

The table presents the earthquake maximum acceleration at specific times in three different directions including North-South, East-West and Up-Down. The acceleration for these directions is situated 90° to the North, 270° to the South, 0° to the East and 180° to the West. From, Fig.5.3 and Table 5.1, it shows that the Chuetsu earthquake has high maximum values of the vector acceleration in all directions compared with the other two earthquakes.

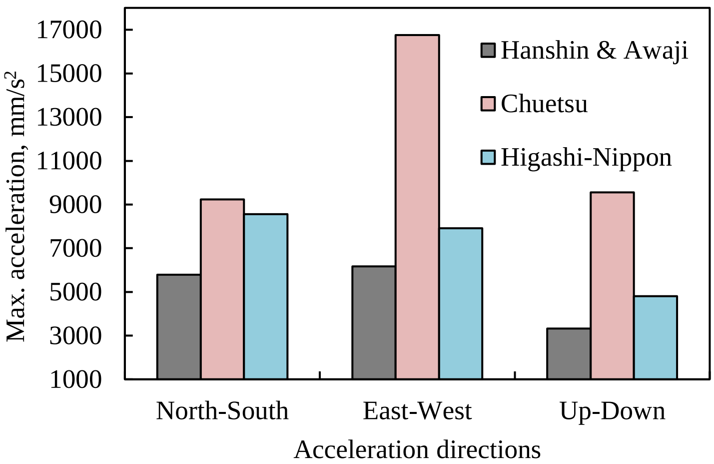
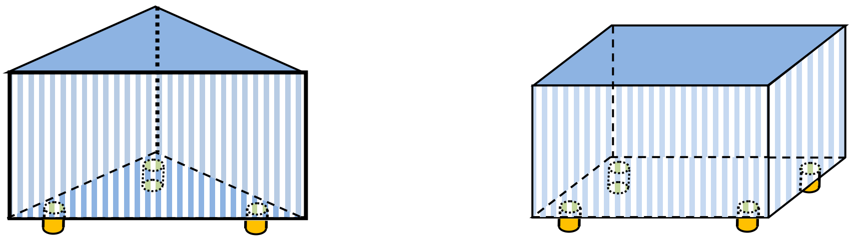


Fig.5.3 Maximum acceleration of all earthquakes in 3 directions

5.4 Analytical models for earthquake motion behavior analysis

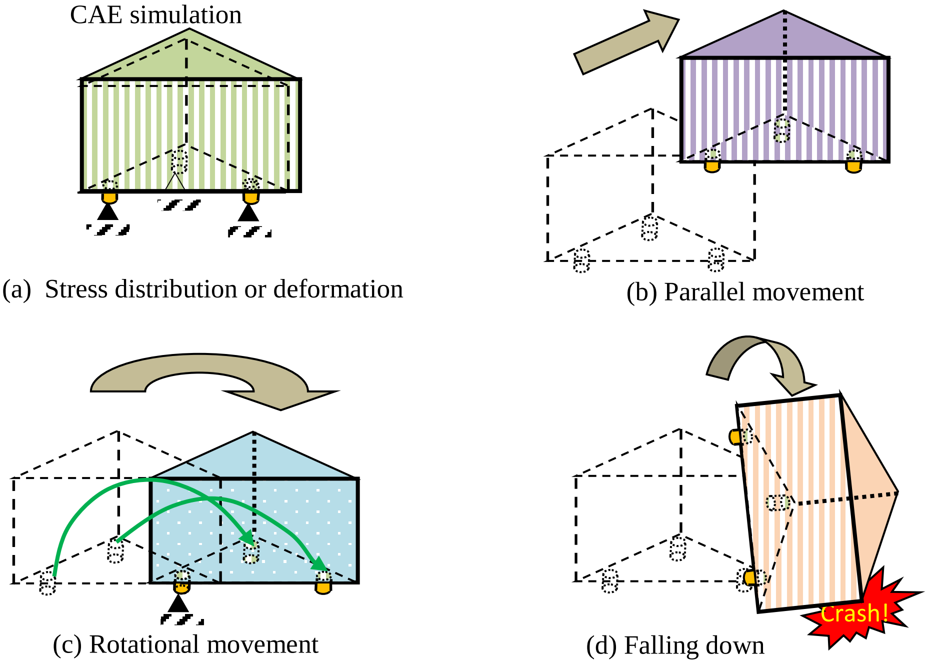
Through several illustrations, it presents the analytical models for machine tool motion behavior regarding seismic activities. It is arranged such to reflect various machine tool motion behavior including parallel motion, rotational motion and turnover or fallen down motion. To approximate this approach, it illustrates two models of structure with three and four supports, as shown in Fig.5.3a and Fig.5.3b.



(a) Structure with three supports (b) Structure with four supports

Fig.5.4 Models of structures supports due to earthquake motion behaviour

On the other hand, the Fig.5.5 illustrates machine tool motion characters. Here, Fig.5.5a reveals the stress distribution or deformation of a machine tool structure with fixed supports.



(a) Stress distribution or deformation (b) Parallel movement

(c) Rotational movement (d) Falling down

Fig.5.5 Check points regarding behaviour for an earthquake

The Fig.5.4a represents a machine tool structure with three support points and the Fig.5.4b for four supporting points. In some previous studies, it asserted that the hazardous of earthquake can results in overturning, falling or sliding that can affect overall manufacture performances [5.14]. Meanwhile the renowned institutions formalized some standard to give importance to the supporting or anchoring system of a machine tool as a general safety rules to prevent unwanted occurrence such as moving or rotating from seismic activities [5.15]. The Fig.5.5b represents the parallel motion of a structure and the Fig.5.5c shows the rotational motion. Meanwhile, the Fig.5.5d illustrates a critical motion of a structure, which may experience turnover or falling. However, the importance of using fixed mounts or concrete anchoring systems can reduce the flexibility of machine tool production area. So, things like screw jacks and leveling jacks are some of the common aspects that considered in seismic prone zones. The detail analysis of these aspects has conducted in a previous study [5.16]. Therefore, this study aims to contribute to the concept of anchoring safety system aspect. For this, it presented three analytical models to evaluate machine tool structure motion behavior namely parallel, rotational and falling down motion.

5.4.1 Time history response analysis method

Here the discussion is for the model that shown in Fig.5.4a. It used the Finite Element Method (FEM) of Solid-Works to develop the model and analyzed its characteristics. The basic analyse approaches are illustrating in Fig.5.6. The figure shows the flow chart regarding strength distribution or deformation by CAE simulation using FEM for a large earthquake. It first developed a solid 3D model by using Computer Aid Drawing (CAD). Here it is asserted that the calculation of deformation regarding a machine tool, the calculation accuracy becomes very positive or good when it considers that one support point is fixed and others are supported with roller. However, if all support points are fixed then it shows that the simulation results can become the conclusion of a machine tool using various anchor bolts. After data such as material properties and mentioned fixed conditions are put in the FEM program, it conducted the free vibration analysis; it then estimated and checked the resonance frequency and the modes. Then the analysis of steady-state forced vibration by applying real earthquake data, and the time history response was calculated. Therefore, the stress distribution, deformation, and judgment of destructions can be understood. As it has stated in a previous study [5.17] in common sense, "*Although a machine tool has a strong structure, it can be broken by an earthquake disaster. However, recently machine tool has very complex and fine structures for simultaneous multiple-shaft precision finishing and micromachining. Therefore, the stress distribution, deformation, and judgment of destruction of the structure examined by this method. However, it is not used for parallel movement, rotational movement and falling of a structure*". The aspects in related to the vibrations affect the structural internal integrity of a machine tool has widely considered and analyzed by many scholars, therefore, it does not consider in this study. On the other hand, the parallel, rotational and overturn motion behavior are the focus of this chapter.

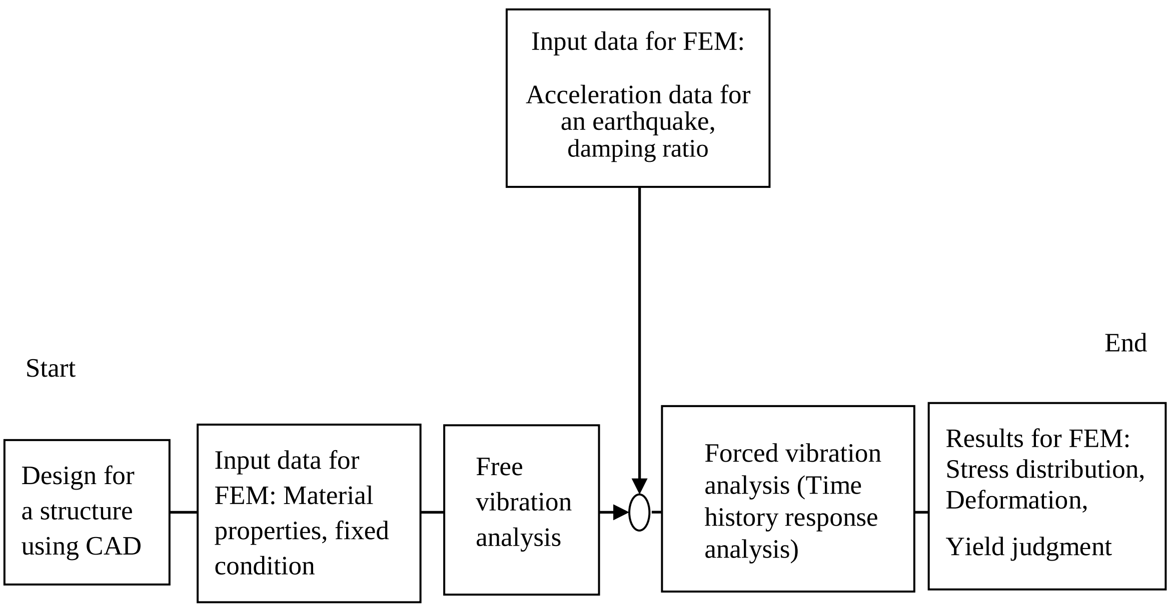


Fig.5.6 Flow-chart for strength distribution or deformation by CAE simulation using FEM for a large earthquake [5.17]

5.4.2 Physical parallel motion analysis model

This section discusses the parallel motion behavior, which is reflected in a mathematical expression. This expression illustrates the developed model, shows in Fig.5.5b. In this analysis, aspects such as force, mass, time, coefficient of friction, gravity, acceleration and its resultants play a very essential role. For a better understanding regarding the parallel motion analysis, the Fig.5.7 shows a detail illustration and representation of the mentioned components. The figure shows the relationship between acceleration $\alpha(t)$ in both North and south directions at vertical axes and time changing Δt in the horizontal axis. Here, both directions are considered as negative and positive coordinates respectively. From the figure, it shows that when "*force* ***F****(=****Mα(t)****) applying on the center of gravity of a structure occurred by the acceleration of an earthquake becomes larger than friction force +****μMg,*** *then the parallel movement of a structure would occur like stick slipping"* [5.17]. On the other hand, if the friction force ***+μMg*** is greater than the acting acceleration force on the body then the structure will not experience the parallel motion.

Mα(t)>+μMg **-----** Parallel movement occurs

+μMg >Mα(t)**-----** No parallel movement (structure is stable)

Where:

- *F* : the force
- *α(t)* : earthquake acceleration, where t is the time
- *μ* : the coefficient of friction,
- *M* : the mass of a structure
- *g* : the acceleration of gravity
- *G* : the center of gravity.

Here, the physical model of parallel motion behavior illustrates in the Fig.5.6. The figure shows that the ground or structure is moving with acceleration $\alpha(t)$ in both south and north directions, where the south direction is negative coordinate and north direction is positive coordinate. The ground moved to north direction during this one cycle, and it stops in rest condition. At that time, force F (= Mα(t)) occurred by the acceleration of the ground acts to the center of the structure. When the value of the acceleration α(t) exceeded ±μMg, the stick-slip of the structure starts.

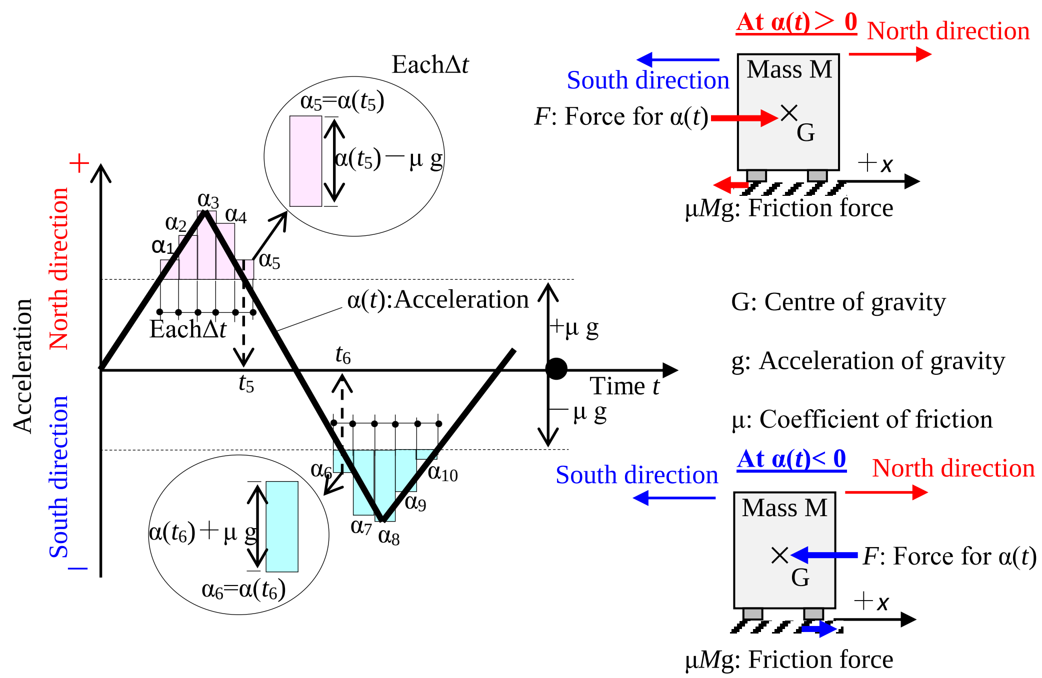


Fig.5.7 Simple model for calculating earthquake parallel motion behaviour

Here it must be asserted that the acceleration curve of seismic was organized in several rectangles (=$\Delta t \times \alpha_n$) for every single time (Δt), the north direction is in pink colour rectangle and the south light blue colour and then the impulse will be M (α_n− μg) Δt, and it is equivalent to the momentum MVn of the structure. In here, Vn denoted the stick-slip of the structure.

At last, the kinetic (=½ MV_n^2) energy that acting on the structure is used as work μMgx, to move a x distance of the structure. All the single rectangles that illustrated in the Fig.5.7 added up and the parallel motion for the north direction X_n then calculated by using the equation 5.1.

$$X_n = \sum_{n=1\sim5} \frac{1}{2} (\alpha_n - \mu g)^2 \Delta t^2 + \sum_{n=6\sim10} \frac{1}{2\mu g} (\alpha_n + \mu g)^2 \Delta t^2 \quad (5.1)$$

Where:

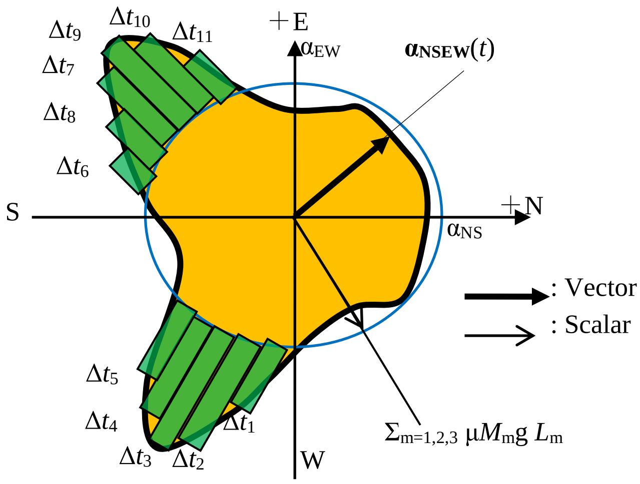
- X_n : parallel motion in north direction
- α_n : acceleration in north direction
- μ : coefficient of friction and g: gravitational force and t : time

It only considers a single vibration time for the value of the north direction X_n motion. On the other hand, it can assert that the parallel motion in south direction X_s can also be estimated by using the same equation. The total values of both north and south direction motions of the structure simply adding up by $X_n + X_s$. Likewise, the same calculation approach is used to obtain parallel motion values for east and west directions X_{ew}. Here it must be asserted that the calculation did not consider the changes shape in-ground as well as the coefficient of friction for a seismic. This is because there is no influence of the mass of a structure, as the parallel motion solely influenced by both coefficients of friction on ground and the earthquake acceleration itself.

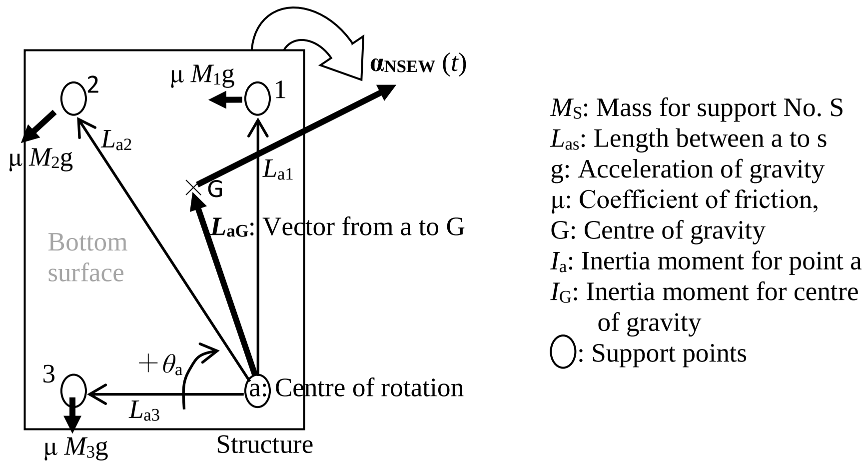
5.4.3 Physical rotational motion analysis model

This section of the work looks at the analytical model for the rotational movement of a structure during seismic activity. The developed mathematical model is to reflect the mentioned motion behavior. For the approximation of the analysis, this motion behavior is based on models that created as shown in the Fig.5.5c. Here Fig.5.8 depicts the best illustration for the analysis. As it is in the parallel motion, parameters such as force, mass, acceleration, coefficient of friction, the center of gravity, the moment of inertia and rotational angle are essential for the construction of the mathematical model equation.

As can be seen in Fig.5.8, the composite vector $\boldsymbol{\alpha}_{\mathbf{NEWS}}(t)$ of accelerations in south, north, east and west directions act on structure, the force $\boldsymbol{F}$ $(=M\boldsymbol{\alpha}_{\mathbf{NEWS}}(t))$ for the acceleration acts to the center of the gravity on the structure. The Fig.5.8a shows the earthquake acceleration vector in the horizontal plane. Meanwhile, the Fig.5.8b shows the rotational movement of the structure in the horizontal plane. The figure Fig.5.8b shows that the coordinate $+\theta_a$, in the clockwise direction on the support point *a* denotes as the center of rotation. Friction forces $\mu M_s g$ will act on each support as depicted in the Fig.5.8. Here, it contains three supporting points. The vector from the support point *a* to the center of gravity is $\boldsymbol{L}_{aG}$. Meanwhile the distance from the support point *a* to the support point s is L_{as}.



(a) Acceleration vector for an earthquake on horizontal plane



(b) Rotational behaviour for a structure on horizontal plane

Fig.5.8 Simple model for calculating earthquake rotational motion behaviour

It was thought that when $M\boldsymbol{\alpha}_{\mathbf{NSEW}}(t)\times\boldsymbol{L}_{\mathbf{aG}}$ is larger than $\sum_{s=1,2,\cdots(\text{number of the supports}-1)} \mu\, M_s g\, L_{as}$, the rotational motion will happen. However if the sum of the moment force $\sum_{s=1,2,\cdots(\text{number of the supports}-1)} \mu\, M_s g\, L_{as}$ is greater than the $M\boldsymbol{\alpha}_{\mathbf{NSEW}}(t)\times\boldsymbol{L}_{\mathbf{aG}}$, then the structure will not experience rotational motion or in another word, it stays in stable condition.

$M\boldsymbol{\alpha}_{\mathbf{NSEW}}(t)\times\boldsymbol{L}_{\mathbf{aG}}>\sum_{s=1,2,\cdots(\text{number of the supports}-1)} \mu\, M_s g\, L_{as}$ ----- motion

$\sum_{s=1,2,\cdots(\text{number of the supports}-1)} \mu\, M_s g\, L_{as}>M\boldsymbol{\alpha}_{\mathbf{NSEW}}(t)\times\boldsymbol{L}_{\mathbf{aG}}$---- no motion

In the Fig.5.7a, it shows that the green areas become the part of the rotational motion where the structure experienced rotational motion, motion magnitude, and its direction during a seismic occurrence. On the other hand, the blue circle is the rotational motion threshold. It was able to observe that the impulse for every time Δt_i is $[(M\boldsymbol{\alpha}_{\mathbf{NSEW}}(t)\times\boldsymbol{L}_{\mathbf{aG}})-\sum_{s=1,2,\cdots(\text{number of the supports}-1)} \mu\, M_s g\, L_{as}]\Delta t$. The impulse is equal to the angular momentum $I_a\omega_a(t)$, where I_a is the moment of inertia on the support point a of the structure, $\omega_a(t)$ is the angular velocity on the support point *a* of the structure at the time *t*. At last, when the rotational kinetic energy ½ $I_a\omega_a(t)^2$ is the work needed to rotate a structure ($\mu Mg\,|\boldsymbol{L}_{\mathbf{aG}}|\theta_x$) at the support point *a*. Here, the $\boldsymbol{L}_{\mathbf{aG}}$ is the distance from the support point *a* to the center of gravity. From these detail considerations, it uses equation 5.2 to calculate all rotational movement of a structure.

$$\theta_x=\sum_{n=1\sim 11}\theta_a(t+\Delta t_n)-\theta_a(t)$$

$$=\sum_{n=1\sim 11}\frac{1}{2\mu g\, M\, I_a}[(M\boldsymbol{\alpha}_{\mathbf{NSEW}}(t)\times\boldsymbol{L}_{\mathbf{aG}})-\sum_{s=1,2,\cdots(\text{number of the supports}-1)}\mu\, M_s g\, L_{as}]^2\Delta t_n^2 \quad \text{(Clockwise)}$$

$$=\sum_{n=1\sim 11}\frac{1}{2\mu g\, M\, I_a}[(M\boldsymbol{\alpha}_{\mathbf{NSEW}}(t)\times\boldsymbol{L}_{\mathbf{aG}})+\sum_{s=1,2,\cdots(\text{number of the supports}-1)}\mu\, M_s g\, L_{as}]^2\Delta t_n^2 \quad \text{(Anti-clockwise)} \tag{5.2}$$

Where:

- θ_x : structure rotational value
- M_s : support mass
- $\boldsymbol{L}_{\mathbf{aG}}$ **:** vector from point *a* to center of gravity *G*

- μ : coefficient of friction
- g : gravitational force
- L_{as} : vector from point *a* to each support point (1, 2, 3..)
- I_a : moment of inertia at point *a* and *G* is the centre of gravity

Here, it did not consider both the changes shape on the ground and coefficient of friction for an earthquake. An earthquake time from the start to the finish of the vibration are divided by minute time Δt, the rotational movement of the structure for each Δt was calculated by the equation 5.2 and was plotted out, then the all rotational movement of the structure can be calculated.

5.4.4 Physical turnover motion analysis model

This section discusses the physical model for falling down motion of a structure. The mathematical model for this behavior motion that developed regarding the shape of Fig.5.5d was discussed in the earlier section. The Fig.5.9 shows the detail visualization of the model. It depicts a simple structure model for turnover or falling down motion.

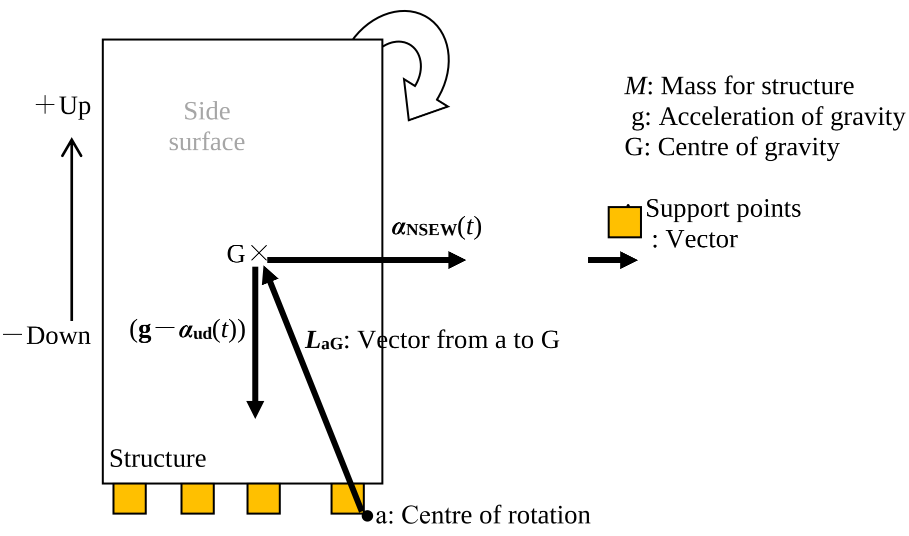


Fig.5.9 Schematic view of turnover analysis model

Here, the parameters such as the mass of the structure, gravity, a center of gravity, time, acceleration, vector and center of rotation are essential for the model construction. When the friction force on the specific support point become very large or the specific support point caught in the projection on the ground the overturn motion will occur. The investigation of the falling down motion of the structure was done based on the illustrated conditions in the Fig.5.9. As it can be seen in Fig.5.9 that the composite vector $\boldsymbol{\alpha}_{\mathbf{NEWS}}(t)$ of accelerations in the south, north, east and west directions act on the structure, the force $\boldsymbol{F}$ ($=M\boldsymbol{\alpha}_{\mathbf{NEWS}}(t)$) for the acceleration acts on the center of the gravity on the structure. Then, the composite vector of earthquake accelerations in vertical motion or up and down direction becomes $\mathbf{g}-\boldsymbol{\alpha}_{\mathbf{ud}}(t)$. Here, the $\boldsymbol{\alpha}_{\mathbf{ud}}(t)$ is the earthquake acceleration at time t in the vertical motion. The upper motion is positive, and the down motion is negative, meanwhile, the g is the acceleration of gravity. Fig.5.9 shows that the L_{aG} denotes the vector from the support point a to the center of gravity (G), and the moment in the clockwise direction that occurs in the a will be $M\boldsymbol{\alpha}_{\mathbf{NSEW}}(t)\times\boldsymbol{L}_{\mathbf{aG}}$. From the above descriptions, it was able to note that when the vector acceleration $M\boldsymbol{\alpha}_{\mathbf{NSEW}}(t)\times\boldsymbol{L}_{\mathbf{aG}}$ is larger than the vertical motion acceleration $\mathbf{g}-\boldsymbol{\alpha}_{\mathbf{ud}}(t)$, then the turnover motion will occur.

$M\boldsymbol{\alpha}_{\mathbf{NSEW}}(t)\times\boldsymbol{L}_{\mathbf{aG}}>\mathbf{g}-\boldsymbol{\alpha}_{\mathbf{ud}}(t)$ -------- turnover motion occurs

$\mathbf{g}-\boldsymbol{\alpha}_{\mathbf{ud}}(t)>M\boldsymbol{\alpha}_{\mathbf{NSEW}}(t)\times\boldsymbol{L}_{\mathbf{aG}}$-------- no turnover motion

Here, it can be asserted that the developed mathematical analytical is appropriate for investigating a structure whether it will be stable, or turnover. It uses equation 5.3 to obtain the results. In this exercise, the focus was given to the supporting point *a*, however; the model can also be used for calculating other supporting points.

$$\text{No falling down} \quad \Rightarrow \quad (\mathbf{g}-\boldsymbol{\alpha}_{\mathbf{ud}}(t)) \times \boldsymbol{L}_{\mathbf{aG}} \quad > \boldsymbol{\alpha}_{\mathbf{NSEW}}(t) \times \boldsymbol{L}_{\mathbf{aG}} \qquad (5.3)$$

Where:

- g : acceleration of gravity

- $\alpha_{ud}(t)$: up-down acceleration with respect to time t
- L_{aG} : vector from support point a to the center of gravity G
- $\alpha_{NSEW}(t)$: acceleration in north, south, east and west direction with respect to time t

5.5 Experimental set-up

In this section, it presents both linear motor machine tool conditions and a developed mock-up structure for mimicking earthquake motion.

5.5.1 The linear motor machine

The specification and photograph of the used lathe with linear motor at the Machining Center of Nagaoka University of Technology (NUT) are shown in Table 5.2 and Fig.5.10, respectively. It is a CNC Mitsubishi M700 type machine with a maximum spindle speed of 10000 min^{-1}.

Table 5.2 Specifications of the lathe with linear motor

Parts	Parameter descriptions	Unit	Value
Head stock	Max. spindle speed	min^{-1}	10000
	Stroke on Z direction	mm	200
	Max. acceleration on Z direction	m/s^2	12.1 (1.23G)
	Max. speed on Z direction	m/min	90
	Max. load on Z direction	N	1674
	Positioning accuracy of Z	μm	0.3
Carriage	Stroke on X direction	mm	195
	Max. acceleration on X direction	m/s^2	19.6 (2.0G)
	Max. speed on X direction	m/min	110
	Max. load on X direction	N	1674
	Positioning accuracy of X	μm	0.5
	Table size	mm	10×80×434
Type of CNC		Mitsubishi M700	

The headstock of the machine has various parameters including stroke on Z direction with 200 mm capacity, maximum acceleration on Z direction is 12.1 m/s^2 with speed of 90 m/min and the maximum load of 1 674 N. The positioning accuracy at Z direction is 0.3 μm. In the carriage part, stroke on X direction is 195 mm with a maximum acceleration of 19.6 m/s^2, the maximum speed is 110 m/min and the maximum load of 1674 N is in X direction. The position accuracy in the X direction is 0.5 μm. The table dimension is 10 mm × 80 mm × 434 mm.

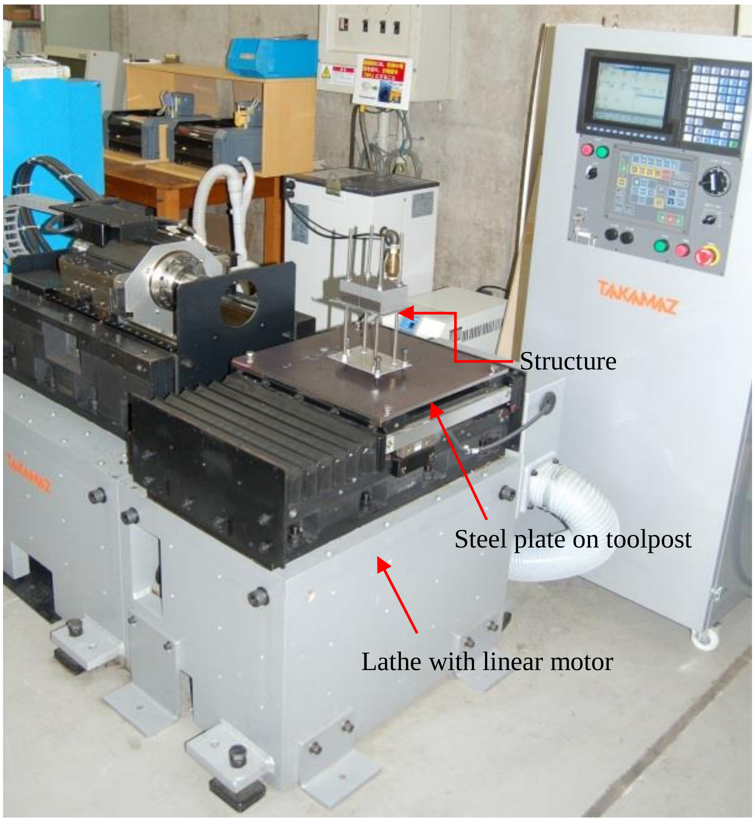
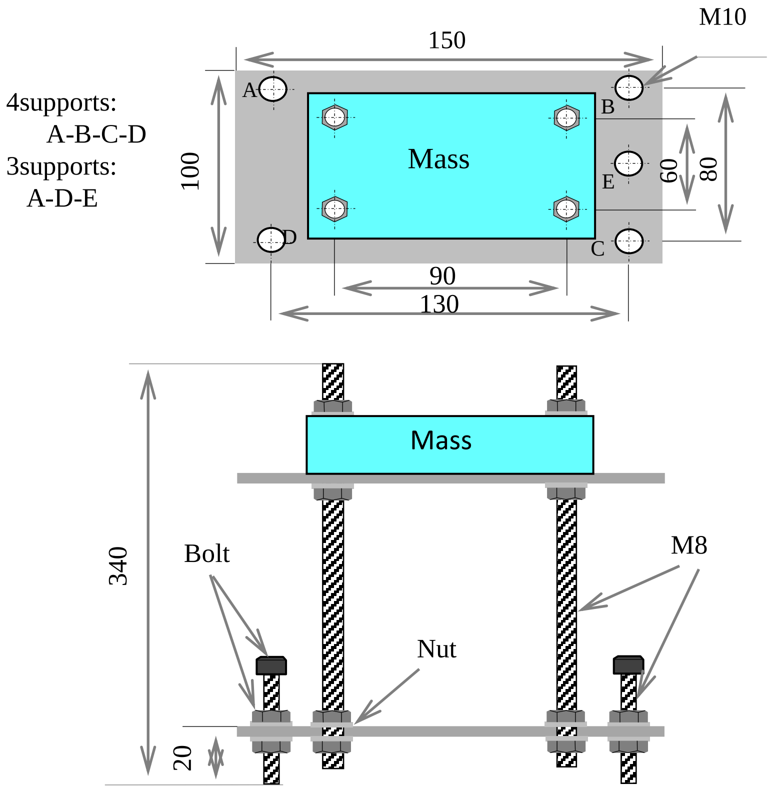


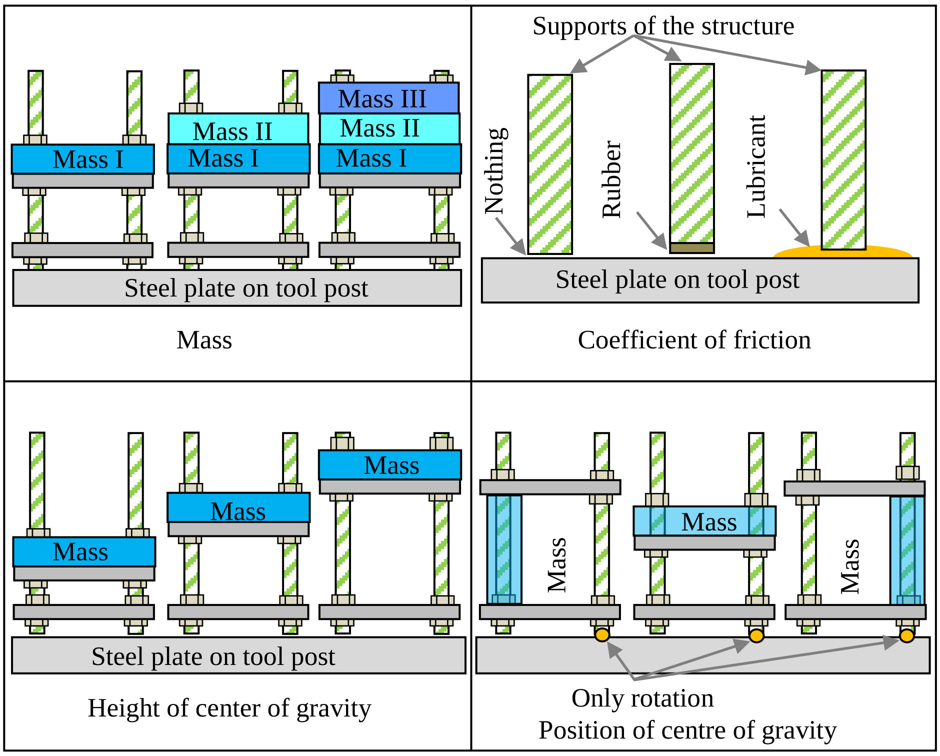
Fig.5.10 Experimental set-up for earthquake analysis

5.5.2 Developed mock-up structure arrangements

The Fig.5.10 shows the mock-up structure that developed to mimic machine tool motion behaviour during an earthquake. It indicates that the structure placed on a steel plate that put on the tool post of the machine. On the other hand, Fig.5.11 shows the arrangement of the structure for the experiments.



(a) Drawing of the structure



(b) Change of parameter

Fig.5.11 Mock-up structure for experiment of earthquake motions

The Fig.5.11a depicts a simple drawing of the structure and the Fig.5.11b shows the various parameters which were used during the experiment. The structure for several experiments consisted of several bolts, nuts, and plate. The mass can change for the supports of 3 points (A-D-E) and 4 points (A-B-C-D) and with different height of the center of gravity.

In specific for the coefficient of friction arrangement, the base of the structure that contacted the steel plate on the tool post was organized in three different conditions including lubrication, with rubber and with original or no lubrication and rubber, refers to Fig.5.11b.

The table of this lathe is possible to move with 2g (g: acceleration of gravity) in the X-direction. A plate which is fixed on the table with 412 mm × 427 mm × 9 mm dimension carries the structure as shown in Fig.5.11. By using this experimental set-up, it was able evaluated the models for parallel, rotational and falling down motions of the structure that described in the previous section (5.4).

5.6 Measurement of coefficient of friction and acceleration curve

In this section, it discusses two main aspects, the coefficient of friction and the acceleration curve of the tool post of the CNC linear motor machine. The coefficient of friction of the structure and acceleration in X-direction of the plate measured before the experimental evaluations. Another words, it was obtained in pre-experiment time.

5.6.1 The coefficient of friction

The coefficient of friction obtained from the experiment is shown in Table 5.3 and Fig.5.12. The coefficient of friction between the plate and the base of the structure was arranged in three different scenarios. The scenarios are the base applied with no-lubricant, lubricant oil with ISO VG5 and the rubber seat. As indicated in the table and figure, for each mass, three coefficients of frictions were obtained from the experiment.

Table 5.3 Values of three different coefficients frictions between plate and structure

No	Mass (kg)	Coefficient of friction (μ)		
		Rubber	No oil	Oil
1	2.8	0.352	0.118	0.099
2	4.4	0.408	0.175	0.145
3	6.0	0.493	0.1778	0.155

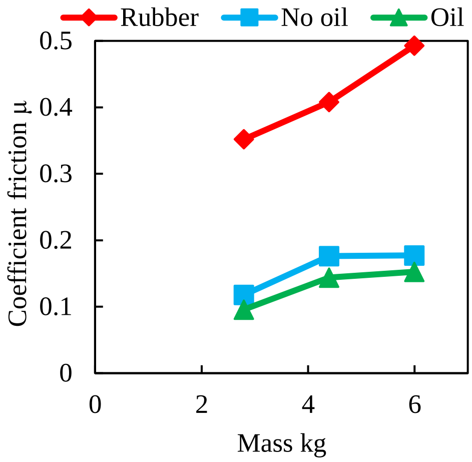


Fig.5.12 Coefficient of friction between the structure and the plate

As depicted in the figure, the no lubricant denotes in the blue line, the green line shows lubricant and the rubber scenario is in red line. The center of gravity of the structure on the plate was pulled with 300 mm/s by a very fine wire. The pulling load was measured by the pull tension gauge, and then coefficient of dynamic friction (Table 5.3) was calculated based on this pulling load. From video recorder the table displacement and time relationship were used for acceleration calculation. Three different type of mass were considered, 2.8 kg, 4.4 kg and 6.0 kg.

5.6.2 Plate acceleration in X-direction

This section presents the calculated acceleration of plates in a horizontal direction. The Fig.5.13 shows the relationship between acceleration and time for the table. It presents around 6 different ideal acceleration results which are indicated in different colors for the clarity. The accelerations are 2.4 m/s^2, 4.8 m/s^2, 9.6 m/s^2, 12.8 m/s^2, 15.2 m/s^2 and 19.2 m/s^2. From the figure, it is noted that the fasted travel of the plate in X-direction is 19.2 m/s^2 against 2.4 m/s^2 as the slowest acceleration obtained from the calculation based on the given structure pulling velocity. It is calculated based on the recorded time of table position in X-direction. It recorded the time by using a video camera. The experimental results are useful for evaluation tests.

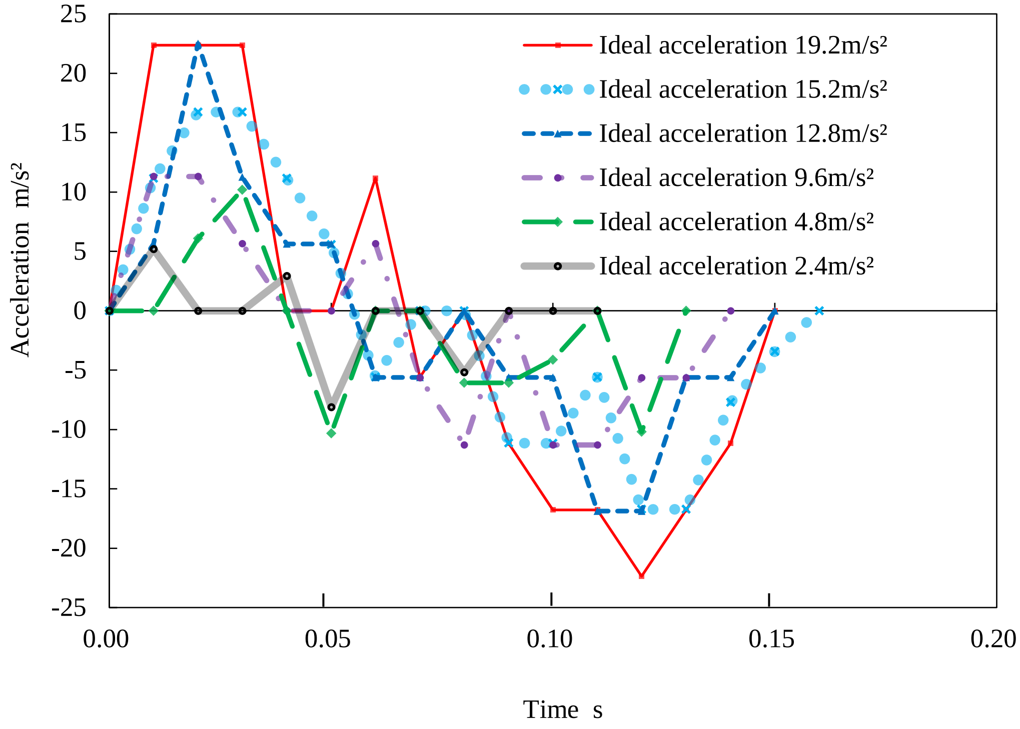


Fig.5.13 Acceleration curve of the tool post

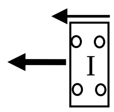
5.7 Experimental of structure motion behavior and its evaluation results

This section is focusing on both experimental and calculated results of the developed analytical mathematical models for analyzing a structure motion behavior due to earthquake activity. Here three important analysis results presented by comparing both theoretical and experimental. These are parallel motion behavior analysis, rotational motion behavior analysis and overturn or falling down motion analysis. The evaluation of the time history method, which utilized the Finite Element Method (FEM), can use the acceleration curves that illustrated in Fig.5.13 by following the procedure in Fig.5.5. It was noted that the application and analysis of this program are very common and easy. It can be asserted that the developed structure such as Fig.5.11 has high stiffness and can break when earthquakes such as in Fig.5.2 occurs. Therefore, the time history part was omitted in this discussion. Here, it only focuses on parallel, rotational and falling down motion behavior.

5.7.1 Physical model for parallel motion evaluation results

Here, it discusses the evaluation of parallel motion analysis results. It used the equation 5.1 to obtain the results. Both theoretical and experimental analysis results are presented. Parameters such as acceleration, surface interferences or surface contact conditions and mass are the main consideration in the experimental work. Table 5.4 outlines the parameters. Here, it uses five different accelerations, 2.4 m/s^2, 4.8 m/s^2, 9.6 m/s^2, 12.8 m/s^2 and 19.2 m/s^2, these are illustrated in the Fig.5.13. The experimentation utilized three different surface contact scenarios including no lubricant, with the lubricant of ISO VG5 and rubber. On the other hand, it used masses of 2.8 kg, 4.4 kg and 6.0 kg. Meanwhile, both experiments and theoretical analysis for every mass apply different coefficient of friction. For the 2.8 kg mass with the condition of no lubricant, the coefficient of friction μ for both experimental and calculated is 0.118; meanwhile, the condition with lubricant oil is with the coefficient of friction μ: 0.10, here the free support condition was applied. The results of both experimental and calculated for parallel motion analysis are shown in the Fig.5.14.

Table 5.4 Experimental condition for the parallel motion

Items	Unit	Conditions
Acceleration	m/s^2	2.4, 4.8, 9.6, 12.8, 19.2
Acceleration curve		→See Fig.5.13
Surface interferences (Contact condition)		Nothing
		ISO VG5
		Rubber
Mass *m*	kg	2.8, 4.4, 6.0→See Fig.5.12
Posture	Acceleration direction (X direction) 	○ Support points (Free condition)

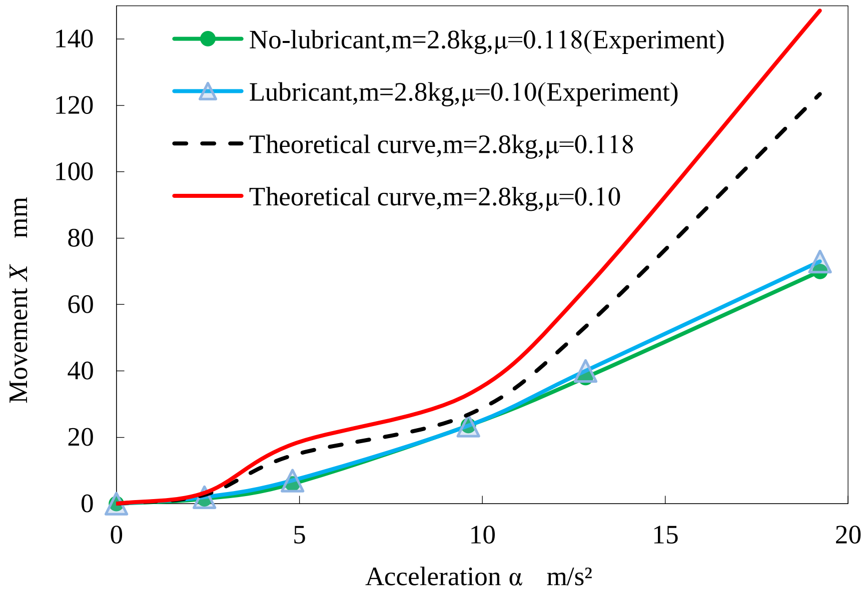


Fig.5.14a The parallel motion evaluation results for Mass 2.8 kg

The Fig.5.14b presents the results for mass 4.4 kg and the mass of 6.0 kg results are shown in Fig.5.14c. The Fig.5.14b shows the evaluation results for both experimental and calculated methods by using a mass of 4.4 kg with the coefficient of friction μ for no lubricant condition for both methods is 0.175 and the condition with lubricant for both experimental and theoretical is 0.145. On the other hand, Fig.5.14c presents the evaluation results for utilizing the mass of 6.0 kg.

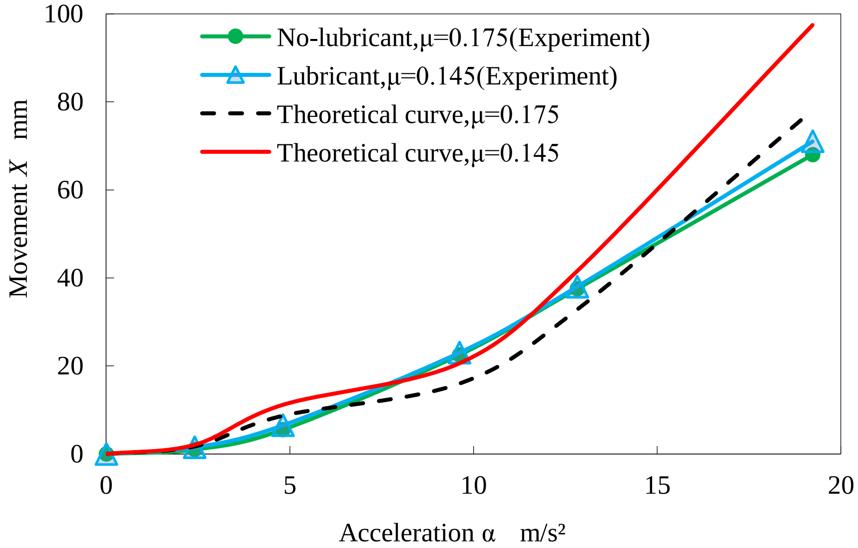


Fig.5.14b The parallel motion evaluation results for Mass 4.4 kg

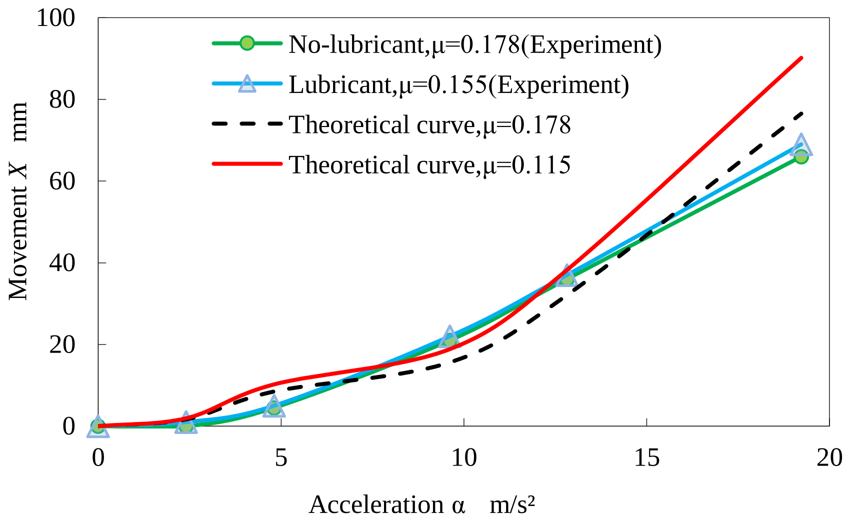


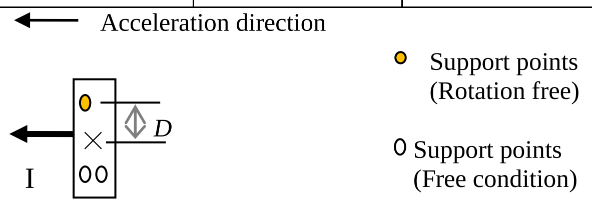
Fig.5.14c The parallel motion evaluation results for Mass 6.0 kg

The calculation used several coefficient of friction μ for both experimental and theoretical; the contact conditions with no lubricant for both options are 0.178 and 0.115 respectively. The value of the parallel motion was measured by using a ruler after the plate moved one cycle of acceleration and deceleration as shown in Fig.5.13 in regard to the condition that outlined in Table 5.4. It was thought that results for the physical model from the estimation of the parallel movement at an earthquake are closely approximate between the experiments and the calculation. In physical model equation 5.1, the relationship between the mass of the structure and the parallel movement is insignificant; however, there are relationships between the mass of the structure and the parallel movement in the experiment. Because, when the mass of the structure has changed, the coefficient of friction was also changed, therefore the parallel movement changed with the non-linear conditions. When the lubricant oil was used for reducing the coefficient of friction, both the parallel movements in the experiment and calculation results became large. Therefore, the coefficient of friction has a large effect on the parallel movement. When the rubber seat was used, the structure felt down at all conditions, and it was hard to measure the parallel movement. Moreover, coefficient of friction and the acceleration of the earthquake influenced the parallel behavior of a machine tool at an earthquake. If the coefficient of friction becomes large, the parallel movement becomes little; however, the structure was easily falling down. When the mass of the structure becomes light, contact surface between the structure and the ground becomes unstable. At that time, the difference between the experiment and the calculation becomes large.

5.7.2 Physical model for rotational motion evaluation results

Here it discusses the physical model for rotational motion analysis results. It used the developed model equation 5.2 for the theoretical calculation to compare with the experimental values. The experimental parameters and conditions are shown in Table 5.5. Likewise, in the parallel analysis, the same five acceleration values are used, and the actual acceleration curve can be observed in the Fig.5.13. In this rotational analysis, it used both no lubrication and lubrication contact condition between the structure and plate.

Table 5.5 Experimental condition for rotational motion

Items	Unit	Conditions
Acceleration	m/s^2	2.4, 4.8, 9.6, 12.8, 19.2
Acceleration curve		→See Fig.5.13
Surface interferences (Contact conditions)		Nothing
		ISO VG5
Mass	kg	4.4
Distance of centre of gravity (*D*)	mm	30, 75, 120
Posture 		

On the other hand, rubber was not included in the experiment. It only deployed one type of mass which is 4.4 kg. Three different distance values from supporting point to the center of gravity are used. These are 30 mm, 75 mm and 120 mm. It considered both no lubricant and lubricant surface contact conditions. Fig.5.15a shows the evaluation results for both experimental and calculation for distance of 30 mm. Fig.5.15b presents the results for distance 75 mm and the results for distance 120 mm is illustrated in Fig.5.15c. The results of rotational motion performances were measured by using a protractor. It was thought that the physical model for rotational movement could be useful for the calculation at an earthquake because of the agreement between the results of the experiments and the calculation. The rotational behaviour of a machine tool at an earthquake would be influenced by the coefficient of friction, reaction force of each supports, the position of the centre of gravity and acceleration of the earthquake. It was able to observe that when increasing the distance from support to the center of gravity, the rotational motion of the structure increases, and the stability of structure affected and resulted in falling down.

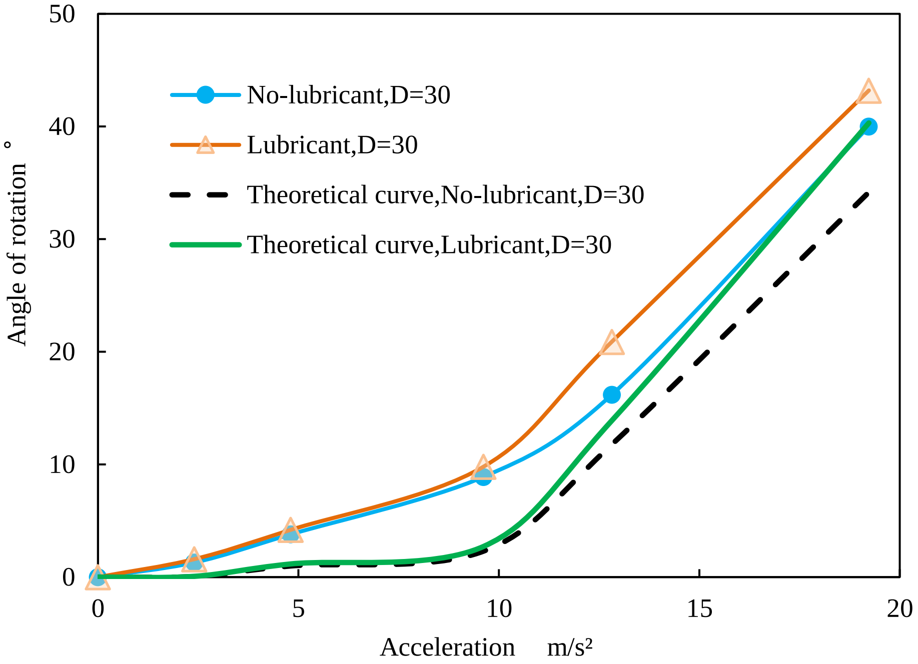


Fig.5.15a The rotational motion evaluation results for distance of 30 mm

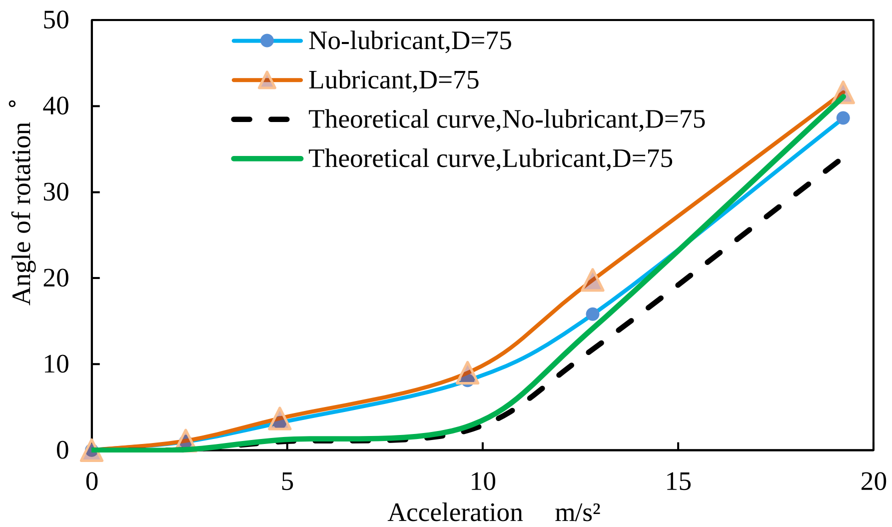


Fig.5.15b The rotational motion evaluation results for distance of 75mm

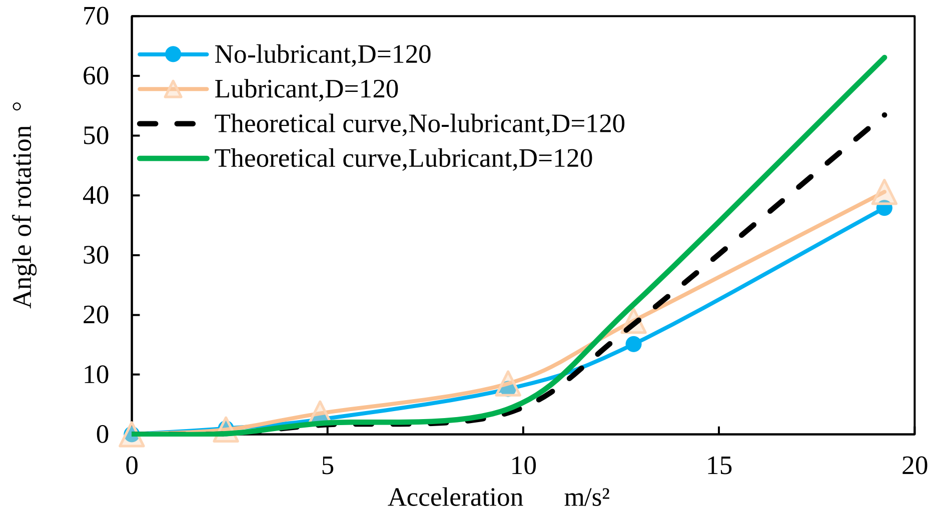


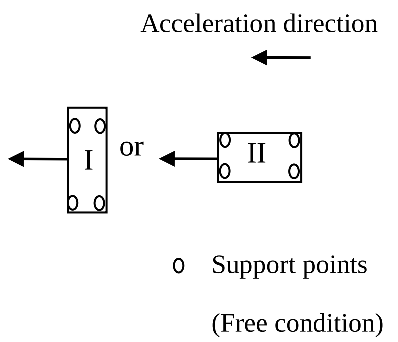
Fig.5.15c The rotational motion evaluation results for distance of 120 mm

When the coefficient of friction becomes large, the rotational movement of the structure becomes little, and the structure fells. If a factory has both machine tools with parallel and rotational movement, the possibility of crash between the machine tools becomes very large. Therefore, all machine tools in a factory should be arranged based on no crash at an earthquake, at that time the physical models for parallel and rotational movements should be used. This indicates that the developed behavior motion models are suitable and important to consider for any anchoring design system for the safety of machine tools due to seismic activities.

5.7.3 Physical model for overturn motion evaluation results

This section discusses the physical model for overturn motion. The developed analytical model which represented in Equation 5.3 was used to estimate and predict a machine tool motion character specifically falling down or turnover motion. Here both theoretical and experimental results are presented and highlighted. Table 5.6 outlines the important parameters and conditions for the experimental analysis. In this overturn motion analysis, six different accelerations (2.4 m/s^2, 4.8 m/s^2, 9.6 m/s^2, 12.8 m/s^2, 15.2 m/s^2 and 19.2 m/s^2) were used. Three surface contact conditions such as no lubricant, with lubricant and rubber were considered. Meanwhile, this motion evaluation analysis only used one type of mass that is 4.4 kg. It was able to observe that when only rubber seat was used, the structure felt. It used two different models which indicated in Table 5.6. The Model I is vertical position wise and the Model II flat-wise or horizontal position. The results regarding the evaluation of the physical model for the falling down movement of the structure are shown in Fig.5.16. Both Fig.5.16a and Fig.5.16b show the overturn motion, no falling and safety region.

Table 5.6 Experimental condition for evaluation regarding overturn

Items	Unit	Conditions	Posture
Acceleration	m/s^2	2.4, 4.8, 9.6, 12.8, 15.2, 19.2	
Acceleration curve		→See Fig.5.13	
Surface interferences (Contact condition)		Nothing	
		ISO VG5	
		Rubber	
Mass *m*	kg	4.4	

After the plate moved with only one cycle of acceleration and deceleration, it checked the falling down movement of the structure. It was thought that the physical model for falling down movement is appropriate for the calculation of the rotational movement at an earthquake because of the agreement with the results of the experiment and the calculation.

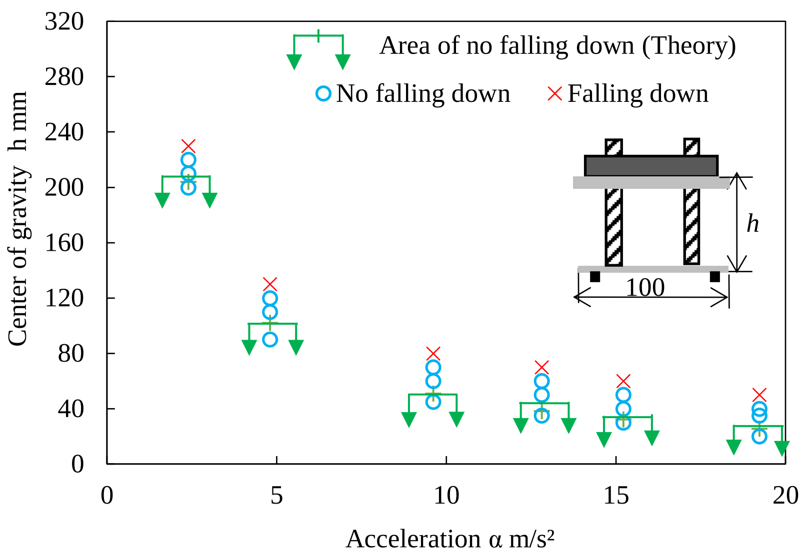


Fig.5.16a Evaluation results of overturn motion for Model I

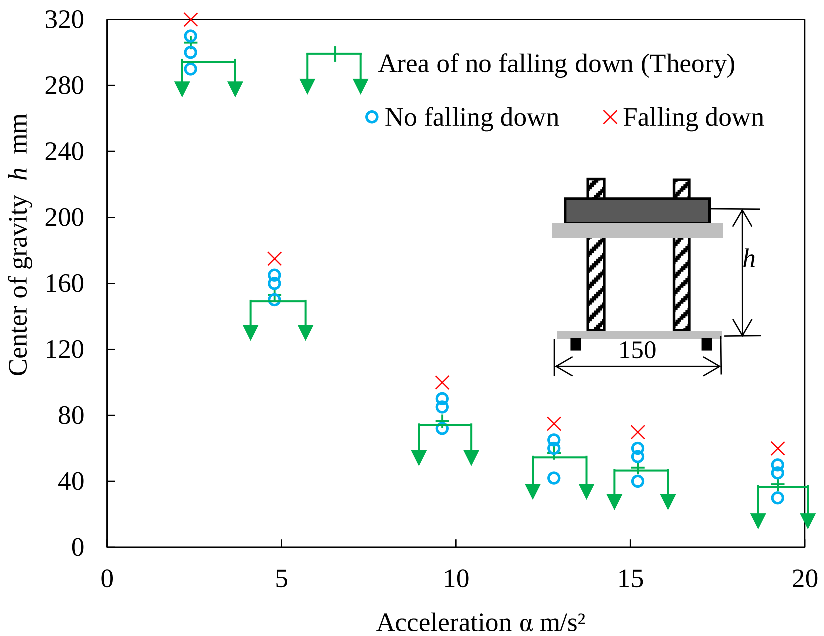


Fig.5.16b Evaluation results of overturn motion for Model II

It is believed that the falling down motion of machine tool at an earthquake is influenced by moment of the earthquake acceleration and restoration force of gravitation. Falling of a machine tool at an earthquake can be investigated by using the data of the past earthquakes such as section 5.3 and the physical model (equation 5.3) for falling down movement. However, the restoration force of gravitation on the structure is influenced by the acceleration of the earthquake in up-down directions, and the restoration force receives influences from mass and height of the table on a machine tool. In the design stage, these considerations are useful for safety aspect during an earthquake. Design of a machine tool without falling at an earthquake is performed regarding the height of the center of gravity, also position, the support points and the center of gravity by the physical model for falling down motion.

5.8 Application of analytical models on machine tool motion behavior

In this section of the work, it presents an important discussion about the application of the developed analytical models specifically both parallel and rotation motion models for a machine tool motion behavior by using a real earthquake data.

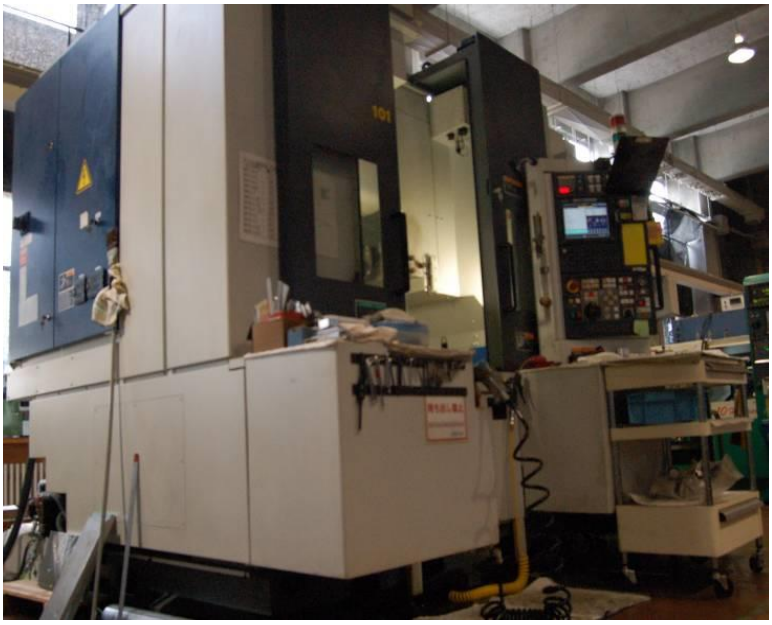


Fig.5.17 Photograph of CNC machining centre at machining shop of NUT

The actual physical CNC machining center is shown in the Fig.5.17. Data of CNC machining center in the machine shop of the Nagaoka University of Technology for the Chuetsu large earthquake [5.6], [5.13] on 23rd October 2004 is shown in Table 5.6. According to the surveyed data that obtained from the machining shop of NUT for the 2004 Chuetsu earthquake, it depicts that at least 1 machine overturned and 2 were experiencing significant displacement from 84 observed machine tools. The CNC machining center occupied an area of 2166 mm × 2685 mm. The mass *M* of the machine is 6.5 ton.

Table 5.7 Parallel and rotational motion of CNC machining centre due to Chuetsu earthquake in 2004 in the machine shop of NUT and the analysis results

Application part	Parallel motion regarding center of gravity		Rotational motion (+:Clockwise)
	NS direction	EW direction	
Behavior at Chuetsu large earthquake	S 83.2 mm	E 132.8 mm	＋5 °
Calculation using Eq.(5.1) and Eq.(5.2)	S 47.3 mm	E 66.4 mm	＋2.9 °
Accuracy of calculation	56.9 %	50.0 %	58.0 %

Accuracy of calculation [%] = Difference between calculation and practice values÷Practice values×100

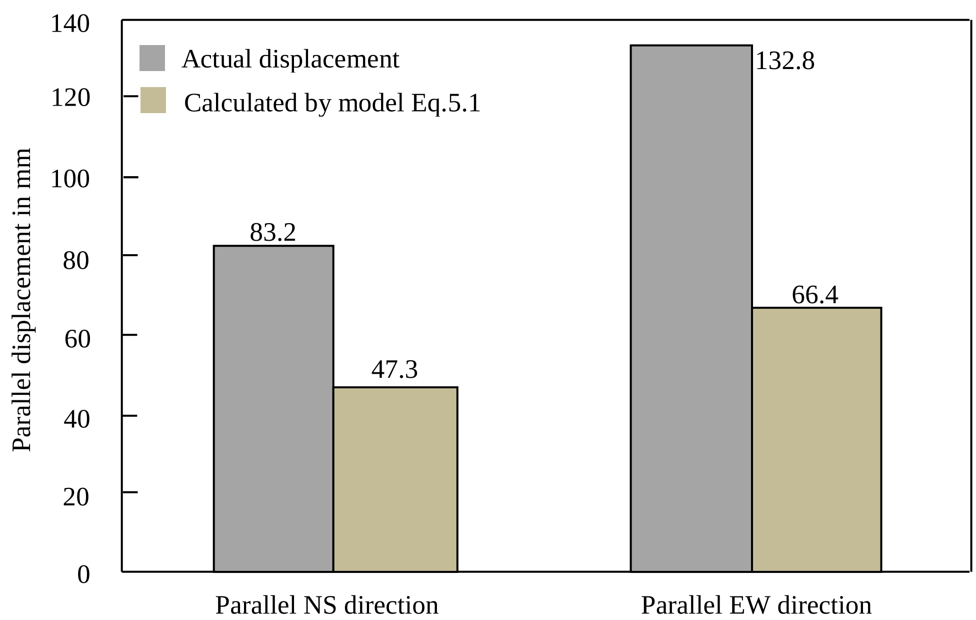


Fig.5.18a Application of real earthquake data for parallel motion by Eq.5.1

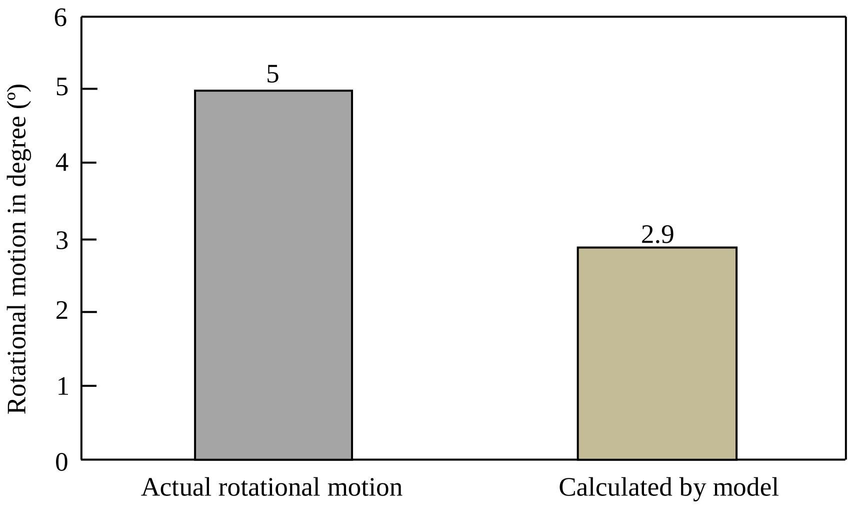


Fig.5.18b Application of real earthquake data for rotational motion by Eq.5.2

The structure of the machine tool is supposed the rectangular block with uniformly density and height h and supported by 4 base corners. In here the parallel and rotational movements regarding the CNC machining center were calculated by the physical models of equations 5.1 and 5.2. The distance from the support point of the rotational center to the center of gravity on the structure is L, the moment of inertia I_a in the equation 5.2 was calculated by $I_a = M(a^2 + b^2)/12 + ML^2$. The calculated results were obtained by using the acceleration curves in Fig.5.2 and equations 5.1 and 5.2 are shown in Table 5.7. Coefficient μ of friction for the calculation was 0.132 which was measured by the structure in Fig.5.10 on the floor in the machine shop of Nagaoka University of Technology. Fig.5.18 shows the calculation results of the developed analytical models specifically both parallel and rotational motion by utilizing real earthquake data and the actual motion of a machine in the NUT machine shop. The Fig.5.18a shows the application of earthquake data results for parallel motion by using equation 5.1 and the Fig.5.18b shows the results for rotational motion by using equation 5.2.

The values of the calculated behavior are from 50 % to 60 % of real behavior for the Chuetsu large earthquake disaster. Distance from the Nagaoka University of Technology to the area of earthquake data in the Chuetsu large earthquake disaster is 15 km, of course, the environment of the set-up also is different, and the conditions of the ground are different. However, our physical models can calculate with the accuracy up-to 60 %. Therefore, physical models for the parallel and rotational movements are effective for calculating behavior of a machine tool at an earthquake.

5.9 Summary

The study developed various motion models for calculating machine tool motion behaviours. It used Japan real earthquake acceleration data for the analysis. Both mathematical analysis and experimental evaluation through a developed mock-up structure were carried out. Both parallel and rotational models were applied to calculate CNC machining center by using the 2004 Chuetsu earthquake acceleration data. The summary of this study follows;

(1) Data of all earthquakes was very different for the accelerations in all directions. Therefore, place, direction of setup and ground conditions influence on machine tool are important.

(2) The physical model for parallel, rotational and falling down motions was constructed. These models were effective for the experimentation.

(3) The proposed analytical model for all motions was deemed very appropriate for analyzing machine tool motion behavior during seismic event as it was able to perform up-to 60 % calculation accuracy.

(4) The relationship between earthquake and manufacturing is very important and valuable for Timor Leste in future. The lessons, concepts and theory such as analytical models for design purposes are very much needed for the country.

Chapter (6)

Double-Eco technology model for promoting risk management in manufacture

6.1 Introduction

Technology development and innovation have dramatically changed the world. The change is not merely referring to the physical instruments but also concepts, knowledge, and techniques that applied for a bigger purpose of solving problems. It is very significant for human because technology, concepts, new ideas and techniques can help to adapt to the changes and the environment. Industries are putting efforts to improve their performances for better results.

Green manufacturing and environmentally friendly products have become main discussions in the last few decades, and has been compromised and highlighted in some global agreements. With commitments and compromise that world-leading countries have, many technology developers and users put into practice by developing environmentally friendly technology which consumes less energy and emits minim harmful pollutant gasses into the atmosphere [6.1], [6.2]. They all are required to implement a green manufacturing approach, who involves technology developments and businesses. They continue showing positive willingness in engaging environmental protection efforts. As one of the leading technology development countries, the Japanese government pays very serious attention to environmental protection issue by issuing laws for controlling emissions and regulates other related environmental activities [6.3]. However, each country has right and free to implement the agreed global issue based on its circumstances (Third and Fourth Paris Agreement). This means countries can continue to develop and invent technologies to serve its needs without affecting the environment.

According to the global framework convention on climate change goals, many countries have shown positive contributions and committed to take necessary actions for contributing to the environmental protection efforts [6.1]. The most important aspects such as environmentally friendly technologies, flexible technology to allow later stage development and applications should be compulsory. There are some available different ways of conducting technology development evaluation [6.4] and including the design process “ecology-economy-equity” fractal triangle which McDonough (2006) suggested. Although most of the current technology evaluation methods are flexible for future stages, they are mostly focusing either on economy or ecology performance due to cost and profit issues. For this, there is a need for a comprehensive method which can integrate environmentally friendly technology and risk aspects into existing categories with the same level of priority.

It was noted from the previous studies [6.5] [6.6] the same degree of priority should be given to all parameters such as mechanical performances, economic and ecological parameters, to achieve a competitive technology. Therefore, to improve the technology performance or mechanical performance aspect and integrate ecology and economy, the study applied the “Double-Eco” model concept. The Double-Eco model is used to reflect a developed double roller technology for lubrication. It is called double, because the technology consists of two parts with four rollers that perform both grease collection and its thickness adjustment. This model is very suitable as provides flexibility for exploring alternatives for technology performance improvements [6.7]. Summary description for assigning weights for each parameter for the double roller evaluation was discussed in the previous studies [6.8], [6.9]. In addition, our previous research [6.10] highlighted a flexible framework by proposing an evaluation method that makes a transition from a focus over environmental friendliness towards an improved eco-efficiency definition. Therefore, it defined a dimensionless evaluation parameter according to the current methodologies, which are also known “DE-Index”. This evaluation method utilized a machine tool lubrication technology. However, it was thought that without considering the safety for risk aspect parameter in any technology development would not achieve its optimal performances. Therefore, this work integrates the mentioned parameter that covered in the previous study [6.10] and re-evaluated the technology performance influences. Meanwhile the content, figures and tables for economy, performance and ecology are duplicated in this work. This technology evaluation concept contributes to the risk management in manufacture sector, and it is very valuable for Timor Leste's future manufacturing management needs and also for teaching and learning activities.

6.2 Study objective and approaches

This section of work presents the main objective of the study and its approaches. The main objective is to promote a comprehensive technology evaluation platform for risk management in manufacture; therefore, environmentally friendly technology is well adapted for the sustainable development in the industry sector. This will be obtained from multi-dimensional evaluation parameters through a comparison between developed Double-roller technology and conventional technology for lubrication. The Fig.6.1 illustrates the overall, specific objective and study outcomes. It also shows the main methodologies of the study.

The study used a simple Life Cycle Assessment (LCA) method. It is one of the appropriate methods for the technology development evaluation analysis. As it is commonly known that LCA is one of the key tools which widely used by many scholars in their literature and works that related to environmental management aspect (ISO 14040) [6.10], [6.11]. In this LCA method, the main considerations are given to some important development stages from the raw material extraction and purchase, manufacture to usage and end-of-life [6.11], [6.12]. As it is stated in the [6.11] study and adopted in the [6.10], the development evaluation that only focus on one specific aspect or stage may hard to see the effects on the environmental. In Fig.6.2, it shows an example of LCA [6.11] for a refrigerator product development at its disposal stage.

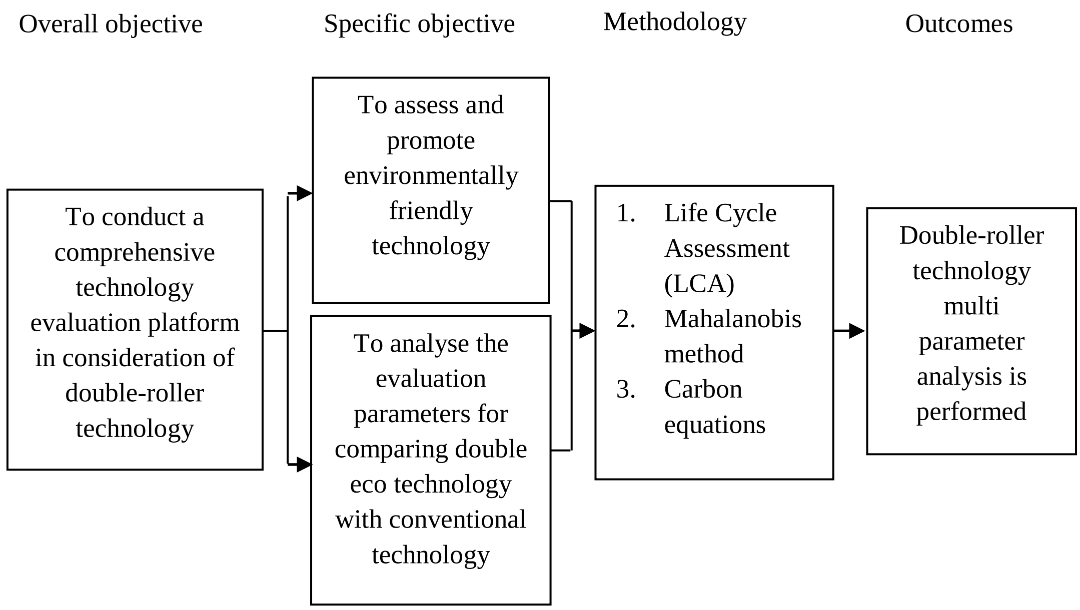


Fig.6.1. Schematic view of study coverage

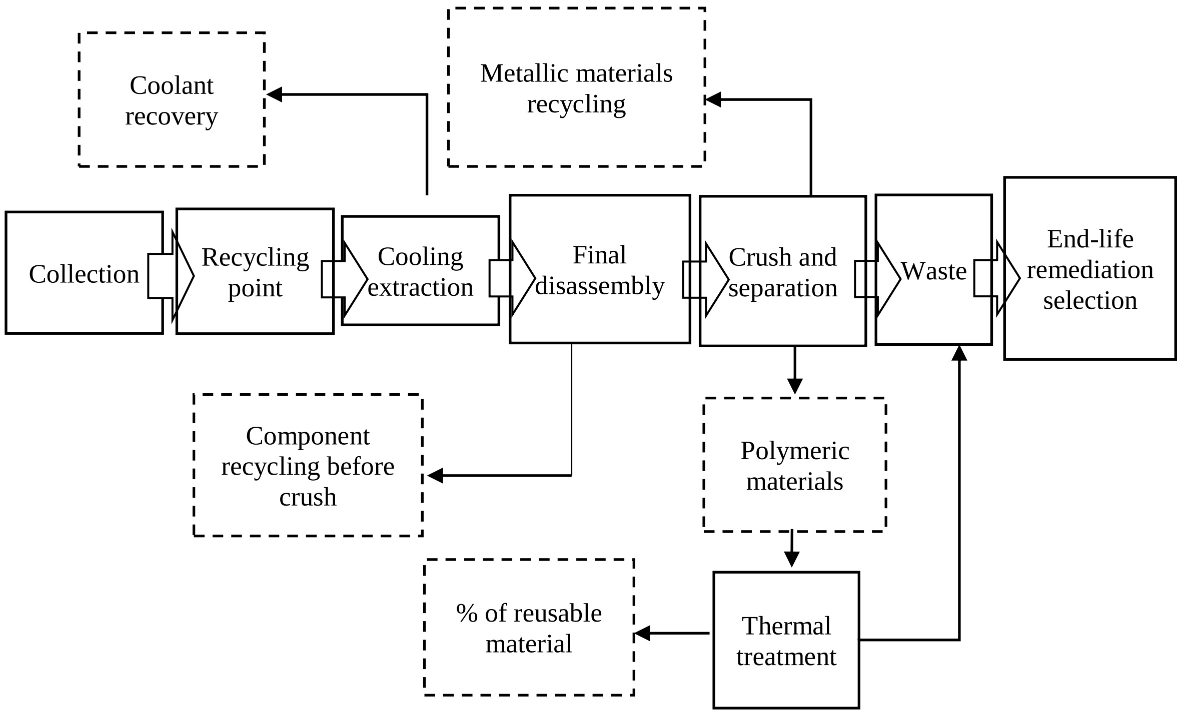


Fig.6.2 Lifecycle of a refrigerator at its disposal time [6.10] [6.11]

One important component which was noticed is that the end-of-life of products is important to integrate into LCA analyses, because it helps to improve the supply-chain management aspect which is often neglected by many scholars. In addition, the study [6.13] suggested that it is important to consider how products could reprocess and integrate back into the nature, which known as the bioremediation concept. Another important aspect is that in many LCA studies, it usually does not consider the social or economic dimensions, but the mentioned study is integrating the cost parameter into the LCA analysis [6.12]. This study integrates all parameters including cost, performance, ecology, and risks for safety in the analysis.

6.3 Double-eco discussions and eco-efficiency explanation

Although the current studies presented some eco-efficiency definitions, there is a need for a comprehensive and reflective eco-efficiency definition [6.14], [6.15]. In the previous work [6.10], it stated that there is a need for global consensus for the mentioned aspect as the current definitions are most likely focusing on economic and environmental ratio parameters. Therefore, it tries to simplify the current general eco-efficiency terms into a dimensionless benchmark. It highlighted in the previous studies that all analyzed parameters including mechanical performances, economic and ecological should be considered in same degree of priority [6.5], [6.6]. However, it was noticed that these parameters perform much better regarding technology competitive achievements if the risk for safety parameter is included. Risk parameter is very important in all stages of any technology development. Therefore, this work integrates the mentioned parameter into the current mechanical performance, ecology and cost parameters at the same degree of priority. Fig.6.3 shows new proposing double eco model principal with the risk for safety parameter. The figure reveals both ideal and real implementations. It depicts that the shaded area indicates the real implementation of the Double-Eco technology principle and the non-shaded area which bounded by shaded lines is the ideal implementation. As highlighted earlier, the Double-Eco is used to reflect the double roller technology for lubricant evaluation. It consists of four rollers, two inside and two outside. It is a dimensionless evaluation parameter measured in percentages. It was thought that the Double-Eco model, an integration of the aforementioned parameters to be possible under the newly developed concepts, eco-efficiency term denominated as the Double-Eco area index or DE-Index that obtained from the comprehensive multi-parameter analysis.

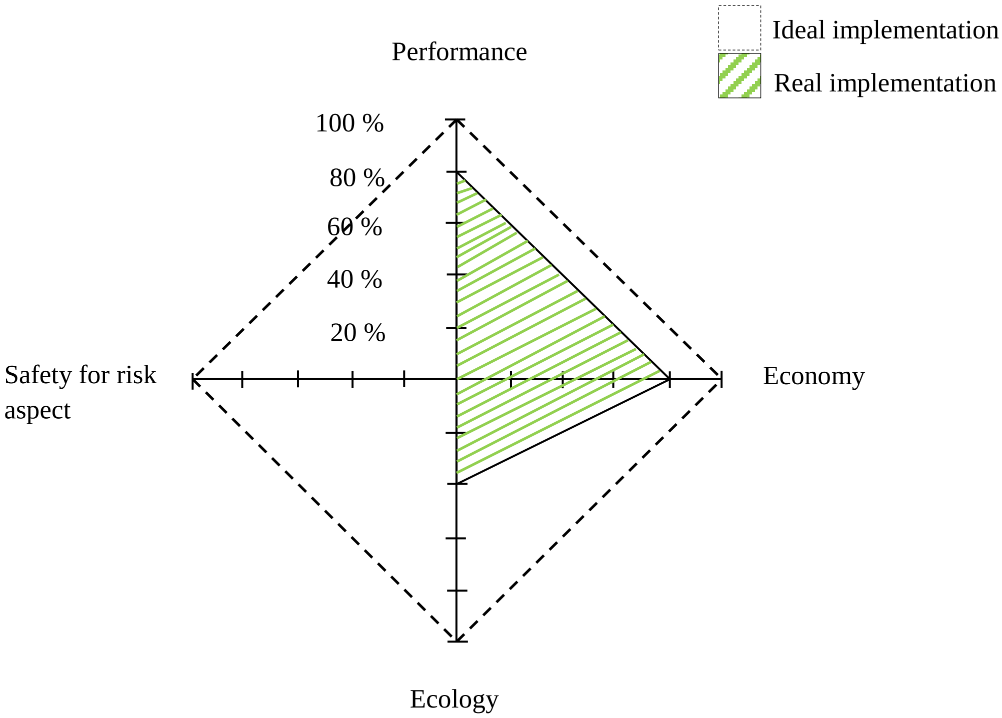


Fig.6.3 The proposed Double-Eco model principle

The lack of said term represents an obstacle for sustainability and opportunity to quantify it with currently available technology trends such as machine learning methods and big data analysis [6.16], [6.17]. It can be stated that this method can be an alternative to avoid the existing arbitrary method and detects the positive external impacts according to Schaltegger (1997) [6.8], [6.14]. The dimensionless index was obtained from the comparison of technologies' ideal or optimal implementation and real implementation through the defined and selected parameters which include economy, ecology, performance and safety for risk parameters. It is represented in equation 6.1 [6.10].

Furthermore, the study [6.10] stated that "*the index depends on comparing all the technologies that serve as input and present which one of the technologies is the best performing with the DE-Index among the portfolio that is being compared. This can be valuable to confront an innovative technology which rarely confronted with its opponents; it, however, can also be significantly value to confront the current existing technologies"*. Therefore, the flexibility of the Double-Eco evaluation concept is more relevant and applicable.

$$\text{DE-Index (\%)} = \frac{\text{Real implementation (RI)}}{\text{Ideal implementation (II)}} \tag{6.1}$$

It is important to be noted that the DE-Index and the utilized data are non-measurable factors.

6.3.1 Environmental conviviality dimension explanation

In environmental management, it uses various tools and approaches for its evaluation needs including Life Cycle Assessment. It plays an essential role in the environmental management aspect. Therefore, this defines some important categories of the lifecycle of technology. These categories including initial stage such as material supply for technology production or manufacturing, the utilization of technology and its applications, then the last category is related to the end-life at the disposal of technology components. Fig.6.4 briefly shows how they are important in an environmental evaluation analysis or assessment. It depicts some important stages which including in the mentioned three main categories are a source, here it includes the source of material extractions from nature or environment, then the material processing stages which later utilized for producing desired goods and technologies in manufacture.

After from the production of technologies, it comes to the stage of application or usages, here it involves a process of defining types of materials and technologies that considered as renewable and non-renewable before sending to final disposal in a landfill. Saling and other scholars (2002) stated that the Badiche Anilin-und Soda-Fabrik (BASF) Company proposed an eco-efficiency approach that relies on several aspects including polling survey and economic studies for defining environmental performances. It can be applied for any institutional, industry or country studies [6.8] [6.10].

The BASF environmental evaluation approach is based on ISO 14040 standards and it focuses on several categories including emissions, energy and resource depletion, toxicity and risk potential [6.8]. Apart from BASF, Bevilacqua (2012) uses a weighting approach for normalization of environmental priority categories [6.11]. Considering these concepts and findings, the study [6.10] conducted analysis to define the categories for ecological parameter evaluation.

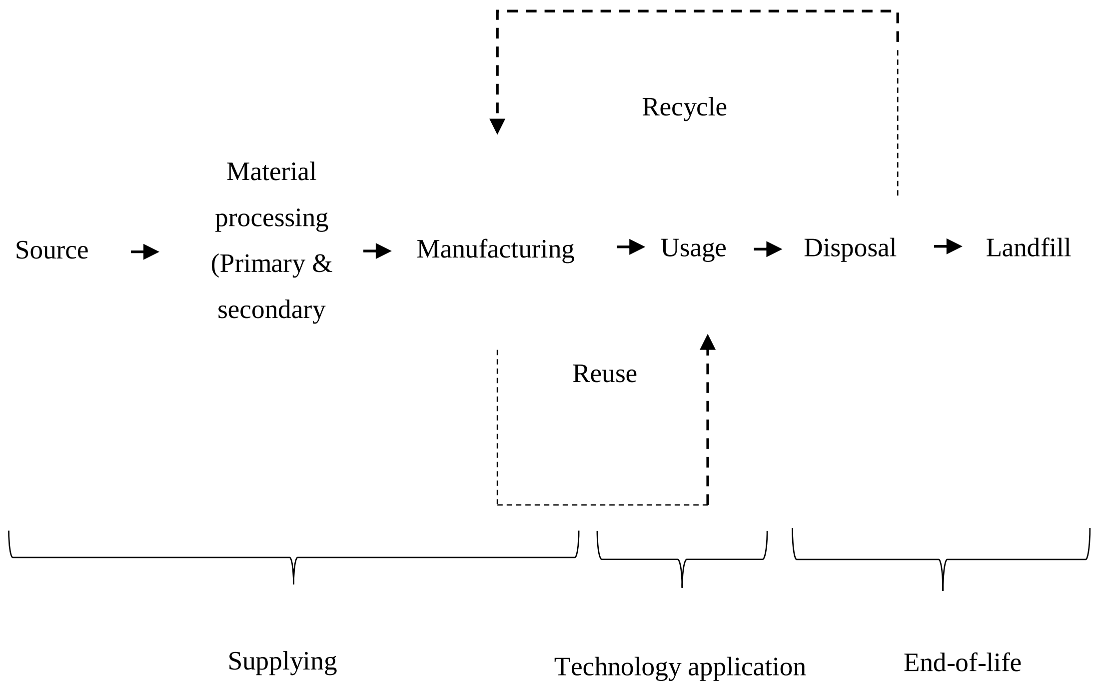


Fig.6.4 Schematic view of LCA diagram with different category [6.10] [6.13]

Table 6.1 The Double-Eco categories and its signification for the environmental dimension [6.10]

Life cycle group	Double-Eco category	Signification
Supplying	1. Locality	From local-to-local site consideration
	2. Renewability	Renewability of technologies or components
Technology application	3. Durability	Frequency of repair or maintenance
	4. Energy efficiency	Least energy consuming technology
	5. Emissions minimization	Least emitting technology
	6. Noise / Vibrations	Absence of unintended effects
	7. Waste minimization	Waste minimization (based on the total material requirement index)
End-of-life	8. By-product safety	Absence of waste that represent a health hazard
	9. Recyclability	Recyclability of the elements used or the product components
	10. End-life waste bioremediation	Industrial waste that can be treated with bioremediation

It was stated that *"these groups will lack weighting and act in a binary manner (0 or 100) except weighting is determined by technology users. Non-binary answers depend on linear estimations between the technologies that confronted, where 100 is the best performing technology and 10 is the worst-performing (0 would mean non-performing)"* [6.10]. In this work, it considers three main life cycle sections including supplying, technology applications and end-life of a product or technology. Meanwhile, it considers 10 Double-Eco categories (Table 6.1) for this evaluation purposes.

6.3.2 Mechanical performance dimension explanation

This section focuses on the mechanical performance; it used the Mahalanobis Taguchi System (MTS) to analyze data of technologies. There are some intensive studies exist regarding the MTS method utilization [6.18], [6.19]. The MTS is a classification technology that devised for conducting diagnoses and forecasting with multivariate data. This method combines quality-engineering principals and utilizes the Mahalanobis Distance (MD) for structured induction of data, serving as a basis for decision-making. The distance is also can be regarded as the measure of the divergence from the variables mean values of a certain population that constitute the Mahalanobis Space (MS) also known as the unit group (Fig.6.5). It is clear that the MS is suitable to discriminate between normal and abnormal data through the distance measurement, this then defined as performance. After establishing the MS, the number of attributes can be reduced by using orthogonal array (OA) and signal-to-noise ratio (SN) by evaluating the contribution of each attribute. There are few stages of MTS, this can be summarized below: Step I: Creating a measurement scale, that is selecting a reference group with suitable variables and observations that are as uniform as possible, then used that reference group as the base point of the scale. Step II: Validating the measurement scale. In this step, some important measures such as identifying conditions that fall outside the reference group, calculate the MD of these conditions and see if they meet the requirement, and then calculating S/N ratios to determine the accuracy of the scale are considered. Step III: Determining the useful set of variables using OA and S/N ratios. Step IV: Diagnosing the useful variables based on the calculated MD values, some appropriate actions or corrections are necessary. The first step is to construct a measurement scale by using MS as a reference. In order to do this, a set data of normal observations is valuable and essential, these data then standardized by using the equation (6.2) below:

$$Z_i = \frac{X_i - m}{\sigma} \tag{6.2}$$

Where:

- m : mean of the attribute
- $\boldsymbol{\sigma}$: standard deviation of attributes
- Z_i : standardized variables, and

- X_i : normal observations

The standardized vector is obtained from the standardized values of X_i (i = 1, 2,…..k). It then calculates the MD by using the following equation (6.3) after conducting matrix correlation:

$$MD_j = {D_j}^2 = \frac{1}{k}\ \mathrm{Z}_{\mathrm{ij}}^{\mathrm{T}}\ \mathrm{C}^{-1}\mathrm{Z}_{\mathrm{ij}} \tag{6.3}$$

Where:

- C^{-1} : the inverse of the correlation matrix that contains correlation coefficients between variables
- T : transpose of the standard vector
- k : number of data sets or total variable that used

The second step is to validate the measurement scale. For this, it uses the observation outside of MS to validate the measurement scale. The mean value, standard deviation and correlation matrix of normal observations are necessary to calculate MD of abnormal observations. For the better measurement scale, it is normally the abnormal observations that have a larger value of MD then normal observations. The third step is to optimize the system, OA and SN are used to identify the attributes that more useful and important. Usually, any types of SN ratios but it often uses the larger better. It uses the following formula (6.4) for calculating the single to noise ratios.

$$SN = \eta = 10 \log \left[\frac{\frac{1}{r}(S_\beta - V_e)}{V\,e} \right] \tag{6.4}$$

Where; r is sum of squares due to input signal, S_β is sum of squares due to slope, V_e is error variance, S_e is error sum of squares and S_T is total sum of squares.

These steps are used for the MTS analysis, however, only two steps are considerably important in the Double-Eco performance evaluation: 1). the creation of an appropriate Mahalanobis Space, and 2). validation of the reference space through abnormal data, in this case, the roller data measurements.

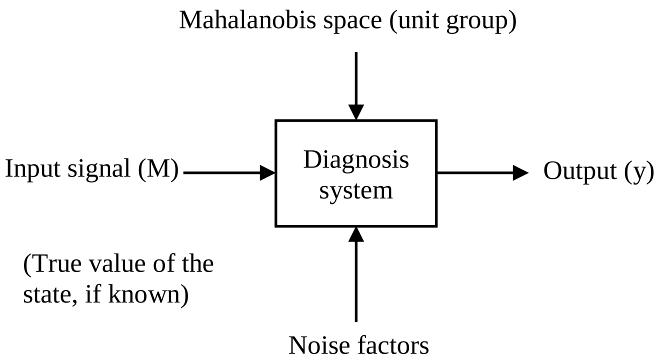


Fig.6.5 Schematic view of MTS diagnosis mechanism [6.10] [6.18]

6.3.3 Economical dimension explanation

In this section, it discusses the important categories of main costs for economical parameter evaluation. These costs are production cost, usage cost and disposal cost.

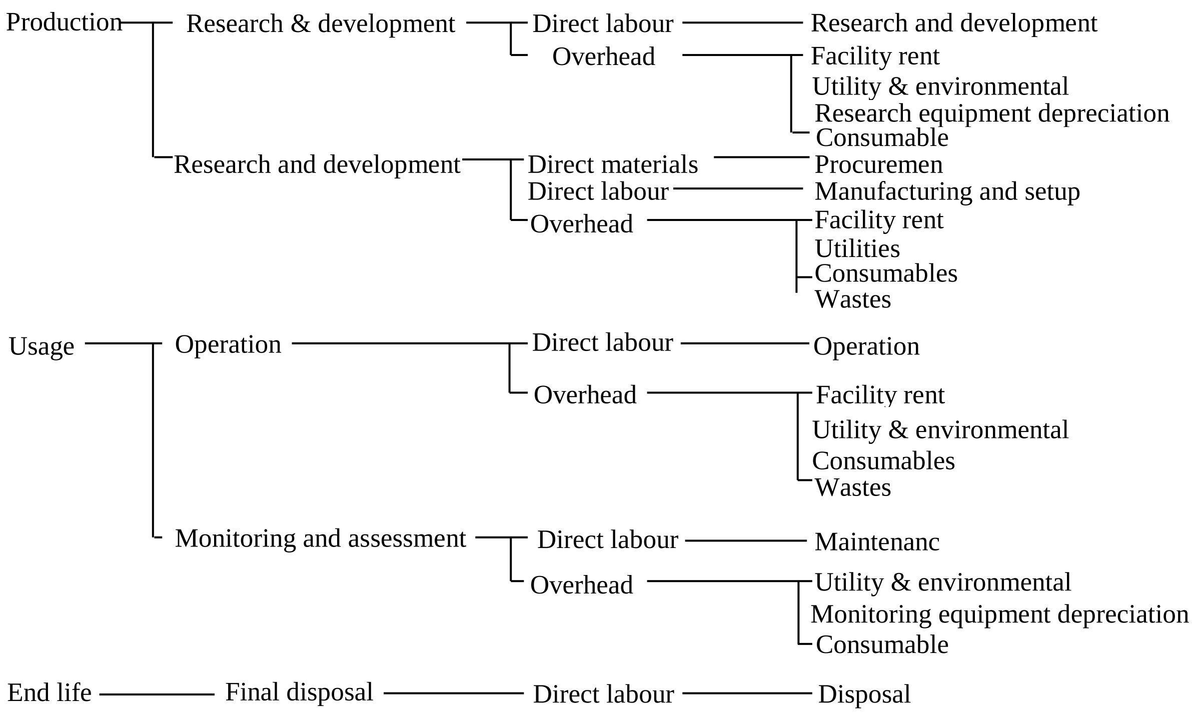


Fig.6.6 Diagram describing the categories devised for the economy parameter evaluation [6.10]

As discussed in the previous study [6.10] the product cost was including direct labor and direct materials as well as overhead that based on normal standard accounting principles [6.20] and acquisition cost, usage cost and disposal costs were considered for the machine tool costs calculation [6.21], [6.22]. In addition, a non-production cost such as research and development costs were considered as non-production costs for production costs [6.20]. As it highlighted in the World Business Council for Sustainable Development (WBCSD) product development category for the ecology evaluation parameter, the usage maintenance costs are replaced by assessment and monitoring costs [6.4], [6.15]. In this study, direct labor for a not-automated scenario considered in the assessment and monitoring part. However, the direct labor could be part of the operation overhead if automation occurs. Likewise, the taxation was included in the overhead costing and then it added the taxation cost for the environment category [6.20]. It was thought that the final disposal cost should be included in the overhead cost which does not directly link with labor issue as the cost for disposal often covers the labor cost. Here it is asserted that all the costs were in the United State Dollar (USD).

6.3.4 Risk for safety dimension explanation

This section discusses the risk parameter for the double-eco technology promotion and provides some important highlights. As it was mentioned in our previous study [6.10], it discussed the important three double-eco technology platform parameters, mechanical performances, economy, and ecology yet risk parameter was not included. Consequently, this work specifically focuses on the mentioned parameter. There are several definitions of risk, Aven (2016) defines that Risk is the severity of the consequences of activity concerning something that human value [6.23]. According to Chartered Institute of Management Accountants (CIMA) official terminology 2005, "*Risk is a condition in which there exists a quantifiable dispersion in the possible outcomes from any activity*". Meanwhile, it is defined as "*Uncertain* *future events which could influence the achievement of the organization's strategic, operational and financial objectives*" by the International Federation of Accountants, 1999 [6.24].

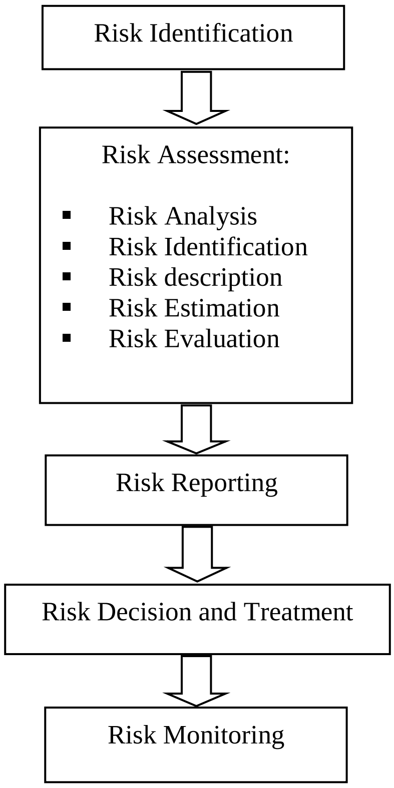


Fig.6.7 The schematic process risk handling

Risk is an aspect which exists in all stages of manufacture and industry activities, from planning to implementations. The paper [6.25] stated that having considering risk aspects in an organization or manufacture means a chance of success will be obtained. It further outlined the outcome of risk management including establish a reliable basis for decision making, planning and minimize losses or defects in the product manufacturing. According to scholars and experts, there are several components and stages of risk, however, the most common stages such as risk identification, risk analysis, risk description, risk quantification or estimation and risk evaluation are often considered [6.23] - [6.33]. The Fig.6.7 reveals the flow of risk approaches.

Table 6.2 Double-Eco categories and definitions of risks

Risks group	Risks categories	Category explanation and definitions
Human health risks	Acute oral toxicity	Adverse effect caused when a hazardous substance is taken into the body by ingestion
	Acute dermal toxicity	Poison due to expose or skin contact with chemicals
	Acid burns	Eye irritation and blindness
	Skin effects	Skin irritation and cancer
	Respiratory effects	Respiratory problems due to Inhalation of chemicals that affect lung functions
	Internal effects	Larynx, rectum, pancreas, skin, scrotum and bladder
Environmental risks	Green House Gas Potential (GWPi)	Less carbon dioxide equivalent
Business risks	Resource scarcity	Availability of raw material resources
	Price escalation	Oil price goes up
	Trust	Prove technology performances

Regarding to the double-eco technology definition and evaluation parameter, this section of work discusses the direct risk that associated with the usage of alternative machine tool lubricant which previously analyzed and discussed in the paper [6.5]-[6.7]. It is believed that various activities can use the suggested processes. However, the risk categories here merely focus on three main aspects. Firstly, it looks at human health risk categories based on scholars' views [6.27] - [6.30], secondly, it considers environmental risk mainly greenhouse gas potentials and last is about business risks. The Table 6.2 lists the risk parameter categories for the proposed double-eco technology.

The described risk categories were considered based on related expert reports and literature reviews [6.27] [6.28] [6.29] [6.30] and [6.43]. Based on the chosen risk categories (Table 6.2), the considerations were merely focusing on these related risks (human health, environmental and business risks) to the entire cycles of technology production risks from raw material extractions to end-life of products to end in landfill and recycling. The chronic daily intake, incremental lifetime cancer risk and total expose risk were not considered as the grease contents have insignificant effects on human health. The Fig.6.8 shows the schematic view and depicts that some products are appropriate for reusing after gone through recycling processes.

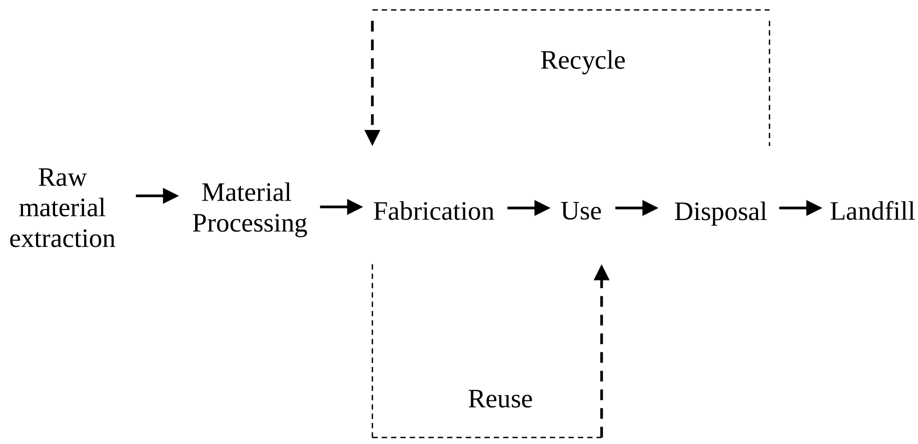


Fig.6.8 Schematic view of risk associated issues in all stages

6.4 Experimental of double-roller technology

In this part it discusses the experimental arrangements and its concepts. Currently, some innovation tools including TRIZ (Teorya Resheniya Izobreatatelzkikh Zadatch or Theory of Rusian inventive problem solving) concept exist and been used to obtain sustainable principle. Regarding this, there are several eco-design related concepts and papers that address the environmentally sustainable design exist [6.35]. This Double-Eco concept and framework will be applicable for innovation tools for future sustainable development when mechanical performance issues are considered in a more accurate way. This paper presents the previous experimental case results based on machine tool lubrication technology which is known as double-roller. Literature shows that currently there are various machine tool guideways lubrication methods exist [6.34]. One of the common methods is using oil pumps to supply lubricant to the guideways surface of machine tool [6.7]. The TRIZ 40 concepts or principles are necessary for analyzing and developing such technologies inefficient manner.

Table 6.3 Adapted TRIZ principles and characteristics for roller technology [6.10] [6.36]

Characteristics to be improved	Principles	Significations
Amount of substance	Local quality	Transition from homogeneous to heterogeneous structure of an object or outside environment (action).
Loss of substance	Replace a mechanical system	Replace fields that are stationary with mobile
Adaptability	Self-service	An object must service itself and carryout supplementary & repair operations.
Reliability	Extraction	Extract only the necessary part or property from an object.

Table 6.3 outlines that factors such as the absence of loss of grease and its amount and adaptability are essential for the machine tool lubrication issue. With the TRIZ principles, it shows how mechanical performance can be arranged including grease distribution that used hybrid grease for its self-service nature [6.36]. The important aspects of TRIZ principle that applicable to Double-Eco concept are locally reflected products, replaceable mechanical system, self-service and reliability.

In Fig.6.9, it shows the double-roller mechanical arrangements for grease distribution on machine tool guideways. The actual machine tool is shown in the Fig.6.9a, and the schematic view for the grease adjustment and distribution mechanism is shown in the Fig.6.9b. Meanwhile, the Fig.6.9c shows the 3D and sectional view of A-A of double-roller. From the figures, it shows that the environmentally friendly lubricant technology consists of two outside rollers which are used to hold or keep the grease, the other two inside rollers are used to control and adjust the grease thickness that presents in the surface of guideways.

The technology also completed with springs and four bolts which are used for load adjustment. From the previous studies, it was observed that the developed technology can provide a self-service mechanical performance for the distribution of hybrid grease [6.5],[6.6],[6.7]. The study [6.6] also explained that for the reason of reciprocating two rollers it mounted to one side of the guide of the machine tool table.

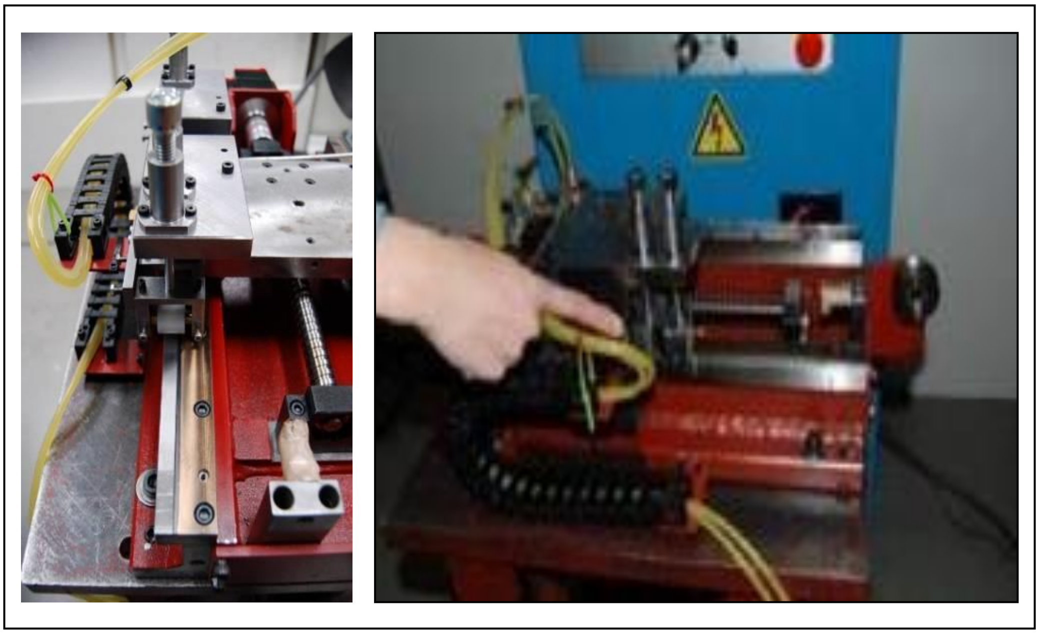


Fig.6.9a The photograph of the Double-Roller technology [6.10]

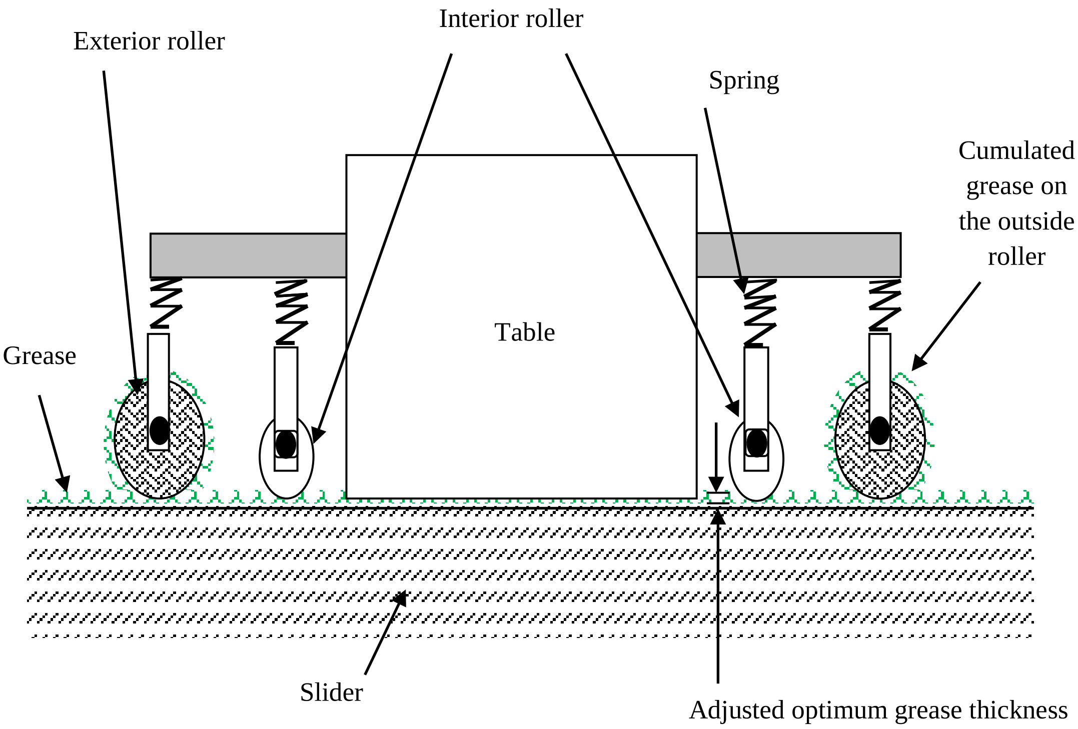


Fig.6.9b The schematic view of the Double-Roller arrangements

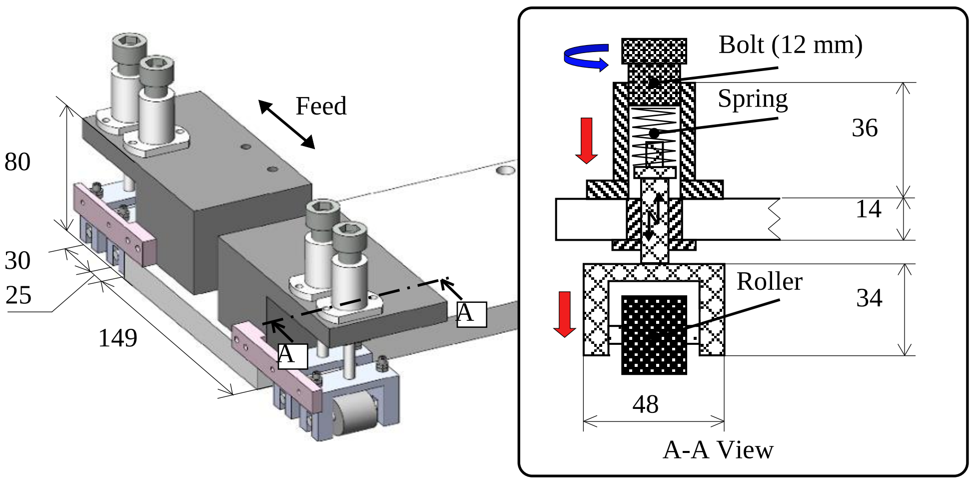


Fig.6.9c The 3D and sectional A-A view of the double-roller

The results of an experimental analysis of these mechanical arrangements of double-roller technology are shown in Fig.6.10. It shows the relationship between the lubrication thicknesses T_g and time duration in hour for each conditions. The results of grease thickness analysis were obtained by the Taguchi method. Here, the three analysis conditions are including conventional lubricant method, worst scenario, and best conditions.

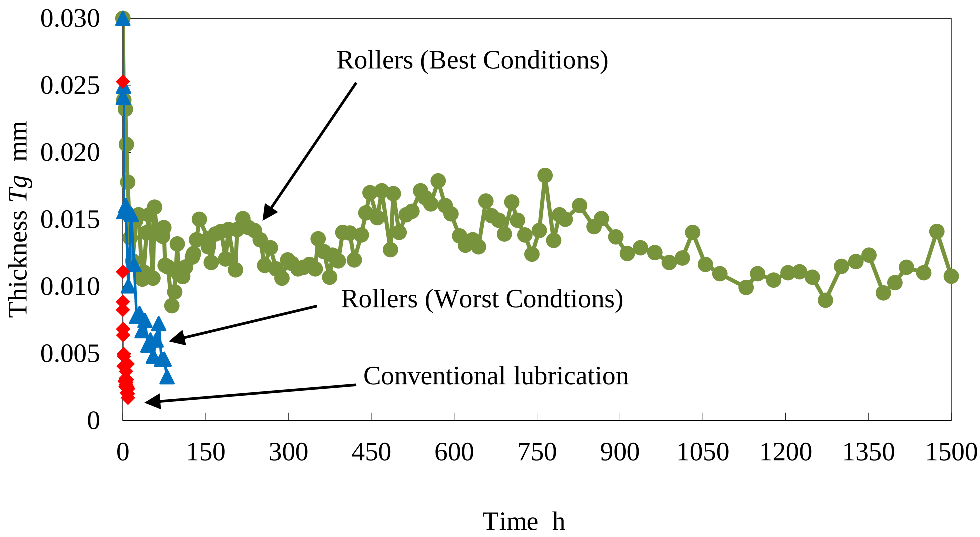


Fig.6.10 Experimental results for three different conditions of lubricant thickness [6.10]

Table 6.4 Mechanical arrangement specifications [6.10]

a. Slider machine specifications

Description	Unit	Values
Feed	mm/min	1000
Guideway length	mm	360
Guideway width	mm	10
Table weight	kg	6.8
Dimensions	mm	360×740×130
Power	kW	1.2

b. Control factors and two different conditions of roller by TM

Control factors		Rollers (Best conditions)	Rollers (Worst conditions)
Exterior roller	Material	Felt	Polyurethane
	Diameter	φ20 mm	φ25 mm
	Load	2.5 N	0.0 N
Interior roller	Material	Polyacetal	Felt
	Diameter	φ20 mm	φ25 mm
	Load	14.5 N	2.5 N

The best condition which can hold grease for a longer period can up-to 15000 hours. In contrast, the conventional method was able only hold lubrication or grease less than 10 hours. Meanwhile, the worst condition category can hold grease up to 80 hours. The experimentation was stopped upon reaching a lubrication thickness threshold of 5 μm.

Both machine tool transfer guide specifications, experimental conditions and its control factors are shown in Table 6.4a and Table 6.4b respectively. In this experiment, it used a handy guideway machine tool with a feed rate of 1000 mm/min, it is powered by a 1.2 kW motor. The overall dimensions of the machine are 360 mm × 740 mm × 130 mm. The machine weight is around 6.8 kg and the guideways length and width are 360 mm and 10 mm respectively.

The control factors for both outside and insider rollers are including material, diameter and load. Here it needs to be asserted that the roller specifications were obtained by Taguchi Methods. In this method, various material types were used for the best and worst roller combination option selection purposes [6.6]. As stated by [6.10] study that because of its lubrication properties, both an Olyisobutylene (PIB) with a concentration of 3 wt% and Multinoc Nippon Oil Corporation were used for the hybrid grease [6.5], [6.37] experiment. The details of best and worst roller conditions are shown in Table 6.4b. In the study [6.6], the best and worst conditions for the roller mechanical arrangements were conducted and defined by using Taguchi Method. Based on these conditions, the evaluation of multi-dimensional parameters for roller technology is deemed important.

6.5 Multi-dimensional parameter evaluation of double-roller technology

6.5.1 Environmental dimension evaluation

As mentioned earlier, the evaluation of the environmental parameter was discussed in [6.10], here the minimizing emissions and wastes, durability as well as reprocessing and reusing (recyclability) is the main consideration. It was defined that 365 days for a one-year period, 8 hours in a day with 1 shift. The time which was needed to change the lubrication was considered for the durability in one year. The best option was 2 times, the worst option was 37 times and the grease option was 292 times. On the other hand, the Japanese Ministry of Environment emission factor was used for the calculation as it was explored in the previous studies [6.5], [6.7]. The best condition was 0.01 g, the worst condition was 0.27 g, and the grease condition was 1.81 g. The total quantity of the used grease for one year was considered for the waste minimization. The best condition with total weight of 0.38 g, the worst condition was with total weight of 7.10 g. Meanwhile the grease lubrication option was with total of 47.30 g.

Table 6.5 Assigned weighted values for each of the ecology categories in the machine tool lubrication case [6.10]

Double-Eco category	Units	Roller (Best conditions)	Rollers (Worst conditions)	Conventional lubrication
1. Locality	(km)	100	100	100
2. Renewability	yes/no/partially	50	50	50
3. Durability	(times/year)	100	89	0
4. Energy efficiency	yes/no/partially	100	100	100
5. Emissions minimization CO_2	(kg/year)	100	87	0
6. Noise / Vibrations	yes/no/partially	100	100	100
7. Waste minimization	(kg/year)	100	87	0
8. By-product safety	yes/no/partially	100	100	100
9. Recyclability	yes/no/partially	50	50	50
10. End-life waste bioremediation	yes/no/partially	50	50	50
Total		850	813	550

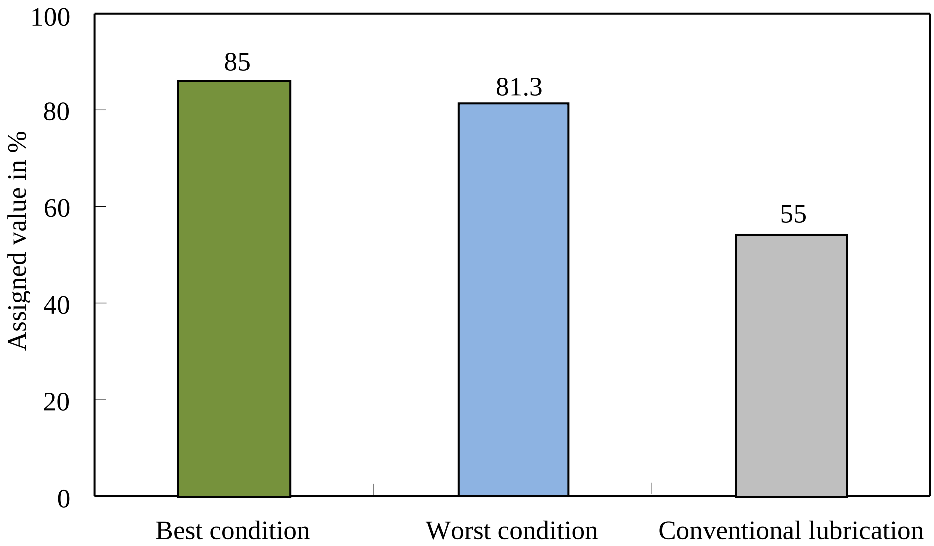


Fig.6.11 Total environmental assigned value per roller conditions

Meanwhile, it compared the waste and emission minimization categories, for example, it weighted the highest waste with the smallest value of 10 and assigned the lowest waste with the higher value of 100. On the other hand, 50 was set for the end-life bioremediation, recyclability and renewability. This is because grease can be re-proposed, re-refined then properly disposed at the end of its life [6.10] [6.39]. Then 0 means not performing. The total environmental assigned value for each condition indicates the best technology option that contributes to the environmental conservation efforts, all the total multiplied with 10 and divided by 100. The results are shown in Fig.6.11 which depicts that the best roller condition is 85 % opposed to 55 % of conventional lubrication.

6.5.2 Mechanical performance dimension evaluation

Again, as discussed in the [6.10], it is highlighted that a certain set of information and data is important to define an MS. To make a proper selection for the performance parameter evaluation under the Double-Eco model platform, proper parameters need to be defined. The defining machine tool lubrication behavior for the MS, three parameters were deployed for the experiment; the grease thicknesses at the first 2 hours of the initial run Tg_{2h}, the grease thickness when reaching the critical 5 µm threshold $T_{5\mu m}$ and the thickness change rate due to the slope of the lubrication graphs. Meanwhile, as seen in Table 6.6a and b, the normal data that used to create the Mahalanobis System was the conventional lubrication data and the roller lubrication data sets were used for the abnormal data.

Table 6.6a MTS input data of MD values for experimental

No	Variables	Conditions for creating MS		
		Thickness after 2 hrs Tg_{2h}(µm)	Time at 5 µm thickness $T_{5\mu m}$ (hrs)	ΔTg (µm/hrs)
1	Conventional lubrication	4.95	1	-2.290
Abnormal data				
2	Roller best conditions	23.92	1948	-0.013
3	Roller worst conditions	15.58	55	-0.334

Table 6.6b MTS output data of MD values for experimental

No	Variables	MD largest values
1	Conventional lubrication	0.001
2	Roller worst conditions	0.534
3	Roller best conditions	19.642

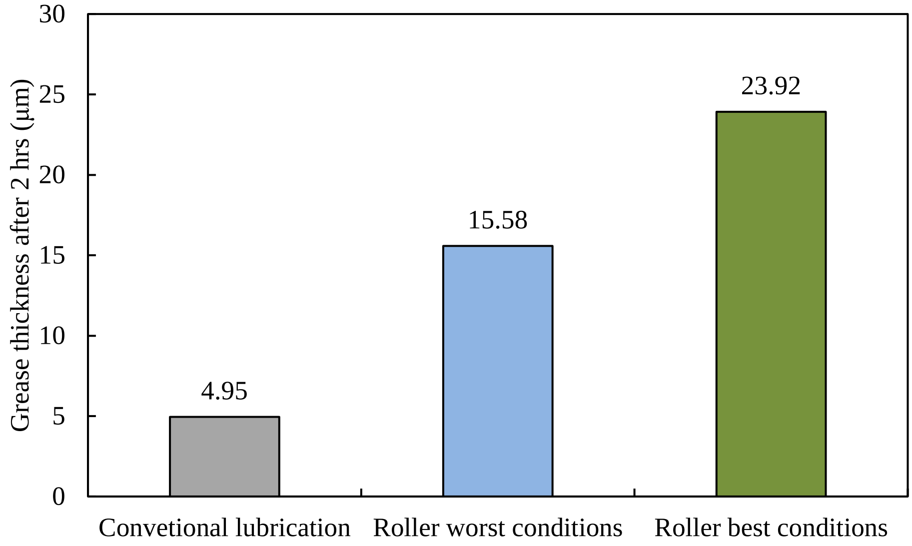


Fig.6.12a Grease thickness after 2 hours observation in experimental case

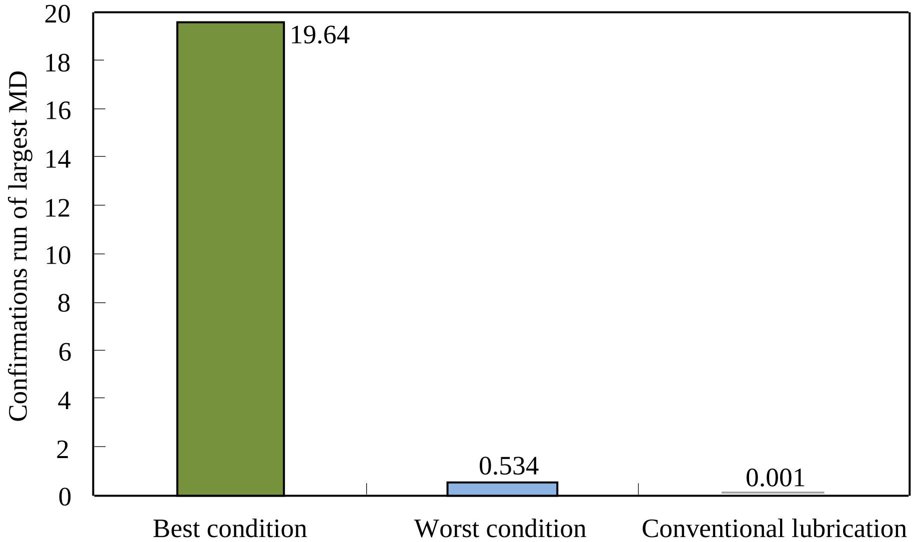


Fig.6.12b The confirmations run of largest Mahalanobis Distance value

The study results reveal that a confirmation operation under abnormal condition was able executed by using the largest value of Mahalanobis Distance and creates a ranking. The Fig.6.12a depicts the grease thickness that observed after two hours of experimentation. Then, in Fig.6.12b, it illustrates the MD for final calculation results for the three conditions. It shows that 19.642 for the best roller condition, 0.534 for worst roller condition and 0.001 for conventional lubrication.

6.5.3 Economical dimension evaluation

In this section for the cost evaluation parameter, it considers several conditions for the evaluation procedures for this experiment of the Double-Eco roller technology model. The considered cost parameters are procurement, manufacturing and setup, operation, utilities, consumables and maintenance cost. Fig.6.13 shows the selected economy parameters for cost considerations. As outlined in the previous study [6.10], first, the production and usage cost for one year assumed 365 days × 1 shift × 8 hours = 2920 hours. Meanwhile, the development and research cost were not considered in this calculation. On the other hand, the cost for energy usage counted for the highest rate that is around 0.15 USD/kWh [6.41].

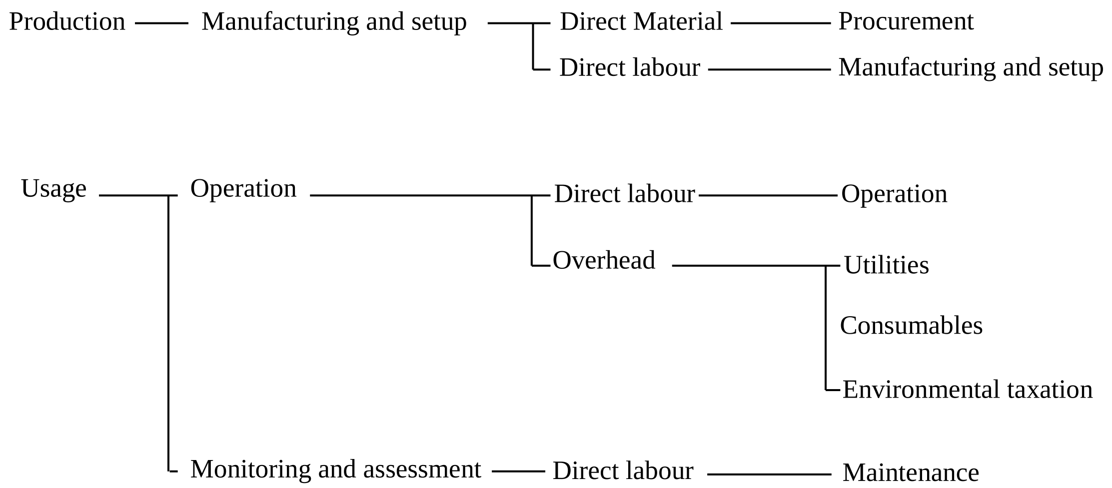


Fig.6.13 Selected economy parameters for machine tool lubrication case [6.10]

Here, the environmental taxation fee is included in the utility cost [6.40]. Then the cost for a technician is around 23.6 USD per hour [6.42]. It must be asserted that the utility costs are the higher portion compare with all other costs in the economical parameter. Meanwhile, it considers a same maintenance cost for all variable conditions. On the other hand, it was assumed that the assembly would take about 5 hours. It needs 5 minutes/day for monitoring, and takes 10 minutes for grease disposal.

For the procurement costs, it explained in the [6.10] *"Procurement costs were the total cost of the assembly parts of the arrangement, utilities accounted for every hour in a year using the transfer machine and consumables were calculated using a 97 % Multinoc grease and 3 % Polyisobutylene mixture"*. Therefore, as it is shown in Table 6.7 and the Fig.6.14, the costs for the three different technology conditions are indicating that the best roller condition option is around USD 589.37 or 18.2 % cheaper compare with the conventional option that costs USD 3242.74.

The worst roller options costs around USD 2825.35 that is about USD 171.98 higher. From these cost calculations, it was able to compare and rank between the three technologies.

Table 6.7 Economy parameters selected for the machine tool lubrication case [6.10]

Cost categories (USD)	Rollers (Best conditions)	Rollers (Worst conditions)	Conventional lubrication
Procurement	433.90	469.91	0
Manufacturing and setup	118.00	118.00	0
Operation	7.66	143.57	1148.53
Utilities	1621.81	1621.81	1621.81
Consumables	0.003	0.060	0.403
Maintenance	472.00	472.00	472.00
Total Cost	2653.37	2825.35	3242.74

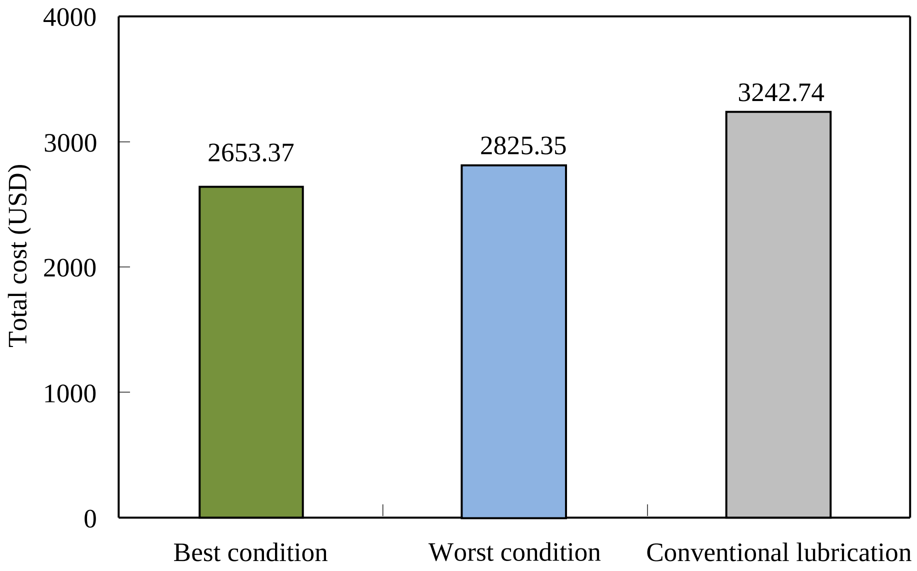


Fig.6.14 The final total economical parameters for all conditions

6.5.4 Risk for safety dimension evaluation

In this section, the discussion is focusing on three different levels of categories. It focuses on health risks of lubricant substances namely polymer and grease, the environmental risks are considered by looking on some gases potential impacts, it was estimated based on CO_2 emission results of lubricant quantity which highlighted and presented in the previous work [6.5] - [6.7]. Subsequently, the equivalent potentials are estimated and valued based on the carbon dioxide results. The business risks are also essential; it highlights the availability of lubricant raw material due to nonrenewable resources. In addition, both price escalation and business trust risks are also equally important in this discussion.

In the study [6.6], it shows the annual emissions that resulted from the conventional lubrication and proposed lubrication are in kg-CO_2/year. It used equation (6.5) to obtain the CO_2 emission that produced by the proposed lubrication method.

$$\text{Exhaust } CO_2 = 3.44 \times 10^{-2} \times W_o + 2.62 \times L_o \tag{6.5}$$

Where; W_o (ℓ) is the amount of the lubricating oil to be discharged, and L_o (ℓ) is the amount of light oil for transporting lubricating oil. In the case of study [6.6], the $L_o = 0$ (ℓ), and the amount of grease that used for the calculation was 2.4 kg/year or 0.4 *g* per 2 months.

The amount of oil for conventional lubrication was around 38 ℓ per year. It needs to be noted that the proposed lubrication, grease was impregnated with 3 wt% of polyisobutylene. The CO_2 emissions of both lubrications were calculated [6.6] and compared as shown in Fig.6.15. It concluded from the result that using the proposed double-roller for the sliding parts of machine tools would not only require less amount of grease but also last for a longer period. As a result, the CO_2 emission from this proposed method compares to the conventional cooling method decreased significantly by one per 188 times, where, the proposed method represents with an annual carbon emission of 0.0148 kg-CO_2/year. On the other hand, the conventional method produces annual carbon emission of 1.31 kg-CO_2/year.

Fig.6.16 shows the gas emission potentials. Instead of weighting, the grease greenhouse carbon dioxide emission factor from the [6.43] in regard to its quantity for three different options including best roller with 0.38 gr/yr, worst roller with 7.10 gr/year and conventional option of 47.30 gr/yr which mentioned in the previous section of 6.8.1 were used for the calculation. The figure depicts that introducing Double-Roller in the guideway of machine tools will help save a significant quantity of lubricants and reduces emissions 124 times compared to the conventional lubricant method. The figure reveals that using conventional lubrication options, the equivalent greenhouse gas emission is 0.251 CO_2-eq gr/yr. Meanwhile, the worst roller option is 0.037 CO_2-eq gr/yr and the best roller option is 0.002 CO_2-eq gr/yr. These were obtained by using equation 6.6.

$$\underset{(CO_2\text{-eq-gr/yr})}{\text{GHGP}} = CO_{2\,GWP} \times \text{Qty [gr/yr]} \times \text{CF } [CO_2/\text{gr}] \qquad (6.6)$$

Where; GHGP: Greenhouse gas potential, CO_{2GWP}: Carbon dioxide global warming potential impact equivalent in gr, CF: grease coefficient factor/gr.

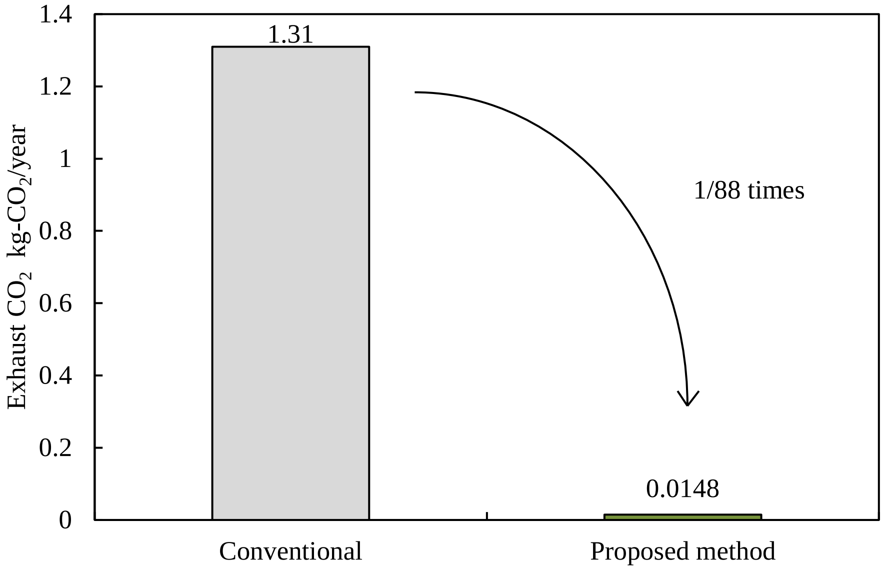


Fig.6.15 Comparison of exhaust CO_2 between the proposed permanent lubrication and the conventional lubrication

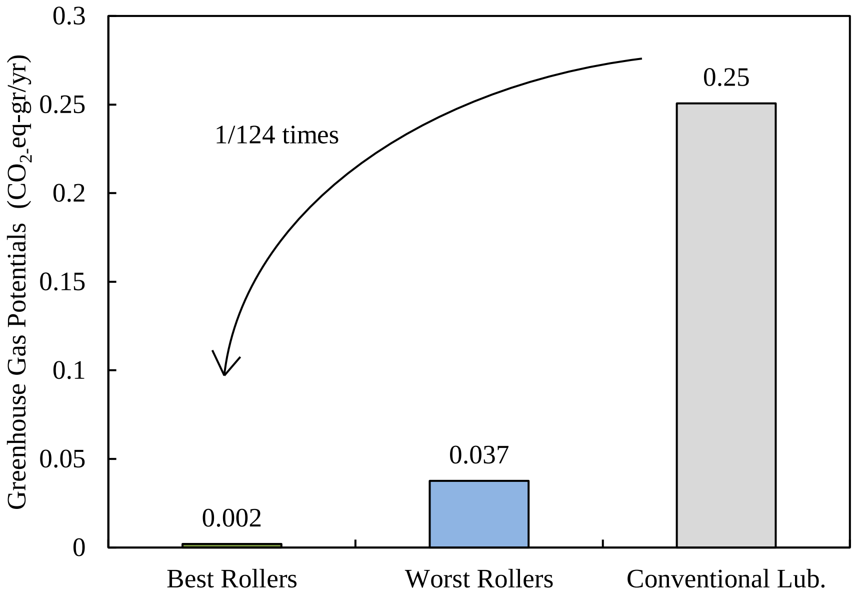


Fig.6.16 The greenhouse gas emission potential for three different technology lubricants

It was subjectively weighted the aforementioned risk categories' (Table 6.8) effects on human when expose and have direct contact with the lubricant substances as suggested by scholars from the literature. The environmental risk is weighted based on the carbon emission and its greenhouse gas emission potential (i.e. the highest risk assigned with 1 point and lowest risk assigned with 10 point).

The last risk category is the business risk. It was thought that it is necessary to aware of availability of raw materials, as both oil and grease are nonrenewable resources. Because of this, the world oil price can be a serious issue and need to be considered, and inventions are needed for substituting the existing environmentally unfriendly technology. However, it needs to consider about trust from public regarding the best of double roller itself. Here, the study shows that by using an effective and efficient technology such as double-roller will conserve natural resources and protect environment in future. With this advantage, it will able to attract technology users in manufacture.

Table 6.8 Assigned weighted values for each of the risk categories in the machine tool lubrication case

Risks Category	Units	Roller (Best conditions)	Rollers (Worst conditions)	Conventional lubrication
1. Acute oral toxicity	yes/no/partially (pp/yr)	10	5	1
2. Acute dermal toxicity	yes/no/partially (pp/yr)	10	5	1
3. Acid burns	yes/no/partially (pp/yr)	10	5	1
4. Skin effects	yes/no/partially (pp/yr)	10	5	1
5. Internal and respiratory effects	yes/no/partially (pp/yr)	10	5	1
6. Internal effects	yes/no/partially (pp/yr)	10	5	1
7. Greenhouse Gas Potential	gr-CO_2 eq/yr	10	5	1
8. Resource scarcity	yes/no/partially	5	5	1
9. Price escalation	yes/no/partially	5	5	1
10. Trust	yes/no/partially	10	5	1
Total		90.0	50.0	10.0

6.6 The Double-Eco technology efficiency evaluation results

In this section, it discusses the comparison between the ideal implementation and real implementation of the Double-Eco Index results. It is important to note that the ideal implementation of technology means 100 % efficiency that considering all parameters in any technology adaption.

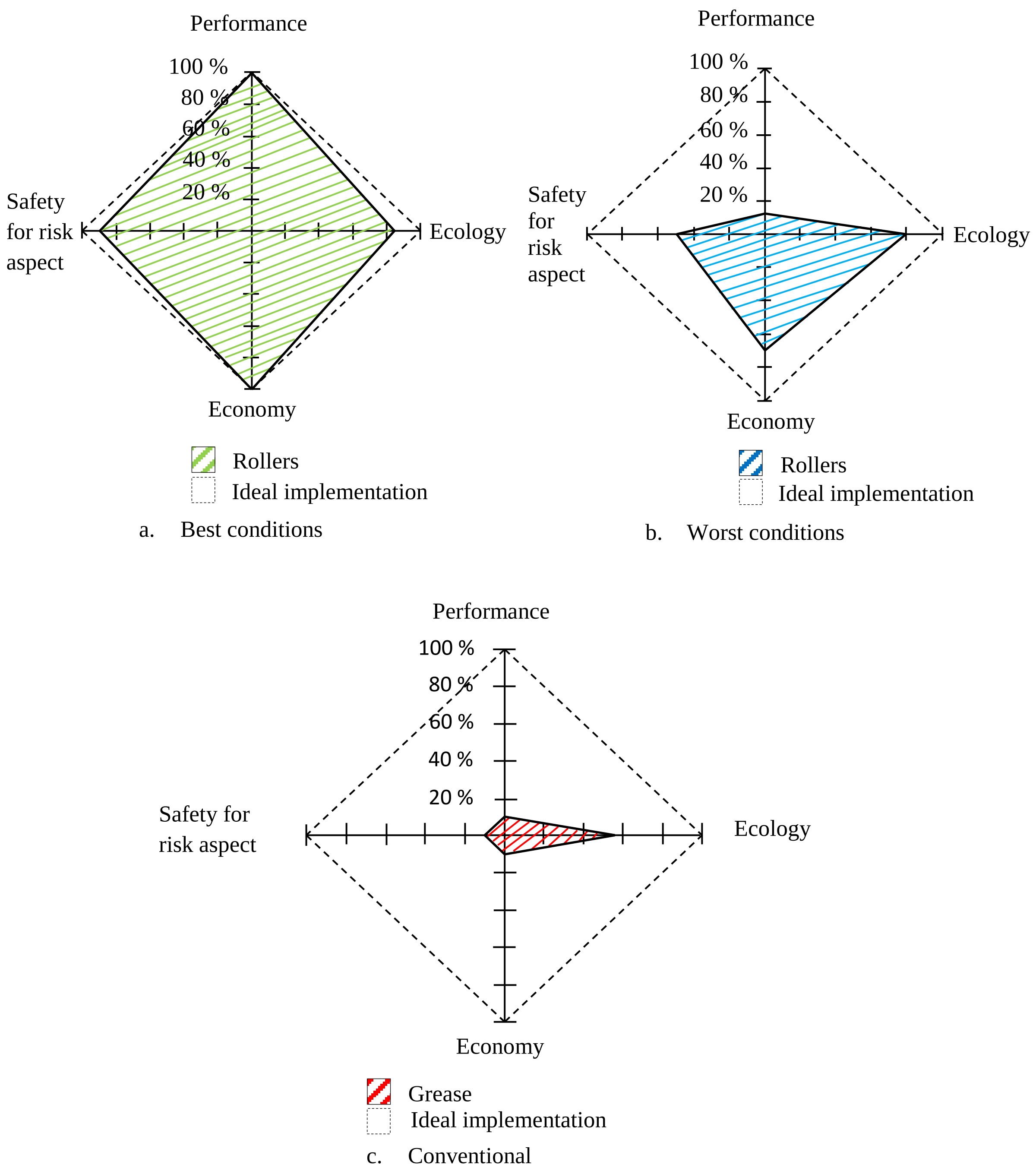


Fig.6.17 Results of the Double-Eco evaluation for each technology in the experimental case

As observed in Fig.6.17, it should be cleared that the best performances of the developed lubrication technology models would be the appropriate option for the DE-Index evaluation. Fig.6.17a shows the best condition of the proposed Double-Roller, Fig.6.17b shows the worst condition and Fig.6.17c depicts the conventional condition of lubrication. The areas are colored, best condition with green, worst with blue and conventional with red. The Table 6.9 outlines the specific data and information for the colored area for each condition.

The area for three different adapted technologies conditions namely; best roller, worst roller and conventional are 17500 u^2, 5678 u^2 and 650 u^2 respectively. Meanwhile, the estimated ideal Double-Eco Index area is 20000 u^2. The Double-Eco Index comparison results are clearly showing some significant impressions. As outlined in Table 6.9 and shows in the Fig.6.18, it estimated DE-Index by using equation 6.1 from section 6.3. The ranking values are based on each parameter subjective weighting approach as discussed in each section, the best performance parameter gains 100.

Table 6.9 DE-Index of eco-efficiency for each technology in the machine tool lubrication case

Technology	Double – Eco roller parameters					
	Performance	Economy	Ecology	Risk for Safety	Calculated area (u^2)	DE-Index (%)
DE Ideal implementation	100	100	100	100	20000	100 %
Conventional lubrication	10	10	55	10	650	3.25 %
Rollers (Best conditions)	100	100	85	90	17500	87.5 %
Rollers (Worst conditions)	12.7	74	81	50	5678	28.4 %

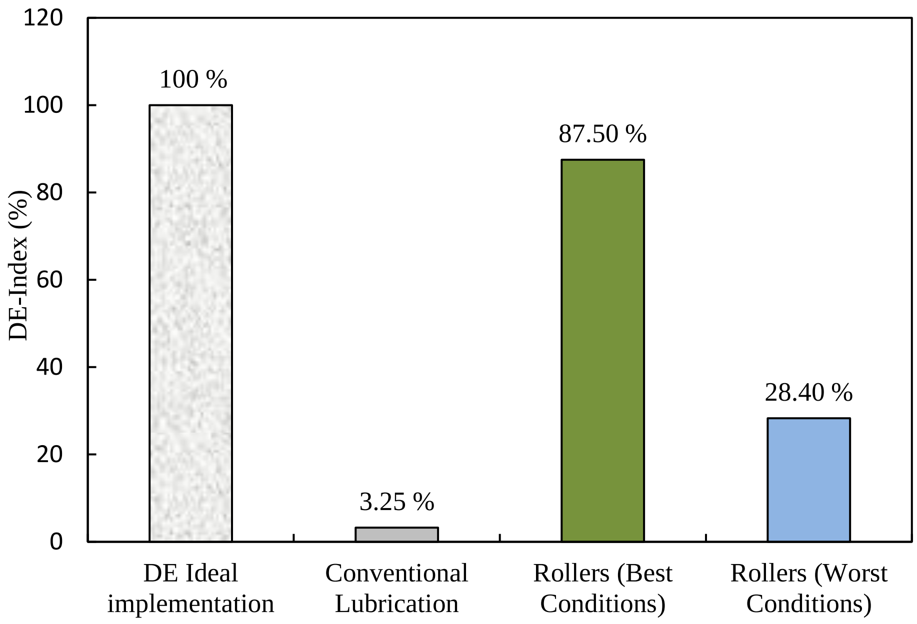


Fig.6.18 Final Double-Eco Index for all technologies

The calculation results show that the DE-Index for conventional technology is 3.25 %, the roller with the worst condition is 28.40 %. Meanwhile, the roller best condition index is 87.5 %.

6.7 Summary

The innovations of technologies have dramatically changed over the years. Technologists, industries, and entrepreneurs have played a significant role in this. As it continues to evolve, there is urgent to consider the environmental protection measures. Therefore, technology producers and users are not only improving their performances for gaining better profits but also need to give priority to the environmental conservation. Perhaps, efforts on this issue regarding technology design, production and evaluation are exist. However, less attention is given to environmental issue due to profit oriented business. For this, the double-roller technology which is used for the Double-Eco Index concept analysis was considered in this multi-parameter technology evaluation analysis study. With the Double-Eco model, the technology eco-efficiency parameters were able compared with conventional methods. The Double-Eco Index or eco-efficiency parameters integrate related multi-dimensional technology evaluation including mechanical performances, ecology, economy and risks for safety aspects in a holistic way. The study therefore summarized:

(1) The proposed Double-Eco concept is appropriate for any technology evaluation with its own characteristics, and as first step towards automation to avoid current arbitrary methods.

(2) There is a significant improvement in all discussed parameters including environmental pollution output, mechanical performances, costing and risk for safety aspects 87.5 % DE-Index opposed to 3.25 % for the conventional method.

(3) This risk manufacture management concept will applicable in Timor Leste's future manufacture development needs. Meanwhile, the concepts and methods will be used as reference for teaching and learning needs at Universidade Nacional Timor Lorosa'e (UNTL).

Chapter (7)

Conclusion

In this final chapter, it summarizes the brief results of research on related manufacture environmental and risk management issues. Energy conservation, environmentally friendly cooling method, high quality machine tool performance and appropriate technology development evaluation concept were the main driven factors for the work. The study researched in detail several related aspects that link to both risks at ordinary time (factory environment influence) and non-ordinary time (due to natural phenomenon and fabricated or man-made).

In the case of risk at ordinary time, it focused on analysing machine tool performance accuracy due to environmental thermal fluctuations. According to the study [7.1], there are many causes of machine tool accuracy issues as shown in Fig. 7.1. In the [7.2] – [7.11] study, it discussed aspects related to geometrical error risk, load-induced error issues. The scholars discussed the causes and asserted three main machine tool error risk aspects including geometric errors, thermally induced error and load-induced errors. The mentioned scholars have studied most of the related causes; this study was only focusing on thermal deformation issue which analysed environmental thermal fluctuation influence on machine tool performance accuracy. Meanwhile, the discussions related to machine tool vibration issues were deemed important and presented in Appendix I. On the other hand, the risk at the non-ordinary time that associated with both fabricated and natural disasters was also essential and explored. As Fig.7.2 shows various natural disasters can affect manufacture and industries especially machine tools. However, this study was focusing on earthquake as the main research and presented a comprehensive review of a flood disaster impact on manufacture in Thailand in Appendix III as representation. Also, electrical energy environmental impacts, specifically for Timor Leste electricity issue was evaluated. In addition, the study assesed the environmental impact of using alternative cooling method of SAW in manufacture by focusing on transportation and machining impacts for the man-made risk category.

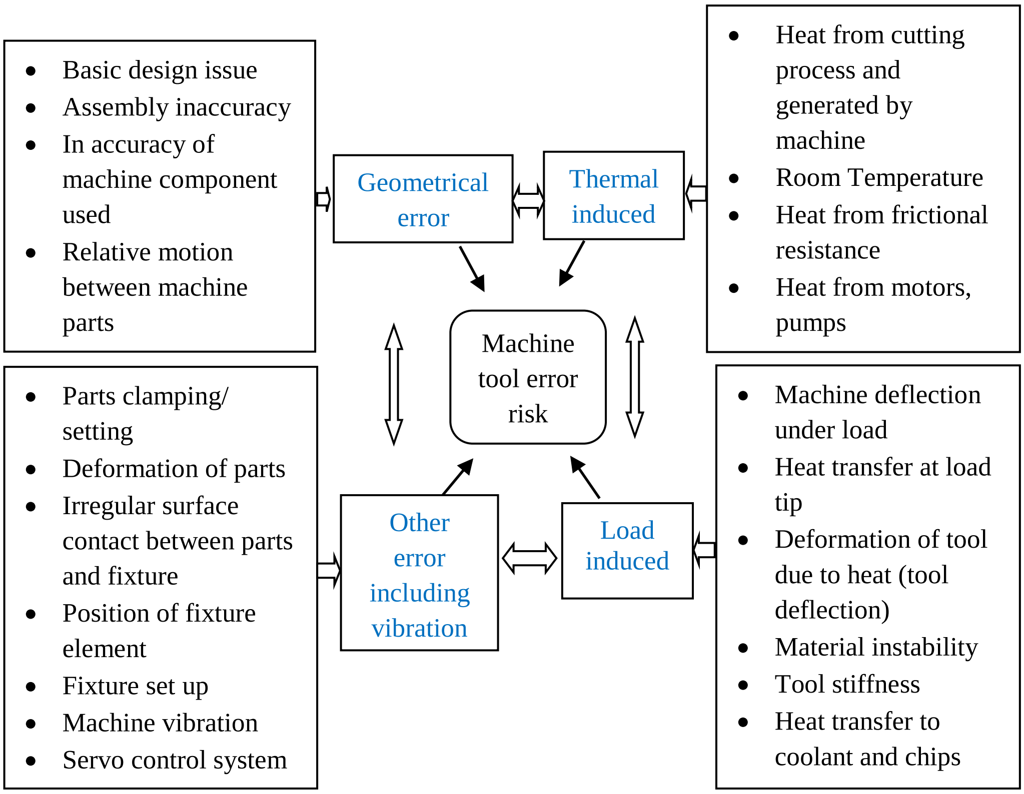


Fig.7.1 The schematic view of machine tool performance cause risks at ordinary time

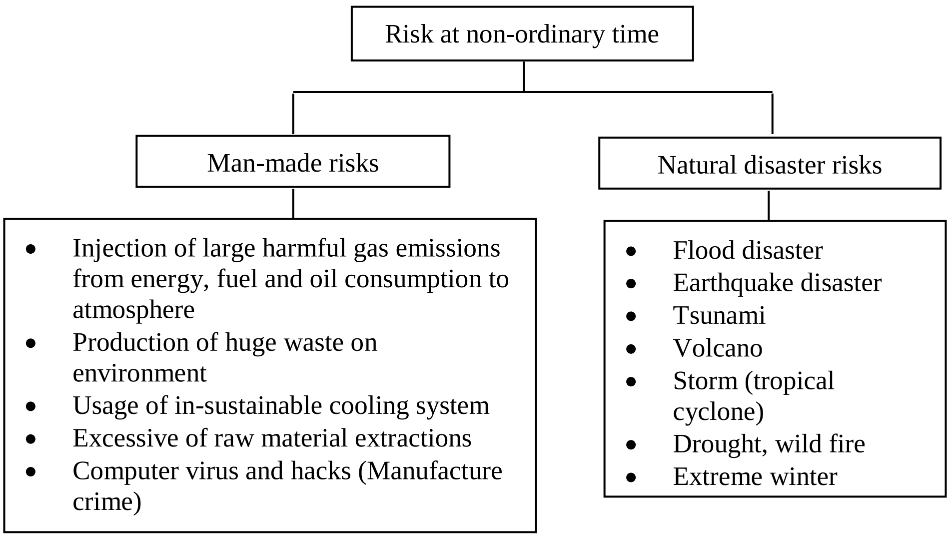


Fig.7.2 The schematic view of machine tool performance cause risks at non-ordinary

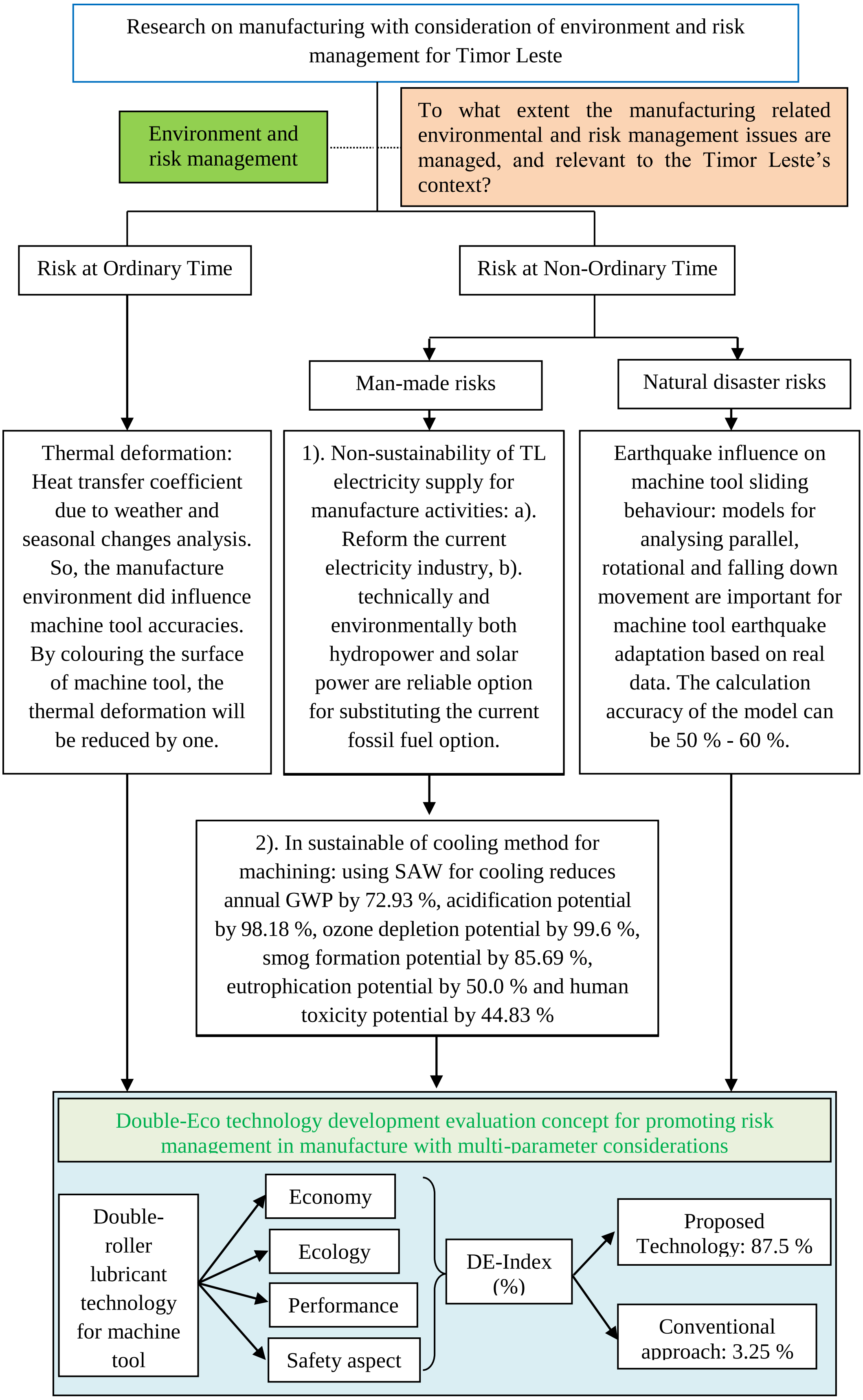


Fig.7.3 The schematic view of machine manufacture risk management holistic approach

Another important of the man-made disaster risks is manufacture computer viruses and hacks. The related issues were summarised from various literatures and presented in Appendix II. The manufacture risks management thus needs to be considered at all categories including risks at ordinary time and risk at non-ordinary time that include man-made and natural disaster risks. To gain a great equilibrium result between environmentally sustainable and economically benefitable, it is worth to state that comprehensive manufacturing planning, design and performance approach are the only key to achieve environmentally sustainable development while having economic benefits. At the same time, a multi-parameter evaluation approximation for technology development evaluation is required.

Regarding this, the study presented an alternative concept for technology development evaluation framework. It proposed a Double-Eco technology model with a multi-dimensional parameter evaluation platform for promoting risk management in manufacture (Fig.7.3). The Double-Eco technology concept was used to reflect a previously developed double-roller lubrication technology.

The study results and summary of each chapter follow:

Chapter (2): There are various approaches concerning thermally induced errors due to the influence that has over the positional accuracy of a machine tool. This study explored the environmental thermal fluctuation influences on machine tool performance accuracy. It focuses on temperature, heat transfer coefficient and thermal radiation. Models for both NC and CNC machine were created for FEM simulation needs. Both simulation and experimentation were performed. The analysis results for NC milling machine show that in summer the maximum error of cut was small due to large heat transfer coefficient and heat generated at headstock that cooled by convection regime such as open window and running fans. Meanwhile in winter the maximum error of cut was large due to constrained regime (windows were closed; central heating and other heaters were used). The maximum error of cut was around 15 μm difference between winter and summer due to environmental thermal fluctuations.

The CNC jig borer machine has precision accuracy of 0.1 μm. However, it generated error of cut for spring, summer and autumn from 3 μm to 8 μm and 12 μm for winter. In winter, the error of cut was large due to forced cooling that contributed to the large thermal deformation at spindle head and ball screw. The results show that both experimental and simulation results of the CNC jig borer machine were significantly approximate.

Here, it can be asserted that the environmental thermal fluctuation, temperature, heat transfer coefficient and coolant thermal properties influenced machine tool thermal behaviour. For contributing to the minimization of thermal deformation issue, an experiment was conducted by painting a device with 8 different Japanese machine tool maker company colours together with black and aluminium. It measured heat transfer coefficient which was used to calculate the thermal radiation. It noted that the convection between two heat transfer coefficients, blackening and aluminium was the influence of the thermal radiation. The overall summary of this study follows:

(1) Errors of cut for both NC and CNC jig borer machines were influenced by the different seasons and weathers, room temperature and heat transfer coefficient in the machining center.

(2) Through the FEM simulation approach, the uncertainty of machining accuracy for the environment representation of world machine shops was able highlighted and compared. It is very effective for machine tool thermal deformation analysis.

(3) It was important to note that coloring the surface of a machine can reduce its thermal deformation by one.

(4) The study approach of FEM simulation and experimentations for analyzing the environmental thermal fluctuation influences on machine tool accuracy can be applicable for Timor Leste's general machine shop, specifically the machining shop of Universidade Nacional Timor Lorosa'e (UNTL, in Hera. The machine shop has no Air Conditioning and with significant large

windows and ventilation for air circulations. Therefore, the approaches of this study will be applicable for Timor Leste situation.

Chapter (3): This chapter overviewed Timor Leste electricity sector development and its challenges. It was challenging when the tiny country regained its independence in 2002. All electricity infrastructures were destroyed during the war. With the international supports the sector was slowly restored and rebuilt to provide electricity to the people. Then in 2007/8, the government invested in 250 MW fossil fuel power plants, transmission and distribution lines. The sector is heavily relying on government subsidy (>$100 million for fuel) for its fossil fuel electricity operations. Currently, it is using diesel for generating electricity. The recorded data shows that million kilograms of carbon dioxide have been pumped into the atmosphere as results of diesel and oil consumptions. At least around 3,924.51 million kg-CO_2 has been emitted from power plants.

Although the sector is facing enormous challenges and using environmentally unfriendly sources, the country has some potential renewable energy sources which could be harnessed for energy needs. However, proper directions and policies are needed for the country to move forward. The brief summary of this study follows:

(1) Revise the current policy and consider proper energy options for minimizing both financial and environmental effects.

(2) Restructure or reshape the electrical energy policy and provide space for private sector to step in for the better improvement and will reduce financial dependency from state.

(3) The AHP analysis results show that hydropower is the first preferred energy option based on the technical and environmental criteria. Technically, it is 75 % reliable, efficient and available compared to fossil fuel.

Chapter (4): The current cooling system of using oil has significant impact on environment. It is serious issue which has become global concern that need proper countermeasures. There are several measures and ways exist for addressing cooling system in manufactures, using strong alkaline water is one of them. The demand for using such environmentally friendly cooling is significant. Regarding this, the study was conducted to explore the environmental impact of using strong alkaline water for cooling during machining. It sought to compare both cuttings using strong alkaline water and using conventional wet cutting. The results from this study proved that strong alkaline water has positive impact on both environment and human health compared with the conventional cutting method. However, it recognized that further investigation on human health impact is required. Some specific summary from the study follows:

(1) The strong alkaline water-cooling method uses less resource for machining processes.

(2) Most emissions are resulted from transportation aspect. This indicates that fuel alternatives, travel route, and better shipping planning are needed.

(3) SAW reduces annual global CO_2 equivalent potential by 72.93 %, acidification potential by 98.18 %, ozone depletion potential by 99.62 %, smog formation potential by 85.69 %, eutrophication potential by 50.0 % and human toxicity potential by 44.83 % compared to the conventional cooling.

(4) The assessment approach and the application of SAW for manufacture cooling are relevant and can be applicable in Timor Leste. This cooling method is one of the global warming countermeasures that needed by the country in near future.

Chapter (5): The study developed three analytical models, parallel, rotational and falling down for calculating machine tool motion behaviours at earthquake. Three Japanese real large earthquake acceleration data were used for the study. Both mathematical analysis and experimental evaluation were performed. Then, parallel and rotational models were used for the validation. It applied to CNC machining center regarding the 2004 Chuetsu earthquake acceleration data. The summary of this study follows:

(1) Data of all earthquakes was very different for the accelerations in all directions. Therefore, place, direction of setup and ground conditions influence on machine tool are important.
(2) The physical model for parallel, rotational and falling down motions was constructed. This model was effective for the experimentation.
(3) The proposed analytical model for all motions was deemed very appropriate for analyzing machine tool motion behavior during seismic event as it was able to perform up-to 60 % calculation accuracy.
(4) The relationship between earthquake and manufacturing is very important and valuable for Timor Leste in future. The lessons, concepts and theory for design purposes are very much needed for the country.

Chapter (6), The innovations of technologies have dramatically changed over the years. Technologists, industries and manufacturers played a significant role in this. As it continues to evolve, there is a need to consider the environmental protection issue. Technology producers and users are not only improving their performances for gaining better profits but also need to give priority to the environmental conservation issue. For this, it needs a technology development evaluation concept that based on eco-efficiency principle. Many studies on this issue exist; yet less attention is given to environmental issue due to profit oriented. For this, the double-roller technology which is used for the Double-Eco Index analysis was considered as an appropriate concept for environmental conservation. With the Double-Eco concept, the technology eco-efficiency parameters were able compared with conventional method. It integrates all multi-dimensional technology evaluation parameters including mechanical performances, ecology, economy and risks for safety aspects in a holistic way. The summary of this study follows:

(1) The proposed Double-Eco concept is appropriate for any technology evaluation with its own characteristics, and as first step towards automation to avoid current arbitrary methods.

(2) There is a significant improvement in all discussed parameters including environmental pollution output, mechanical performances, costing and risk for safety aspects 87.5 % DE-Index opposed to 3.25 % for conventional method.

(3) The manufacture risk management concept will be applicable in Timor Leste's future manufacture development needs. Meanwhile, the concept and methods will be used as teaching and learning reference at Universidade Nacional Timor Lorosa'e (UNTL) in the short-term.

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Appendix I

Machine tool vibration and countermeasures
(Literature review)

Contents

Machine tool vibration and countermeasures

1. Introduction

In this summary, it is important to state that no new findings are presented here in the review, the related vibration contents and considerations and solutions for addressing vibration issue are obtained from literatures that indicated in this literature review. It is simply summarising the important key factors, which the authors discussed. This work does not present new materials and solutions for addressing the machine tool vibration issue; however, it only provides some valuable references as supporting factor to the aim of handling risk management issue at a usual condition that discussed in the main content of the paper. Vibration is an important factor in machine tool performances and has significant effects on final machining accuracy and it is an undesired effect that influences the quality of a workpiece. It causes machine tool faults [A1.1]. Machining vibrations are as the most obscure and delicate of all problems in machine tool activities. Inappropriate machine tool handling can result in producing excessive vibration on a machine tool. Excessive vibration can cause operational inefficiency, product quality problems and even increasing extra costing for manufacturing companies [A1.1]. Therefore, appropriate attention on vibration prevention should highly be considered in the manufacturing field. There are significant various studies and researches [A1.1]-[A1.17] have been carried out regarding machine tool vibration issues. The scholars provided important highlights on various aspects including some possible ways of preventing machine tool vibration.

The researchers [A1.1-A1.5] presented the main features of machine tool vibrations which they classified into three main components namely, free, forced and self-excited vibrations which also known as chatter. The paper [A1.2] discusses in detail about chatter vibrations in both facing and turning processes through its experimental investigations by capturing and analysing chatter vibrations on various sensor signals through frequency-domain methods. Meanwhile, study [A1.1] outlined several machine tool vibrations causes and effects. On the other hand, paper [A1.3] presented some reasons why often loss of vibration resistance. The effects of vibration on finishing surface machining products are elaborated by [A1.4] in its multiphase micro alloyed steel machining experiments on machine tools. Meanwhile the [A1.6] discussed and presented ways for handling vibration absorption and isolation issue for machine tool foundation part. Kishore and other scholars in [A1.7] presented an online consideration for addressing machine tool vibration in turning operation using electro-magneto rheological damper. Meanwhile, the scholars in the paper [9] proposed Vibration Assisted Machining (VAM) method; the method is introducing vibration in the workpiece, tool and working medium to obtain high precision machining. On the other hand, the [A1.10] offering a solution for the machine tool vibration issue regard to the oscillation of the whole body of the machine tool by using visco elastic damper support for reducing vibration.

In this appendix, it put forward a useful consideration suggested by [A1.11] in handling machine tool vibration regarding the substitution of conventional materials with lightweight materials for moving parts of machine tools. The study aims to evaluate the static and dynamic performances of a set of machine tool structures made of hybrid materials. Three selected hybrid materials were used author for the study [A1.11], they are Al foam sandwiches (AFS), Al corrugated sandwiches (ACS) and composite material reinforced by carbon fibres (CFRP). The results of the study reveal that these hybrid materials greatly satisfying some technical requirements such as high static stiffness for bending and torsion, have a high value of elastic modulus and yield strength, have good dynamic characteristics and dimensional stability. The study was validating the work by comparing both the Finite Element Method (FEM) analysis and experimental results. The section 4.2 highlighted the detail discussion of this consideration.

This summary considered and organized in a few different sections. In section 2, it presents the classification of machine tool vibration and its causes per literatures. Meanwhile, in section 3, it outlines the effects of vibration. Finally, the section 4 presents both prevention and consideration for machine tool vibration prevention from literature.

2. Types of machine tool vibration and its causes

In all machine tool operations, the authors [A1.1], [A1.2] and [A1.3] stated that there are three different categories of mechanical vibrations. These categories are: (1) Free vibration, (2) Forced vibration and (3) self-excited vibration which also technically known as chatter. The Fig.A.1.1 (from literature) illustrates these types of mechanical vibrations. Furthermore, the [A1.2] and [4] stated that the self-excited vibrations consist of two parts; primary and secondary chatters.

The detail explanations of each vibration category are in the following:

2.1 Free Vibration

Cheng and other scholars [A1.1] stated that free vibration occurs when "*the mechanical system is set off with an initial input*". The free vibration is induced by shock [A1.2] [A1.4]. The [A1.5] confirms also that free vibration is due to shock or impulse loading of the machine tools. The study [A1.5] presented that the free vibration occurs when cutting tool strikes a hard grain during cutting processes.

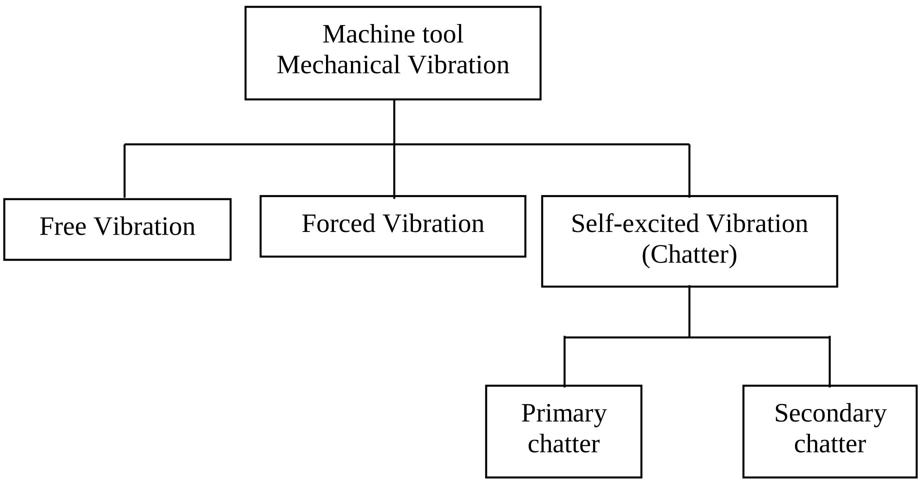

Fig.A1.1 The classification of machine tool mechanical vibrations

The author further explained, "*When the damping is assumed to be zero the structure will oscillate at its natural frequency, because the involved potential energy will be converted without a loss (friction-damping) into kinetic energy"* [A1.5].

2.2 Forced vibration

Mostly, the forced vibrations are induced by several factors including unbalance, misalignment, mechanical rigidity and gear defects in the machine tools [A1.4]. The [A1.2] is also agreeing that this type of vibration is due to the unbalance of machine tool assemblies, for example, gears, bearings, and spindles. In addition to these causes of forced vibrations, the [A1.1] added that vibrations are often transmitted from other machines through foundations, and it is caused by chip formation. The paper [A1.1] explains, "*When a discontinuous type of chip is formed, the recurring fractures of the metal in the shear plane ahead of the tool produce periodic variations*". Similarly, in the case of machining operations that produce a continuous chip with a built-up edge, there is a variation in the force on the cutting tool. Meanwhile, [A1.5] stated that forced vibrations are caused by periodic excitation. It outlined that spindle imbalance, gear drive irregularities, electric motors, pumps and periodic break of the chip due to build-up edge are among the causes of forced vibrations.

2.3 Self-excited vibration

The self-excited vibration is technically also known as chatter [A1.1] [A1.2] [A1.4] and [A1.5]. This third category of mechanical vibration is divided into two parts, namely primary chatter and secondary chatter [A1.2] [A1.4]. According to Sivaraman [A1.4], the primary chatter occurs due to friction between workpiece and cutting tool and thermo-mechanical process or by mode coupling. Then, the regeneration of a wavy surface on a workpiece could cause the primary chatter [A1.2] [A1.4]. The [A1.1] and [A1.4] stated that out of these three vibrations, the self-excited vibration is the more severe one. It further explained that the dynamic instability of the cutting during operation is probably the main cause of the self-excited vibrations.

3. Effects of vibration

There are many possible effects of mechanical vibrations. Haase [A1.5] stated that when vibration occurs over its limits it may cause some serious issues including accelerates tool wear, resulting in poor surface finishing and it even damaging spindle bearing of a machine tool. Meanwhile, the [A1.1] highlighted that excessive vibration may cause operational inefficiency and product-quality problems. It also explained that it might bring an extra financial burden, i.e. extra costing on manufacturing. On the other hand, the study [A1.4] listed several negative effects which are caused by chatter vibrations including: "*poor surface quality, excessive noise and tool wear, machine tool damage and reduced material removal rate, waste of work material and energy, increased cost in terms of production time, recycling and waste material*".

4. Prevention and consideration

The studies [A1.2] [A1.5] discuss some of the common vibration prevention actions. Here, the section 4.1 presents the important related actions that induced by scholars. Meanwhile, section 4.2 presents the consideration of machine tool vibration that discussed in the [A1.10].

4.1 Prevention

Many ways and actions are presented by both [A1.2] and [A1.5] researches for preventing machine tool related vibrations. Sidapura and Paurobally [A1.2] explained that earlier automatic detection of regenerative chatter is very essential to avoid detrimental effects on surface integrity and damage to the workpiece or machine tool. They also stated that having and early detection, it will help to even prevent catastrophic tool failure because of large amplitude vibration.

Meanwhile, Haase and other scholars (2001) presented some common technical prevention actions which very important for all machine tool users. They argue that vibration occurs due to chatter. To avoid this; it needs to consider the following Chatter prevention strategies [A1.5]:

- *Changing cutting parameters (e.g. depth of cut)*
- *Improve the stiffness at the design stage*
- *Passive vibration control using a tuneable passive damper*
- *Active vibration control by introducing anti-vibration using an actuator.*

Apart from these prevention actions, some advance and useful ideas and measures are presented by [A1.6] [A1.7] and [A1.9] regarding machine tool vibration matter. Although efforts have done through various presented solutions, the vibration on machine tool body still needs to consider, especially the machine tool foundation. Therefore, the paper [A1.11] presented a most suitable solution that helps to prevent machine tool vibration by proposing lightweight hybrid materials as alternative for substituting the conventional moving part materials of machine tools.

4.2 Consideration for vibration damping analysis of light weight structure of machine tools

In this last section of literature review, as the machine tool vibration classifications, causes and effects highlighted in the previous sections, consideration regarding the vibration damping of lightweight structure for moving parts of a machine tool were significantly relevant. Vibrations are undesired effects that may influence the quality of a workpiece. Normally, it considered during the machine tool design stage. This is because the dynamic behaviour of a machine tool plays a very important role in fulfilling the machining requirements such as high-speed operation, precision in axis positioning and capacity for quick remove of a high quantity of work-piece material. It is no doubt to state that these performances directly related to the chosen materials used for the machine tool construction. As asserted by [A1.11], the importance machine tool body such as foundation and other moving parts, materially need to be considered. Aggogeri et al. (2007) presented the potential and appropriate material for the construction of machine tool moving parts, these including *Al foam sandwiches (AFS), Al corrugated sandwiches (ACS) and composite materials reinforced carbon fibres (CFRP). The author stated that these materials are selected as it has high* *dynamic characteristics and capacity to dampen mechanical vibrations that also satisfy the other requirements such as high static stiffness for bending and torsion, a high value of elastic modulus, yield strength and dimensional stability* [A1.11]. According to [A1.12] [A1.13] AFS has low density with good shear and fracture strength. It also has other advantages such as lightweight and stiff structures with low costs. Meanwhile, the author suggested ACS material as it offers 30 % - 40 % less weight compares with the conventional material [A1.11]. On the other hand, the CFRP materials are also another alternative solution; this is because of its ratio of mechanical strength to density according to authors. These materials are propsed by authors in their study based on experimental results which indicated that for AFS has higher stiffness 152.7 % in X-axis, 11.4 % in the Z-axis and 14.7 % in Y-axis. Meanwhile, the study [A1.11] also revealed that the CFRP tested results show positive feedback in mechanical characteristics regarding stiffness and damping. It has around 48.5 % less weight compares to conventional material steel, so it could help to handle operation in rough conditions and reduce energy consumption during machining.

5. Summary

This work summarised the vibration issues on the machine tool from reviewed literatures. It looked at common characteristics of machine tool mechanical vibrations, some main causes and effects of the vibrations and it finally put forward a scholar's recommendation as consideration for addressing and reducing machine tool vibrations. The study [A1.11] recommended that the AFS materials have 20 times damping ratio higher than conventional steel material. Also, the CFRP lightweight material has high stiffness with a weight reduced by 48.5 %, therefore it suggested that by using such materials it will help to save machine tool energy consumption and suggest effective application in rough operations.

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Appendix II

Computer viruses in manufacture and its considerations

(Literature review)

Contents

Computer viruses in manufacture and its considerations

1. Introduction

In this summary, it is important to state that no new findings are presented in this review, the related computer virus contents and findings as well as considerations or solutions for addressing computer virus issue are obtained from literatures that indicated in each section of the summary. It is simply summarising the important key factors, which the authors discussed. This work does not present new materials and solutions for addressing manufacture related computer virus issues; however, it only provides some valuable references as supporting factor to the aim of handling risk management issue that discussed in the main content of the paper. The development of manufacturing and industries has significantly improved in the last few years. It plays very important role in the current situation, not only contributing to economic growth but also addressing social issues in many aspects. In, Ramakrishna et al (2017) study, it states that the manufacturing sector accounts for 25 % of worldwide employment. Scholar also stated that the advancement of manufacture performances is highly required and needed for contributing to the issue. Digital manufacturing or smart manufacturing or intelligent manufacturing and computing technologies are taking a role in this advancement need [A2.1]. The studies [A2.1] [A2.2] [A2.3] [A2.4] [A2.5] [A2.6] Stated that "*developments continue to enhancing manufacturing performances through digitalizing its equipment and facilities and enable for the connection of fragmented physical objects into integrated ones which known as Internet of Things*" (IoT) [A2.1] [A2.3] and Computer Integrated Manufacturing (CIM) [A2.2]. Meanwhile, Zhong et al (2017) outlined the key technologies such as cyber-physical systems (CPSs), cloud computing, big data analytics (BDA) and information and communications technology (ICT) share equally important role [A2.7]. Also, with the same view, both Nagalingam and Lin (1998) highlighted that Advanced

Manufacturing Technologies (AMTs) is another feature expression that also adapted in the manufacturing field [A2.3].

These digital technology features offer several significant advantages in advancing manufacturing performances. The scholars in the previous studies [A2.1] [A2.3] point out that by having these approaches; it helps manufacturers and industries to improve their performances including eliminating functional barriers and help to achieve the competitive goals. Meanwhile, Abollado et al (2017) stated that optimizing company performances through digitalization would enable them for ongoing competition, cost reduction; improve efficiency and accountability, reduce number of errors and increase flexibility [A2.4]. Also, the study [A2.3] states that using IoT is a potential tool for addressing insufficient information sharing or communication between stakeholders.

However, the [A2.5] states that using these approaches is not only helping to improve the manufacturing performances but also creates new cyber-security vulnerabilities. Furnell and Warren (1999) highlighted that with the advancement of ICT via internet will also be explored by hackers to enter the system and create disruption and damaging communication systems [A2.8]. Meanwhile, some scholars pointed out that in manufacturing, "*the attacks could destroy design files or process parameters and systems that related to quality control systems of a manufacturer and it could attack cyber-physical systems that integrate physical hardware with software systems*" [A2.9] [A2.10]. Hence, addressing threats and attacks through viruses and damaging data storage devices that will affect internal manufacturing systems is very essential.

However, some views that in the current development of technology advances through, communication, information and data sharing may have risks and disadvantage users. In Manufacturing, sharing data for big groups through internet network systems may results in huge effects if proper protection is not well designed. As technologies advancing, data sharing in industrial fields may also essential yet the controlling and processing systems devices are weak to resist attacks. Wang and other scholars (2013) states that Universal Serial Bus (USB) is currently considered as a most common and secure storage device which can be used to facilitate computer operators and hardly attacked from viruses [A2.11]. However, he adds that although using flash disk or USB is safe from viruses and attacks, it has several shortcomings. These including, the USB cable is easy to be monitored by hackers, the disk is not applied to big groups so it may easily be removed, stolen or damaged and it cannot resist corruption attacks [A2.12]. Hence, USB applications need improvements that enable to tackle its shortcomings. Therefore, considerations for addressing these shortcomings of the mobile storage device presented based on previous research [A2.12] findings.

2. Definition of computer virus

It is hard to have a proper definition of "computer virus" term. Dr. Cohen presented a mathematical definition. He said, "*A virus is a program that can 'infect' other programs by modifying them to include a possibly evolved version of itself*" [A2.12]. Some may see that computer virus is a kind of the classical Trojan Horse [A2.13] attacks and are characterized by its ability to reproduce and spread. It may however be firstly imported and executed by an authorized operator. Computer virus happens in different types with specific objectives and targets, it for example, can aim to change or steal data in computers, it may destruct the computer networking system and refusing of computer works [A2.12].

3. Computer virus classification and USB attacks

This section summarises two main aspects that include varieties or features of computer viruses and types of portable flash disk data hacks and attacks.

3.1 Features or varieties of computer viruses

Worms, Trojan Horses, Droppers and Logic Bombs are the features that are threatening computer programs. Horton and Seberry (1997) states that *"a worm is an independent program that is able to spread copies of itself or of parts of itself to other computers, commonly across network connections, and these copies are themselves fully functional independent programs, which are capable either of spreading further and or of communicating with the parent worm"* [A2.12]. People sometimes not clear between worms and viruses, the program that badly affected the internet in November 1988 [A2.12] is internet virus. However, authors [A2.14] [A2.15] [A2.16] argue that it is more appropriately to name as internet worms. Horton and Seberry (1997) stated that the difference between internet worm and viruses is that "*while a virus may take advantage of network connections to infect other programs, and not capable of causing its code to execute on a remote machine"* [A2.12]. Meanwhile, Trojan horse is "*a computer virus as a replicating Trojan horse that inserts a copy of itself into some other programs"* [A2.12].

There are different ways that viruses affect computer systems. However, two main types often affecting computer network systems are file infectors and boot sector infectors [A2.12]. Author [A2.12] stated that "*file infectors are the viruses that attach themselves to some form of executable code*. *For example, on a DOS-based system, file infectors will commonly attach themselves to .COM or .EXE files, although there are many other kinds of infect-able objects*" [A2.12]. "*A virus that can spread by infecting files and by infecting via any code executed at boot time is known as a multipartite virus. Boot sector viruses are extremely widespread; as a group, they are easily and most commonly found variety of viruses on the PC-compatible system"* [A2.12]. These are some of the main features of viruses that often-affecting computer network systems and considered as computer viruses. Hackers or attackers are often not only destroying programs and stealing data that save in computers but also trying to obtain data that saved in portable storage device such as flash disk.

3.2 Features of USB attacks

One of the convenient and comfortable data storage devices is the USB, which also known as flash memory, considered as the most secure mobile storage device [A2.11]. Although it is a very efficient device for saving data, there are several disadvantages and shortcomings of this device. Wang (2013) pointed out some potential safety hazards of this device such as easily loss, illegal copy, and uncontrollable rage of use [11]. He stated that "*the weaknesses of the flash memory or USB are; the USB cable easily monitored by hackers, it is not appropriate for a big group and it cannot resist attacks or viruses. Adversary can attack it easily"*; Sometimes hackers illegally enter to computers and read important data and information and make duplication or even steal flash disks when they have opportunity to do so. This is what commonly known as active attacks in computer. In addition, hackers may obtain data in directly, for example they make special connections with internal people and ask to provide them data and pay them in return. Wang et al (2013) highlighted that there are three main problems of flash disk, *"the problem of USB cable monitor, the problem of group application and the problem of corruption attack"* [A2.11].

4. Detection and elimination of computer viruses and USB attacks

It is important to detect and prevent in early stage as much as possible as computer viruses can cause very serious problems and results in computer system or network breakdown or damage. Researchers [A2.13] and [A2.17] pointed out that both technical and management mechanisms are the main features that help in address computer virus issues. Xioujuan (2017) defines both a technical and management measures are considered as passive and active defence approach respectively. He suggested that these two aspects are should be considered in same degree of priority. He further outlined that there are two ways of technical approach, manual method and automatic method [A2.17].

According to [A2.17] "*the technical approach consists of a manual method and automatic method. The manual method requires operators to be familiar with the* *computer system, the operation is more complex than the automatic one, prone to error and there are certain risks and lead to unexpected consequences".* On the other hand, "*the automatic method is using specialized anti-virus software or anti-virus card automatically to eliminate or delete viruses".* This method considered more effective, simple, running speed is fast and does not delete the system data. Meanwhile, the technical report of the National Computer Security Centre (NCSC) [A2.13] provides some valuable technical aspects regarding this issue. It highlighted that the technical measures should also be considering aspects such as a trusted computing base approach, access control which include discretionary access control and mandatory access control, audit trails and architecture are also important, the report also said that both identification and authentication are highly needed.

On the other hand, author [A2.17] states measure such as server cards and anti-virus card are essential to protect computer network as it is considered as backbone of system, therefore virus spread or attacks can be prevented.

The management mechanism plays a very important and equal role in preventing virus attacks. Researcher [A2.13] [A2.17] stated that "*hardware and software equipment maintenance need specific schedule and attention. It needs scheduled on a routine basis. It requires strict rules and regulations should be introduced, password management, facility management, configuration control, strengthen legal education and occupational moral education on network administrator and user (user awareness), working procedures and standard operating procedures should well be updated and introduced, system evaluation, punishment for collective and individuals who engage in illegal activities should be take*n". Also, the researchers stated that "*virus symptoms timely inspection systems should be in place, new situations and problems should be reported, conduct detection of the virus on network system of workstations regularly and development of tracking network virus prevention technology should be highly considered".*

Considerations for USB attacks

In this section, an alternative of a USB device is presented per literature suggestions. Flash disk is a portable device that used to save data and information, it is also often shared by groups. Study [A2.11] suggested that data that saved in flash disk should have proper security protection and not know by other people, the study further states that it is better only encunter with a secure device or computer users who is well known and not suspected. The study stated that "*storage encryption, transmission encryption, mutual authentication, key agreement, accessed password and effective protection of the secure computers*" are prevention security measures that important [A2.11]. The specific explanation of each security measure is presented by author as follows;

- *Storage encryption: all the files stored in the flash are in the form of ciphertext, and each flash disk has its private key.*
- *Transmission encryption: Data transferred through the USB cable should be in the form of ciphertext, i.e. the data sent after encrypted by the sender and decrypted after received by the receiver. Because a flash disk may insert into different computers each time in which the session key should be re-established, different keys should employ for storage and transmission.*
- *Mutual authentication: When the flash disk connected to the computer, the two sides cannot continue to communicate until the mutual authentication finishes.*
- *Key agreement: Once the flash disk inserted into the computer, a session key for transmission encryption should established through a key exchange protocol. If the disk pulled out, the key will expire and destroyed at once.*
- *Accessed password: Users must enter the correct passwords before using flash disks.*

However, this will only fully be achieved if appropriate rules and regulations are in place, as part of a management mechanism approach.

5. Summary

The discussions in this literature review are summarised as follows: using computers in today's lives is continuing to evolve including in the manufacturing field. Industries are competing in improving their performances by using computers and the internet. However, it involves some serious risks in its developments, computer networks often affected by viruses, portable data storage devices such as a flash disk or USBs are often attacked. The main aim of an adversary is to destroy and dismantle computer systems and steal data and information. These problems can be addressed by enforcing both technical and management mechanism approaches and introducing a secure flash disk with proper criteria and conditions. Therefore, data and information will hardly be detected, destroyed and stolen by the adversary; meanwhile, computer network systems well protected and above all, appropriate rules and regulations need to be introduced.

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Appendix III

Flood damage - in case of Thailand 2011 flood disaster
(Literature review)

Contents

Flood damage - in case of Thailand 2011 flood disaster

1. Introduction

In this summary, it is important to state that no new findings are presented in this review, the contents and findings and considerations for addressing flooding issue are obtained from literatures that indicated in each section of this summary. It is simply summarising the important key factors, which authors discussed. This work does not present new countermeasures for addressing flooding impacts on manufacture; however, it only provides some valuable references as supporting factor to the aim of handling risk management issue that discussed in the main content of the paper. Flooding is one of the natural disasters that occur in many parts of the world. Asia is one of the regions which often vulnerable to natural disasters such as earthquakes, tsunami and floods. Many countries in Asia experienced flood disasters. For example, in July 1996, flood destroyed many infrastructures including a dam in northern Gyeonggi province of Korea [A3.1]. Flood occurred in northeast areas in Bangladesh in 2004 resulted around 800 fatalities [A3.2] and many lost their homes and properties, in addition, another flooding in July and September 2007 that even brought much greater loss of Bangladesh citizens around 1100 [A3.2]. Meanwhile, the 2010 floods in Pakistan caused serious impacts on people's farms, livestock and business and affecting 18 million people's lives [A3.3] [A3.4]. In June 2007, flood occurred in Bangladesh and around 500 people were lost their lives [A3.4]. Meanwhile in Dadeldhura, Nepal in June-August 2010 and Indus Basin, Pakistan in July 2010 [A3.4] [A3.5], an overwhelming flood occurred in Thailand in 2011 [A3.5] [A3.6] [A3.7] and China that affected over 67.9 million [A3.8]. These studies [A3.1]-[A3.8] show that the flood disaster in the last 10 years has affected a great loss in many ways including fatalities. It stated that flood disasters are part of nature events and will continue to exist. Hence, the human who experienced these natural phenomena should have the capacity to adapt, to recovery and able to prevent reoccurring in the future. Lessons were important, people learned and taken from previous disasters and human continues to develop their capacities to cope with future natural events. Therefore, understanding of previous flood disasters, measures and possible consideration actions for flood recovery are very essential. This work is reviewing previous studies [A3.6]-[A3.8] on flood disasters, by highlighting specific recovery lessons from flood damage to manufacturing and industry sector in Thailand after the 2011 flood. Thailand historically is one of the countries in Asia that vulnerable to flood disasters. It faced about 15 flood disasters since 1985 [A3.8]. This discussion provides some useful summaries of lessons learned from the Thailand 2011 flood disaster including damages and losses in the manufacturing sector both large and SMEs, it also summarises some valuable considerations that proposed for the flood damage that discussed in the previous studies [A3.6]-[A3.8]. The objective behind this work is to understand strategies and measures in dealing with risk management associated with natural disasters specifically flood disasters.

2. Thailand 2011 Flood disaster impacts

Natural disasters are often hard to avoid as it occurs due to natural phenomenon and beyond human control. Flood is one of the natural disasters that occur in many parts of the world including in Asia countries. In 2011, Thailand experienced the worst flood disaster in its history, it was due to heavy and overwhelming rainfall throughout the country during rainy seasons in quarter four of the year [A3.7]. Singkran (2017) pointed out that three factors were the main causes of the 2011 flood [A3.8]. Firstly, Thailand was hit by five tropical storms (Haiama on 24-26 June, Nocten from July 30th to August 3rd, Haitang on September 28th, Nesat on September 30th – October 1st and Nalgae storm from October 5 to 6) during the raining season [A3.8]. Secondly, the precipitation from January to October and the southwest monsoon from mid-May to October are contributing to the flood event. Thirdly, human error, the miss management and lack of proper handling of water storage in two dams (Bhumibol and Sirikit dams) were also causing the disaster. The flood has significant impacts on various aspects including affecting the country's economy, increasing social problems such as jobless and resulting in deaths [A3.5]-[A3.8]. In this section, the summary focuses on several impacts such as general damages and losses; it then presents the flood disaster impacts on manufacturing and small-medium enterprises and how social aspects heavily heated during the disaster per literatures.

2.1 Damage and losses

Singkran (2017) pointed out that Thailand significantly heated by the 2011 flood disaster. The flood affected over 110,554 km^2 [8] throughout the country. Many people lost their properties and hundreds of thousands were displaced from their homes, at least 165,000 people [A3.8] were forced to move to other safe places. The country faced many flood disasters since 1998. The table A3.1 [A3.8] shows that properties with a worth of millions of dollars damaged every time a flood disaster hits the country.

Table A3.1 Historical flood event in Thailand [A3.8]

Year	Area affected (km^2)	People Dead	People Displaced	Region	Damage (USD)
2011	110,554	813	165,000	Across Thailand	46,500,000,000
2006	213,081	195	2,000,000	North	8,100,000
1995	444,498	260	4,220,000	North, Central	240,000,000
2002	371,596	65	400,000	North, Northeast	32,000,000
2002	139,684	1	3000	Central, East	Not available
2016	62,208	96	1,000,000	South	25,000
2007	299,972	10	17,000	North, Northeast, Central	Not available
2010	3,874	258	0	Central, Northeast	332,000
2004	378,045	11	60,000	Northeast, Central	Not available
2005	70,521	69	700,000	South	14,900,000
2005	134,287	21	119,270	North	121,000
1996	314,300	29	343,386	North, Northeast, South	13,500,000
2002	51,699	2	150,000	North	Not available
2000	119,920	33	25,000	Northeast	6,000,000
2003	314,896	7	10,000	North, Northeast	3,690,000

The table depicts that the 2011 flood disaster not only resulting in 813 [A3.8] dead but the country in general, lost around USD 46.5 billion [A3.8]. This is the worst flood disaster in Thailand history. According to previous studies [A3.6]-[A3.8] many sectors heated by the flood disaster. A study from the Bank of Thailand (BoT) (2012) highlights that the manufacturing sector encountered a worse impact than the non-manufacturing sector, it further noted that both automotive and electronics industries were the worst industries that hit by the floods [A3.7]. Meanwhile, Pathak et al (2016) also stated that the small-medium enterprise that suffered most from the flood disaster was the manufacturing sector [A3.6].

2.2 Manufacturing impacts

Manufacturing is the most affected sector by the Thailand 2011 flood disaster, the BoT report [A3.7] stated that the automotive and electronics industries were the worst industries hit by the flood. A joint assessment report [A3.9] between the Thai Government and the World Bank estimated that around 14,243 factories affected in five provinces (Ayutthaya, Bangkok, Nakornsawan, Patum Thani, Sumut Sakorn) in Thailand. The report [A3.9] shows that the total damages to buildings and machinery were largely on electrical components such as motors, electrical panels and others. It estimated around THB 285 billion lost. Meanwhile, the Thai Ministry of Industry report which forwarded by the [A3.9] is also pointed out that the losses for the industry sector around THB 493 billion.

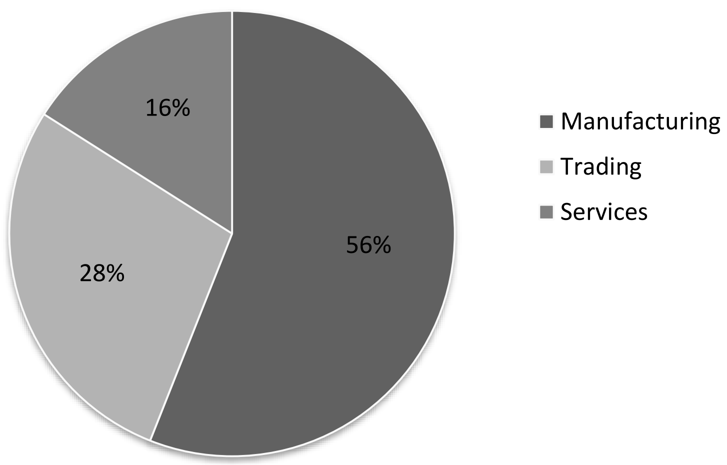

Fig.A3.1 SMEs flood affected by sector [A3.9]

Pathak and other scholars (2016) outlined that the most affected sector from the small-medium enterprises was the manufacturing sector. Fig.A3.1 [A3.6] shows that it accounts for 56 %, meanwhile, trading and services are 28 % and 16 % respectively. Most small to medium factories were unable to operate and produce due to raw material shortages and have to move to the temporarily halts, as warehouse storages, factory plants, machinery and transportation were affected [A3.6].

2.3 Social impacts

There are no exact figures for people who lost their lives, however, according to [A3.8] around 813 people and [A3.12] 774 people became victims of the 2011 flood disaster in Thailand. Furthermore, the online source [A3.12] highlighted that the number of affected families until mid-November was around 1.9 million households or around 5.3 million people that is about 8 % of the Thai population. It shows also that around 400,000 people were falling ill due to water-borne diseases during the floods. These people had some common diseases such as athlete’s foot, flu, muscle pains, skin diseases and anxiety [A3.12]. Also, there were around 37,728 people [A3.12] had dengue fever. On the other hand, the internet source [12] indicated that there were around 370,316 people become jobless after flooding.

Table A3.2 Education sector damage and losses [A3.9]

School Types	Disaster Impacts			Ownership	
	Damage	Losses	Total	Public	Private
Basic education	1,163	922	2,085	2,085	0
Private schools	215	74	289	0	289
Non-formal education	61	84	145	145	0
Higher education	9,402	170	9,572	5,626	3,946
Vocational education	519	364	883	883	0
Non-official schools’ agencies	1,690	185	1,875	1,875	0
Total	13,051	1,798	14,849	10,614	4,235

Many people lost their income sources, stocks, agriculture fields that used to produce foods that were flooded and most of them were no longer in operation, as result prices of foods and other goods extremely high. For example, cabbages used to be 10 baths and it increased to 50-100 baths [A3.9]. Meanwhile, around 1,435,378 students [A3.9] were difficult to go to schools and their studies were affected due to 2,934 schools [A3.9] were heavily damaged by the flood. The source [A3.9] points out that the damage to the school infrastructure and its properties was estimated at around US$430.5 million [A3.9]. The table A3.2 [A3.9] shows both public and private schools were affected by flood disaster. It is not only formal education or schools but the disaster also affected non-formal education during the flooding period.

2.4 Environmental impacts

The environmental impact is another aspect that also heavily hit by the flood disaster in 2011. Thai natural assets such as biodiversity resources, forest resource and coastal ecology were heavily hit [A3.9]. The report [A3.9] shows that in both Ayuthaya and Pratum Thani provinces, in the industrial areas, the flood got as high as 1-3 meters. This massive invasion of water in the factory sites was resulting in water contaminations from the toxic substances used in the factories. As result of this water contamination, many people were reported, at least experienced skin infection and bun after contact with water [A3.9]. The source [A3.9] also presented that the Bung Boaraped is a wetland located in Nakorn Sawan Province; it was home to 15 types of amphibians, 49 types of reptiles, 306 types of birds and 15 types of mammals. These livings were significantly disturbed. The 2011 flood disaster has generated a total of 375 million baht in damage [A3.9] and around 87 % damaged to the industrial waste management sector. In addition, the table A3.3 [A3.9] shows that there was around Bath 64 million losses for the biodiversity. On the other hand, the report [A3.9] indicated that the total loss during the 2011 flood in the whole country for the environmental sector was around Baht 550.67 million, both Ayutthaya and Bangkok provinces were having huge environmental lost. They specifically account, Baht

219.13 million and Baht 108.10 million respectively or they both sustained at least 60 % of the lost. Meanwhile, other provinces such as Prachinburi, Samut Sakorn, and Patum Thani lost about Baht 44.64 million, Baht 42.71 million and Baht 33.81 million respectively. Whereas the other provinces have an environmental lost between Baht 3 million to Baht 11 million [A3.9].

Table A3.3 Environmental sector losses in Thai Baht, Millions

Type of losses	Public	Private	Total
Municipal solid waste	101	-	101
Biodiversity	64	-	64
Industrial waste	-	11	11
Total	165	11	176

3. Manufacturing sector recovery

From the report [A3.7], it states that most of the business in 2012 expecting their increase in production and sales as in previous year. The report shows that around 63 % of manufacturing businesses and 57 % of non-manufacturing businesses were anticipating the increase of production and sale in the following year after the disaster. Most of them expected higher sales as their competitors were still on the stage of recovery.

The main source of fund for recovery after the 2011 flood disaster was firstly from insurance claims. Secondly, it credited from government and financial institution [A3.7]. Meanwhile, the big companies were able to recover easily; the majority used their financial savings. On the other hand, the majority of SMEs, specifically for manufacturing businesses were heavily relying on both insurance claims and financial credit programs. The report [A3.7] states that the insurance claims were expecting to get pay in the beginning of January 2012; however, it was only providing minimum payment of claims just to help small manufacturing businesses to restart their businesses. On the other hand, the companies were moving their machinery to temporary places and repairing for re-operating and producing while waiting for insurance claims to be paid.

Another main financial source for the small and medium manufacturing business for helping rerun their businesses was credits from government and financial institutions. The Thailand Government launched many financial projects for supporting private businesses through some specialized financial institutions. The total amount of 100,000 million Baht [A3.7] provided through 15 commercial banks [A3.7] in the country for-credit programs. In addition, the Bank of Thailand was also supporting flooding victims, for example, "*commercial banks and non-banks were allowed to maintain flooded customer's loan classification as a pre-flood class and consider credits to such borrowers as new loan approval with special interest rate. While the repayment period would be extended, and principal and/or interest payment could be reduced. Besides, monthly debt repayment of flooded credit card holders could be less than 10% of debt outstanding, effective until 30 June 2012*" [A3.7].

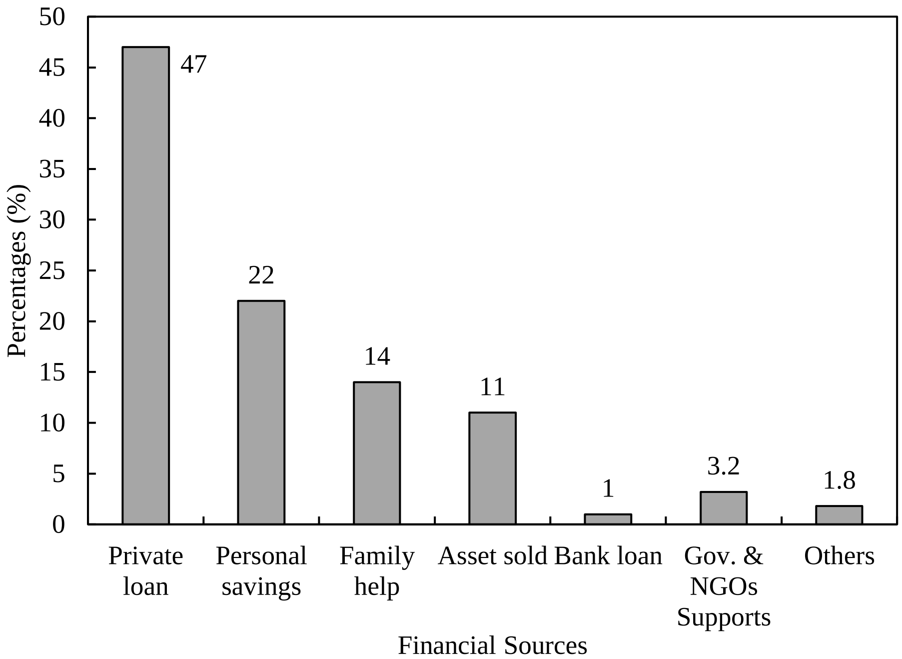

Fig.A3.2 Identified financial sources for business recovery [A3.6]

Meanwhile, Asgary and other scholars (2012) identified several sources as financial resources used in business recovery. These are private loans 47 %, personal savings 22 %, family helps 14 %, assets sold 11%, government and NGOs support 3.2 % and bank loan 1 % [A3.6], as indicated in the Fig.A3.2.

4. Consideration for flood prevention

In this section, it is important to assert that the presented materials, contents and findings for flood prevention measures are obtained from literatures and presented here as supporting factor for risk management measures in related to natural disaster aspects. Flood causes much destruction and affects various aspects; it is not only destroying infrastructures, affects transport networks and interrupts economical activities, it also causes some serious fatalities. Although it is a natural phenomenon and beyond human capacity, efforts and strategies are needed to minimize the effects and prevent huge damage as well as handling flood risks. Managing flood risks is very crucial and needs an effective and efficient approach. Many scholars in A3 [8, 13, 14, 15, 16, 17, 18, 19 and 20] have the same view that flood management has to be reviewed and need an integrated and holistic approach. Singkran [A3.8] argue that "*flood risk management should shift from passive to a progressive paradigm and participatory collaboration among government agencies, stakeholders should engage*". Therefore, it will be able to manage from the whole level of flood risk management from adaptation, recovery and prevention for flood reoccurring. Thus, it is very important to have some specific approach that could contribute to better flood risk management aspects. Therefore, in this section, two aspects including advance flood monitoring and forecasting system [A3.20] and introduction the concept of Labyrinth Sharp Crest Spillway (LSCS) [A3.21] used as considerations for addressing flood problem from literatures.

4.1 Advance flood monitoring and forecasting system

It believed that having adequate and reliable information in advance will contribute to risk management efforts. In order communities are well informed, it is essential to have proper forecast that provides valuable information for communities to prepare for any flood events. A study [A3.22] proposed a forecast system called Bayesian flood forecasting methods. It is a robust theoretical framework forecasting system that focuses on probabilistic river stage forecast, river discharge or run-off value. This forecast system has proposed several useful aspects for contributing to flood risk management issue yet it does not provide practical solutions as the information still centralized and efficiently distributed to community individuals.

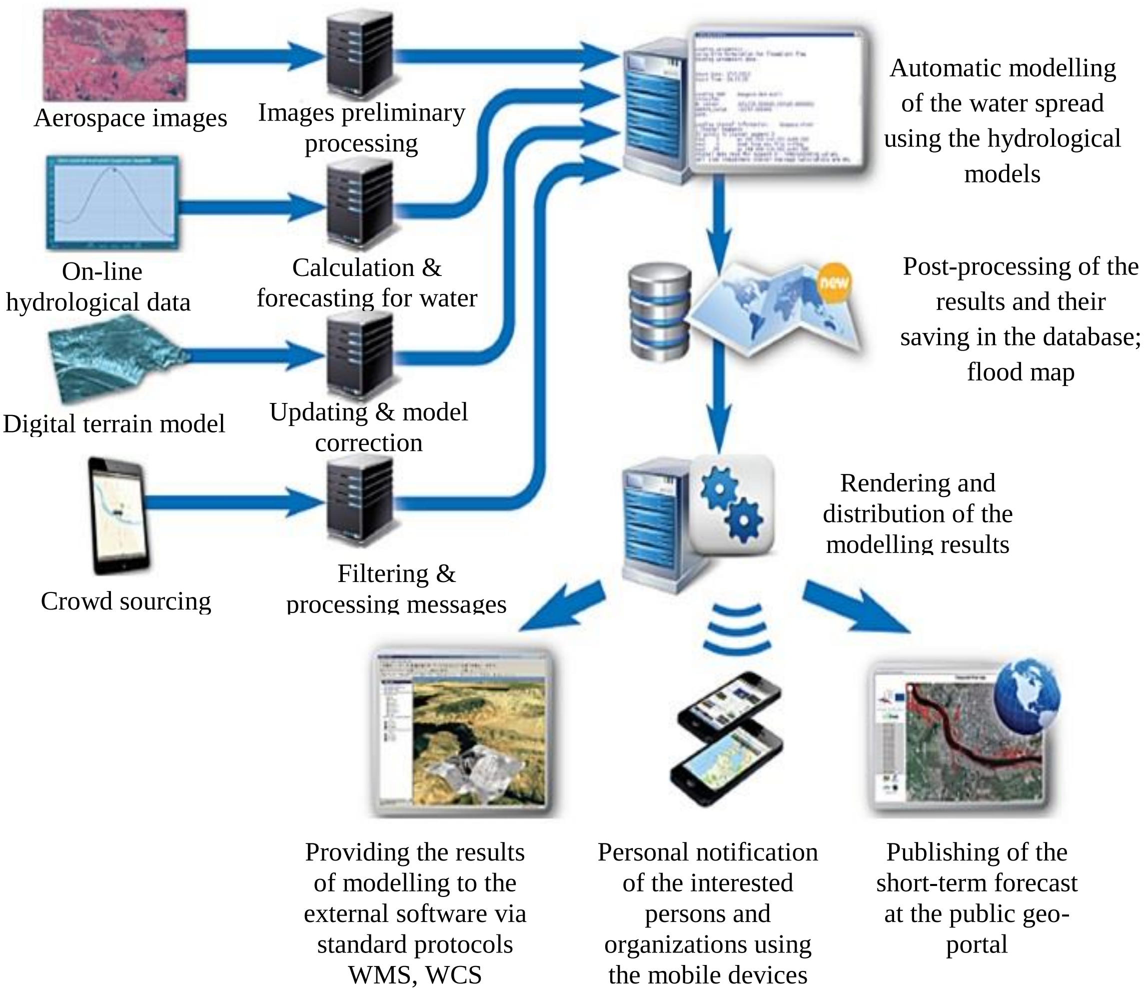

Fig.A3.3 Flood monitoring and forecasting system [A3.20]

Merkuryeva et al. [A3.20] proposing a holistic advanced river flood monitoring and forecasting system. The feature of data collection and forecasting systems are shown in the Fig.A3.3. It depicts the beginning stage of data and information collection, preliminary processing, integrating data and modeling and a distribution that reaches individuals. [A3.20] presented four main forecasting components including: "*Input data collection and pre-processing, modeling and forecasting, post-processing and visualization and nformation distribution".*

"In the first component (a), it provides input data collection that comes from aerospace images, online hydrological data from meteorological stations; a digital terrain model obtained by the airborne leader technology and pre-processing such as primarily image processing, information filtering, and information fusion. The second component (b) will allow forecasting of water level, calculation and forecasting of the water discharge as well as automatic modeling of the water spread using hydrological models. The third (c) component provides post-processing of modeling results, output data storage in a database, flood map vectorization and visualization of inundation areas. Then the last component (d) provides distribution of the modeling results to the external software, publishing short-term forecasts at the public GeoPortal and automatic notification of the local citizens and organizations. For example, through personal cell phones, individuals will notify of the emergency information and emergency rescue services" [A3.20].

4.2 Introduction the concept of Labyrinth Sharp Crest Spillway

The change of climate in the last few decades has resulted in many natural disasters including flooding in many countries, for example, in Thailand 2011 flood disaster [A3.5,6,7]. In many situations, with the high intensity of rainfall, it increases the reservoirs' water level and hard to be controlled [A3.22]. Suprapto (2013) stated that one way to contribute to flood management aspects is to have an alternative for existing reservoir spillways. Dams have completed with spillways and the majority is Ogee spillway. He stated that "*the spillway has the drawback of less width of water* *passage its weir. This system often easily topping up water reservoirs and increasing reservoir water level capacity is quite worrying"* [A3.22]. Therefore, alternatives needed for addressing the limitations of the existing systems. Suprapto (2013) proposed a solution that called Labyrinth Sharp Crest Spillway (LSCS). This proposed option will help to increase spillway capacity without reducing water storage or reservoir capacity. The advantages of the LSCS [A3.22] are: *"Increase the capacity of the spillway flow. This can prevent the abnormal rise in the reservoir water level. It can drain a large discharge of water over the spillway with a thinner water layer. This can reduce the rate of increase in the level of water reservoirs".*

The study [A3.22] presented that if the spillway capacity increases, the flood control function would decrease. However, the increase in spillway capacity can reduce the rate of rising of water level, so the dam can safe from overtopping. The author [A3.22] conducted a study by comparing both the Ogee spillway type and LSCS type and provide significant results as consideration and measure for contributing to the flood control prevention measures. The detail content of aforementioned findings is presented in [A3.22].

5. Summary

From the information the literature review and the summary, the main points can be concluded as follows:

- Flood is a natural disaster that resulted from the changes in weather and climate due to human activities.
- Flood disaster brought multidimensional impacts and affect economic activities.
- Flood risk management is an important aspect that needs to consider in a more integrated manner.
- The advanced forecasting and monitoring system should target individual citizens and organizations. Therefore, possible prevention actions will be needed.

- Reservoir spillway improvement by introducing the LSCS model with a specific type of Trapezoid will help to control water discharge volume and help control floods.

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Appendix IV

Data collection evident

(For chapter 3)

Contents

1. Data for criteria and alternatives

Respondents	Criteria	Criteria			
		Technical	**Financial**	**Environmental**	**Resource uses**
1	Technical	1.0	3.0	3.0	7.0
	Financial	0.2	1.0	5.0	9.0
	Envrironment	0.3	0.2	1.0	5.0
	Re usage	0.1	0.1	0.2	1.0
2	Technical	1.0	4.0	5.0	6.0
	Financial	0.1	1.0	6.0	6.0
	Environment	0.2	0.2	1.0	7.0
	Re usage	0.2	0.2	0.1	1.0
3	Technical	1.0	0.1	0.1	0.1
	Financial	0.5	1.0	2.0	0.5
	Envrironment	10.0	0.5	1.0	2.0
	Re usage	10.0	2.3	0.5	1.0
4	Technical	1.0	0.2	0.5	0.5
	Financial	0.5	1.0	3.0	0.8
	Envrironment	2.0	0.3	1.0	2.0
	Re usage	2.0	1.3	0.5	1.0
5	Technical	1.0	2.0	0.8	3.0
	Financial	0.3	1.0	2.0	2.0
	Envrironment	1.3	0.5	1.0	3.0
	Re usage	0.3	0.5	0.3	1.0
6	Technical	1.0	0.5	0.5	0.5
	Financial	0.5	1.0	3.0	2.0
	Envrironment	2.0	0.3	1.0	2.0
	Re usage	2.0	0.5	0.5	1.0
7	Technical	1.0	0.1	0.1	0.1
	Financial	0.5	1.0	2.0	0.5
	Envrironment	10.0	0.5	1.0	2.0
	Re usage	10.0	2.2	0.5	1.0
8	Technical	1.0	5.0	6.0	4.0
	Financial	0.3	1.0	4.0	9.0
	Envrironment	0.2	0.3	1.0	4.0
	Re usage	0.3	0.1	0.3	1.0
9	Technical	1.0	2.0	3.0	2.0
	Financial	0.1	1.0	5.0	5.0
	Envrironment	0.3	0.2	1.0	8.0
	Re usage	0.5	0.2	0.1	1.0
10	Technical	1.0	4.0	0.5	0.2
	Financial	4.0	1.0	0.2	0.5
	Envrironment	2.0	5.0	1.0	0.3
	Re usage	6.0	2.0	8.0	1.0

11	Technical	1.0	0.3	0.2	0.2
	Financial	8.0	1.0	0.1	0.3
	Envrironment	5.0	7.0	1.0	0.3
	Re usage	6.0	4.0	3.0	1.0
12	Technical	1.0	4.0	5.0	7.0
	Financial	0.2	1.0	7.0	8.0
	Envrironment	0.2	0.1	1.0	6.0
	Re usage	0.1	0.1	0.2	1.0
13	Technical	1.0	8.0	6.0	8.0
	Financial	0.2	1.0	5.0	6.0
	Envrironment	0.2	0.2	1.0	5.0
	Re usage	0.1	0.2	0.2	1.0
14	Technical	1.0	4.0	0.2	0.5
	Financial	3.0	1.0	0.2	0.3
	Envrironment	5.0	6.0	1.0	0.3
	Re usage	2.0	3.0	4.0	1.0
15	Technical	1.0	6.0	8.0	6.0
	Financial	0.2	1.0	5.0	7.0
	Envrironment	0.1	0.2	1.0	6.0
	Re usage	0.2	0.1	0.2	1.0
16	Technical	1.0	3.0	4.0	6.0
	Financial	0.1	1.0	5.0	8.0
	Envrironment	0.3	0.2	1.0	8.0
	Re usage	0.2	0.1	0.1	1.0
17	Technical	1.0	2.0	2.0	3.0
	Financial	0.3	1.0	5.0	4.0
	Envrironment	0.5	0.2	1.0	3.0
	Re usage	0.3	0.3	0.3	1.0
18	Technical	1.0	7.0	8.0	8.0
	Financial	0.1	1.0	7.0	8.0
	Envrironment	0.1	0.1	1.0	8.0
	Re usage	0.1	0.1	0.1	1.0
19	Technical	1.0	2.0	0.3	0.3
	Financial	2.0	1.0	0.5	0.2
	Envrironment	4.0	2.0	1.0	0.5
	Re usage	3.0	5.0	2.0	1.0
20	Technical	1.0	0.5	0.3	0.3
	Financial	2.0	1.0	0.3	0.2
	Envrironment	4.0	3.0	1.0	0.5
	Re usage	3.0	5.0	2.0	1.0
21	Technical	1.0	4.0	6.0	3.0
	Financial	0.1	1.0	7.0	6.0
	Envrironment	0.2	0.1	1.0	8.0

22	Re usage	0.3	0.2	0.1	1.0
	Technical	1.0	6.0	4.0	7.0
	Financial	0.3	1.0	5.0	6.0
	Envrironment	0.3	0.2	1.0	4.0
	Re usage	0.1	0.2	0.3	1.0
23	Technical	1.0	2.0	5.0	7.0
	Financial	0.2	1.0	5.0	4.0
	Envrironment	0.2	0.2	1.0	6.0
	Re usage	0.1	0.3	0.2	1.0
24	Technical	1.0	0.2	0.3	0.3
	Financial	4.0	1.0	0.3	0.5
	Envrironment	4.0	4.0	1.0	0.2
	Re usage	3.0	2.0	5.0	1.0
25	Technical	1.0	4.0	3.0	8.0
	Financial	0.1	1.0	7.0	6.0
	Envrironment	0.3	0.1	1.0	8.0
	Re usage	0.1	0.2	0.1	1.0
26	Technical	1.0	3.0	3.0	7.0
	Financial	0.2	1.0	5.0	9.0
	Envrironment	0.3	0.2	1.0	5.0
	Re usage	0.1	0.1	0.2	1.0
27	Technical	1.0	8.0	7.0	7.0
	Financial	0.3	1.0	3.0	7.0
	Envrironment	0.1	0.3	1.0	3.0
	Re usage	0.1	0.1	0.3	1.0
28	Technical	1.0	8.0	7.0	7.0
	Financial	0.2	1.0	8.0	5.0
	Envrironment	0.1	0.1	1.0	5.0
	Re usage	0.1	0.2	0.2	1.0
29	Technical	1.0	7.0	6.0	6.0
	Financial	0.2	1.0	7.0	6.0
	Envrironment	0.2	0.1	1.0	6.0
	Re usage	0.2	0.2	0.2	1.0

2. Data compilation of criteria and alternatives

Criteria matrix normalization

Criteria	Technical	Financial	Environmental	Resource usage	Sum of Rows
Technical	0.52173913	0.5	0.545454545	0.333333333	1.900527009
Financial	0.173913043	0.25	0.272727273	0.222222222	0.918862538
Emission	0.130434783	0.125	0.136363636	0.333333333	0.725131752
Resource usage	0.173913043	0.125	0.045454545	0.111111111	0.4554787
Total	**1**	**1**	**1**	**1**	4

Criteria priority vector

Criteria	Priority vector
Tech. criteria	0.475131752
Fin. criteria	0.229715635
Env. Criteria	0.181282938
R. usage criteria	0.113869675

Alternatives matrix normalization for alternatives

Respect to <u>Technical</u>

Alternative	Fossil fuel	Wind power	Solar Power	Hydropower	Sum of rows
Fossil fuel	0.077777778	0.026548673	0.095022624	0.1	0.299349075
Wind power	0.311111111	0.132743363	0.090497738	0.15	0.684352211
Solar Power	0.222222222	0.398230089	0.271493213	0.25	1.141945523
Hydropower	0.388888889	0.442477876	0.542986425	0.5	1.87435319
Total	**1**	**1**	**1**	**1**	4

Priority vector for Technical

Alternative	Priority vector
Fossil fuel	0.074837269
Wind power	0.171088053
Solar power	0.285486381
Hydropower	0.468588298

Respect to Environmental

Alternative	Fossil fuel	Wind power	Solar Power	Hydropower	Sum of rows
Fossil fuel	0.046511628	0.026162791	0.027777778	0.028169014	0.12862121
Wind power	0.023255814	0.261627907	0.555555556	0.126760563	0.96719984
Solar Power	0.465116279	0.130813953	0.277777778	0.563380282	1.437088292
Hydropower	0.465116279	0.581395349	0.138888889	0.281690141	1.467090658
Total	**1**	**1**	**1**	**1**	4

Priority vector for Environmental

Alternative	Priority vector
Fossil fuel	0.032155303
Wind power	0.24179996
Solar power	0.359272073
Hydropower	0.366772664

Respect to Resource usage

Alternative	Fossil fuel	Wind power	Solar Power	Hydropower	Sum of rows
Fossil fuel	0.181818182	0.069767442	0.1	0.117647059	0.469232683
Wind power	0.090909091	0.348837209	0.6	0.176470588	1.216216888
Solar Power	0.363636364	0.11627907	0.2	0.470588235	1.150503669
Hydropower	0.363636364	0.465116279	0.1	0.235294118	1.16404676
Total	**1**	**1**	**1**	**1**	4

Priority vector for Resource usage

Alternative	Priority vector
Fossil fuel	0.117308171
Wind power	0.304054222
Solar power	0.287625917
Hydropower	0.29101169

Respect to <u>Financial</u>

Alternative	Fossil fuel	Wind power	Solar Power	Hydropower	Sum of rows
Fossil fuel	0.181818182	0.214285714	0.1	0.090909091	0.587012987
Wind power	0.090909091	0.428571429	0.6	0.363636364	1.483116883
Solar Power	0.363636364	0.142857143	0.2	0.363636364	1.07012987
Hydropower	0.363636364	0.214285714	0.1	0.181818182	0.85974026
Total	**1**	**1**	**1**	**1**	4

Priority vector for financial criteria

Alternative	Priority vector
Fossil fuel	0.146753247
Wind power	0.370779221
Solar power	0.267532468
Hydropower	0.214935065

Priority of all alternatives

Alternative	Technical	Environmental	Resource usage	Financial
Fossil fuel	0.074837269	0.032155303	0.117308171	0.146753247
Wind power	0.171088053	0.24179996	0.304054222	0.370779221
Solar Power	0.285486381	0.359272073	0.287625917	0.267532468
Hydropower	0.468588298	0.366772664	0.29101169	0.214935065

Lambda value of all criteria

Criteria	Sum of rows	Priority vector	Lambda
Technical	0.903000728	0.475131752	1.900527009
Environmental	0.211077091	0.229715635	0.918862538
Resource usage	0.131454015	0.181282938	0.725131752
Financial	0.051865212	0.113869675	0.4554787

Lambda (λ) value of each criteria and overall priority

Criteria/ Alternative	Tech.	Env.	Re. usage	Fin.	Overall priority
Fossil fuel	0.03556	0.00583	0.01336	0.03371	0.08846
Wind power	0.08129	0.04383	0.03462	0.08517	0.24492
Solar power	0.28549	0.06513	0.03275	0.06146	0.44482
Hydropower	0.22264	0.06649	0.03314	0.04937	0.37164

Overall priority vector

Alternative	Priority global
Fossil fuel	0.088456129
Wind power	0.244919913
Solar power	0.444824538
Hydropower	0.371642157

Final ranking points for each alternative with respect to criteria

Criteria/ Alternatives	Tech.	Env.	Re. usage	Fin.	Priority Global	Multi-sectoral impact	Sum
Fossil fuel	10	10	10	10	10	25	75
Wind power	25	25	100	100	25	25	300
Solar power	50	50	25	50	100	50	325
Hydropower	100	100	50	25	50	100	425

Alternatives	Percentage of priority	Total value gained
Fossil fuel	0.066666667	75
Wind power	0.266666667	300
Solar power	0.288888889	325
Hydropower	0.377777778	425
Total		1125

3. List of respondents

No	Institution	Total	Background	Original	Job	Remark
1	Mekanika UNTL	5	Mechanical	Timor Leste	Teaching staff	Fill questioner
2	Electro-UNTL	3	Electrical engineers	Timor Leste	Teaching staff	Fill questioner
3	EDTL	7	Electrical engineers	Timor Leste	EDTL staff	Fill questioner
4	Parliament	1	Electrical Engineer	Timor Leste	Member of Parliament	Fill questioner
5	Startec ltd	1	Electrical Engineer	Timor Leste	Staff	Interview
6	Individual	2	Electrical and Mechanic	Australia	Consultant staff	Fill questioner
7	ATA	1	Energy Renewable	Australia	Staff	Fill questioner
8	Individual	2	Energy Planning and Policy	Fiji	Consultant staff	Fill questioner
9	Individual	1	Energy Planning and Policy	Indonesia	Lecturer	Fill questioner
10	Individual	1	Mechanical	Portugal	Consultant staff	Fill questioner
11	Individual	1	Electrical	Brazil	Consultant staff	Fill questioner
	Total	25				

List of interviewed people

No	Institution	No. of people	Remark
1	President of infrastructure commission of national parliament	1	In National Parliament of Timor Leste
2	Minister for public work, water and electricity	1	In Ministry office in Dili
3	EDTL director for research and development	1	In EDTL office-Kaikoli
4	EDTL senior technical staff	4	In EDTL office-Kaikoli
5	Lecturer from F. Engineering UNTL	5	Interviewed in Hera campus
6	Private local electricity company	5	In Dili

4. Hera power plant yearly performance data

Year	Gross energy production (MWh)	Net energy dispatch (MWh)	Fuel consumption (kg)	Oil consumption (ltr)
2012	235 061.339	230 795.562	47 367 919	115 000
2013	323 734.824	318 497.203	65 089 488	180 300
2014	343 776.488	338 074.787	69 541 924	158 400
2015	326 997.520	321 528.461	65 833 352	126 200
2016	299 090.880	293 891.685	59 990 456	117 100
2017	304 597.616	299 242.041	60 907 624	117 700
2018	452 963.260	-	104 342 141	131 400
Total	**2 286 221.927**	**1 802 029.739**	**4732 903**	**946 100**

5. Electricity annual revenue from 2010 to 2018

Year	Total collected (USD)	Remark
2010	10 209 018.43	
2011	12 749 505.51	
2012	15 386 803.73	
2013	16 044 430.21	
2014	19 461 065.82	
2015	22 581 010.77	
2016	28 798 298.27	
2017	30 656 160.42	
2018	33 077 664.30	
Total	**188,963,957.46**	

EDTL annual electricity revenue

Electricidade de Timor Leste - EDTL
Aligaçāo ao futuro para si e para Timor Leste
Switching on the future for you and East Timor

EDTL
Estrada de Balide
Caicoli - Dili
Telefone 3339510

RECAPITULATION OF REVENUE COLLECTION FOR 2010 - 2017 FINANCE YEAR

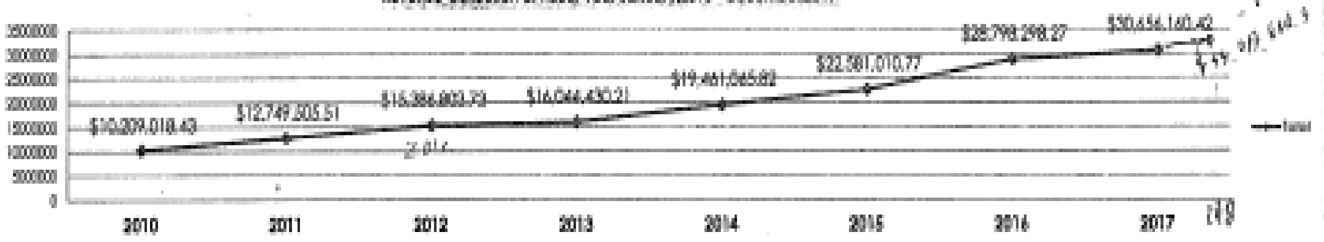
ELECTRICIDADE DE TIMOR LESTE - EDTL

TARGET REVENUE COLLECTION OF FISCAL YEAR JANUARY,2010 - DECEMBER,2017

No	FISCAL YEAR	Conventional Meter				Prepaid Meter			Others	New Conn.	Interest		Total
		Dili	Government	District	Sub District	Dili	District	Sub District			BNU	ANZ	
	FY. 2010 - 2017	A	B	C	D	E	F	G	H	I	J	K	L
1	2010	$ 3,863,189.01	$ 1,300,004.66	$ 197,102.96	$ 33,534.94	$ 4,714,629.05	$ -	$ -	$ -	$ 43,412.06	$ 53,031.28	$ 4,114.47	$ 10,209,018.43
2	2011	$ 5,784,842.62	$ 1,397,490.51	$ 80,249.43	$ 23,020.75	$ 5,387,460.90	$ -	$ -	$ -	$ 72,799.72	$ 2,896.23	$ 745.35	$ 12,749,505.51
3	2012	$ 6,438,391.35	$ 2,790,565.27	$ 52,283.14	$ 7,155.74	$ 6,034,246.95	$ -	$ -	$ -	$ 39,116.50	$ 15,139.63	$ 9,905.15	$ 15,386,803.73
4	2013	$ 7,008,798.44	$ 2,670,343.70	$ 126,164.90	$ 10,404.06	$ 6,166,274.87	$ -	$ -	$ -	$ 60,542.68	$ 737.53	$ 1,164.03	$ 16,044,430.21
5	2014	$ 8,181,382.84	$ 2,417,588.40	$ 37,269.94	$ 135.48	$ 6,891,644.98	$ 1,034,582.42	$ 131,479.31	$ 727,617.36	$ 38,217.09	$ 117.72	$ 1,030.78	$ 19,461,065.82
6	2015	$ 8,274,288.41	$ 3,323,333.85	$ 60,363.85	$ -	$ 8,999,557.96	$ 1,558,190.31	$ 219,491.85	$ 65,320.60	$ 80,459.09	$ -	$ 4.94	$ 22,581,010.77
7	2016	$ 10,537,606.80	$ 4,399,794.11	$ 307,657.30	$ 13,178.75	$ 12,007,157.16	$ 1,175,996.60	$ 81,198.70	$ 166,038.13	$ 79,652.40	$ 12.59	$ 5.73	$ 28,798,298.27
8	2017	$ 12,449,949.28	$ 3,165,481.39	$ 604,336.15	$ 2,522.50	$ 14,078,482.34	$ 94,441.60	$ 9,456.75	$ 138,857.87	$ 112,633.36	$ -	$ 1.19	$ 30,656,160.42
Total		$ 62,538,448.76	$ 21,464,601.89	$ 1,465,425.67	$ 89,952.22	$ 64,279,453.81	$ 3,863,210.93	$ 441,626.61	$ 1,097,833.95	$ 526,832.71	$ 71,936.98	$ 16,971.64	$ 155,886,293.16

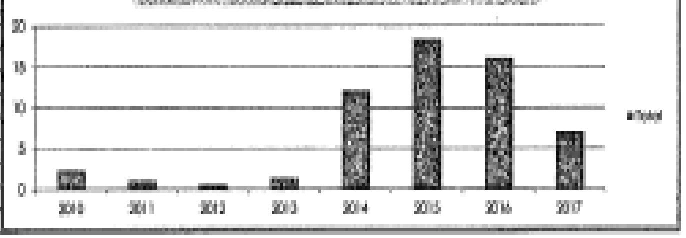
Receitas	$ 154,172,719.88
New con.	$ 526,832.71
Interest	$ 88,906.62
Others	$ 1,097,833.95

Revenue Collection of Fiscal Year January,2010 - December,2017



No	Fiscal year	Revenue Dist and Sub Dist		Total
		District	Sub District	
1	2010	$ 197,102.96	$ 33,534.94	$ 230,637.90
2	2011	$ 80,249.43	$ 23,020.75	$ 103,270.18
3	2012	$ 52,283.14	$ 7,155.74	$ 59,438.88
4	2013	$ 126,164.90	$ 10,404.06	$ 136,568.96
5	2014	$ 1,071,852.36	$ 131,614.79	$ 1,203,467.15
6	2015	$ 1,618,554.16	$ 219,491.85	$ 1,838,046.01
7	2016	$ 1,515,653.90	$ 94,327.45	$ 1,609,981.35
8	2017	$ 698,775.75	$ 11,979.25	$ 710,755.00
Total		$ 5,358,636.40	$ 531,528.83	$ 5,890,215.49

Recapitulação de Receitas Distritos e Sub Distritos AP. Jan,2010 - Dez, 2017



6. Electricity tariffs

Electricidade de Timor-Leste - EDTL

Rua Estrada de Balide - Caicoli, Dili, Timor – Leste Telp. +670 331 7283

Aviso Importante (alteração do tarifário, com efeitos a partir de 01 de Agosto de 2010)

O governo de Timor Leste anunciou uma mudança de tarifa de electricidade para todas as categorias de cliente. O objetivo desta mudança é a taxa de refletir com maior precisão o custo real de produção e incentivar os esforços de poupança de energia.

Cliente Residencial

Os primeiros 20 K.w.h. no mês ______________ 5 cêntimos / kwh

Mais de 20 Kwh no mês ______________ 12 cêntimos / kwh

Igrejas e ONGs locais estão sendo cobrados na tarifário residencial.

Cliente Comercial (com base no consumo médio mensal de ano de 2010)

Pequenas (média mensal <1000 kwh ______________ 15 cêntimos /kwh

Medio (média mensal> 1000 e <3600 kwh) ______________ 20 cêntimos / kwh

Grande (média mensal> 3600 kwh) ______________ 24 cêntimos / kwh

Todos os edifícios governamentais, embaixadas, ONGs internacionais são considerados "grandes" clientes.

Informasaun Importante (Mudansa das Tarifas komesa 1 de Agusto de 2010)

Governo Timor-Leste anunsia tia ona mudansa ba tarifa electricidade ba tipo consumidor hotu. Objetivo ba mudansa tarifa ne'e atu refleta diak liu kusto produsaun ne'ebe iha no atu incentiva esforcos atu poupa energia.

Cliente Domestico.

20 K.w.h. uja uluk iha fulan ida nia laran ______________ 5 centavos/kwh

Liu husi 20 kwh iha fulan nee nia laran ______________ 12 centavos/kwh

Igreja no ONG local sira sei cobra hanesan tarifa Domestico.

Cleinte Comercial (baseia ba media consumo cada fulan iha tinan 2010)

Kiik (media cada fulan < 1000 kwh) ______________ 15 centavos/kwh

Medium (media cada fulan > 1000 no < 3600 kwh ______________ 20 centavos/kwh

Boot (media cada fulan > 3600 kwh ______________ 24 centavos/kwh

Governo nia edificio sira, embaixada sira, no mos ONG internasional sira, considera hanesan consumidor "Commercial Boot".

7. Letter to EDTL for data collection in 2018 and approval from general director

Autorizado 10/01/17

10 01 2018

NAGAOKA UNIVERSITY OF TECHNOLOGY (NUT)
Department of Mechanical Engineering
Information Science and Control Engineering Post Graduate Program
Telp. No: +81 080 920 63602, Email: ppaasilva@yahoo.com.au

Nagaoka, 06 Janeiro 2018

Hato'o ba : Diretor Geral Eletricidade de Timor Leste (EDTL)
Dili – Timor Leste.

Assuntu: Husu Autorizasaun foti daduz eletricidade iha dirasaun EDTL

Excelencia,

Hau Paulo da Silva, hanesan estudante Posgraduasaun (Dotouramento) husi Universidade Technologia Nagaoka, Niigata, Japao, mai hasoru Shr. Diretor Geral EDTL, hodi husu ita nia autorizasaun para bele foti dadus energia eletricidade nian iha institusaun EDTL. Dadus nebe atan hau presisa maka hanesan tuir mai ne'e:

1. Total produsaun energia kada tinan husi 2012 – 2017
2. Total energia nebe uza kada tinan husi 2012-2017
3. Quantidade combustivel (diesel) kada tinan ba sentru produsaun sira husi 2012-2017
4. Quantidade oleo ba manutensaun makinas iha sentru produsaun sira husi 2012-2017
5. Total reseitas annual nebe dirasaun EDTL hetan husi venda energia hahu 2012 - 2017

Objetivo husi dadus hirak nee sei ajuda atan hau atu halo analiza no projeksaun (forecasting) konaba implikasaun ambiental no ekonomiku ba iha futuro. Topiku nebe atan hau konsentra ba maka: "Environmental and Economical Impacts of Green Electricity Policy for Timor Leste". Husi dadaus presente no nia analiza impaktu sira, maka ikus mai hau sei koko atu sugere opsaun energia alternative nebe sustentavel no reflectivo ho strutura enokomika, social, ambiental Timor Leste nian.

Ikus liu, atan hau ho haraik an husu Sua. Ex., nia ajuda no tulun hodi bele fasilita informasaun no dadus hirak ne'e para bele fasilita hau nia pesquisa ho diak. Hau la haluha hato'o hau nia obrigado wa'in ba ita nia laran luak.

Paulo da Silva
Pesquisador, NUT

8. Support letter from academic supervisor of NUT

NAGAOKA UNIVERSITY OF TECHNOLOGY (NUT)
Department of Mechanical Engineering
Information Science and Control Engineering Post Graduate Program
Telp. No: +81 080 920 33602, Email: tanabe@mech.nagaokaut.ac.jp

Nagaoka, 27 December 2017

To: Academics, Energy experts and the Government officials

Subject: Requesting for providing data and information to Mr. Paulo da Silva's research

Dear Sir/Madam,

I am Professor Tanabe IKUO from Nagaoka University of Technology (NUT) as academic supervisor for Mr. Paulo da Silva who is currently studying his doctoral course at our university. He is doing several researches on engineering related topics including green energy options for possible substitution of the current conventional electricity power in Timor Leste. Mr. Da Silva is currently collecting technical data for completing one of his works, therefore; I kindly request your support in providing data and information which will help him to accomplish his research.

Your kind supports and good cooperation are highly appreciated.

Sincerely yours

Prof. Tanabe IKUO
Academic Supervisor-NUT

9. Data collection schedule in Dili, Timor Leste

Date	Activities
7-8 Jan 2018	Leave Japan and arrive in Dili, East Timor
9 Jan 2018	Visit Hera Campus to Inform JICA project officer
10 Jan 2018	Prepare questionnaires: print hard copy based on the needs
11 Jan 2018	Distribute Questioners in Hera Campus targeted lecturers
12 Jan 2018	Distribute Questioners to EDTL in Dili
13-14 Jan 2018	Weekend, adjust and working on thesis: chapter III
15 Jan 2018	Interview with director for Hera power plant
16 Jan 2018	Interview with director of EDTL in Dili
17 Jan 2018	CO_2 recording in Comoro area in Dili
18 Jan 2018	CO_2 recording in Hera near power plant
19 Jan 2018	CO_2 recording in Comera area in Dili
20-21Jan 2018	Weekend, data recapitulation from CO2 recordings
22 Jan 2018	CO_2 recording in Audian area in Dili
23 Jan 2018	Visit EDTL Commercial office to collect energy consumption level data
24 Jan 2018	Visit Hera Campus for re-collecting questionnaires from lecturers
25 Jan 2018	CO_2 recording in Culuhun area in Dili
26 Jan 2018	CO_2 recording in Balide area in Dili
27-28 Jan 2018	Weekend, data recapitulation and adjust some works
29 Jan 2018	Re collect Questionnaire from EDTL offices
30 Jan 2018	CO_2 recording in Becora area
31 Jan 2018	Visit Hera Power Plant for CO_2 recording
01 Feb 2018	Data recapitulation from respondents
02 Feb 2018	Visit Hera Campus to meet JICA project officers before departure
03-4 Feb 2018	Depart Dili for Japan

10.Letter of request for filling questionnaire

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Letter of request

Subject: Requesting for filling
the survey questionary

Dear respondents,

I wish you are in a good health condition. I am grateful to meet you and requesting your generosity in filling out my research questionary in regard to one of my works at Nagaoka University of Technology – Niigata, Japan. Basically, the work is focusing on identifying a reflective and efficient energy option for Timor Leste that will serve the country's energy needs for the long run. I have identified four important criteria including technical, environmental, resource usage and financial as bases for the energy option selection. The options which considered as alternatives are fossil fuel, wind power, solar power and hydropower. You are requested to compare and weight each of them against each other based on your knowledge and expertise, or you may even taking into account the ground level condition (Timor potential energy situation if you aware) for each option. The subjective weighting value is from equal strong to extremely strong one (1 = equal, 3 = marginal strong, 5 = strong, 7= very strong, 9 = extremely strong. Meanwhile the 2, 4, 6 and 8 are the intermediate value). If you do not mind, please provide me with your professional information in the provided sheet, it will be used for acknowledgement at the end of my work.

Your kind support and cooperation in filling out this questionary is highly appreciated.

Sincerely yours

Paulo da Silva
Researcher

11.Sample of questionnaire

Part one

THE CRITERIA

In this first part, you are requested to either fill out the following table to compare the each criteria or you may go through each question and circle the numbers from 1 - 9.

Criteria	Technical	Financial	Environmental	Resource usage
Technical	1	2	4	3
Financial	0.3	1	2	2
Environmental	0.25	0.5	1	3
Resource usage	0.33	0.5	0.33	1

TECHNICAL CRITERIA

1. Technical Criteria against financial criteria, how strong is the technical criteria:

1	2	3	4	5	6	7	8	9
Equal		Margin strong		Strong		Very strong		Extremely strong

2. Technical Criteria against environmental criteria, how strong is the technical criteria:

1	2	3	4	5	6	7	8	9
Equal		Margin strong		Strong		Very strong		Extremely strong

3. Technical Criteria against resource usage criteria, how strong is the technical criteria:

1	2	3	4	5	6	7	8	9
Equal		Margin strong		Strong		Very strong		Extremely strong

FINANCIAL CRITERIA

1. Financial criteria against technical criteria, how strong is the financial criteria:

1	2	3	4	5	6	7	8	9
Equal		Margin strong		Strong		Very strong		Extremely strong

1/3

2. Financial criteria against environmental criteria, how strong is the financial criteria:

1	2	3	4	5	6	7	8	9
Equal		Margin strong		Strong		Very strong		Extremely strong

3. Financial criteria against resource usage criteria, how strong is the financial criteria:

1	2	3	4	5	6	7	8	9
Equal		Margin strong		Strong		Very strong		Extremely strong

ENVIRONMENTAL CRITERIA

1. Environmental criteria against technical criteria, how strong is the environmental criteria:

1	2	3	4	5	6	7	8	9
Equal		Margin strong		Strong		Very strong		Extremely strong

2. Environmental criteria against financial criteria, how strong is the environmental criteria:

1	2	3	4	5	6	7	8	9
Equal		Margin strong		Strong		Very strong		Extremely strong

3. Environmental criteria against resource usage criteria, how strong is the environmental criteria:

1	2	3	4	5	6	7	8	9
Equal		Margin strong		Strong		Very strong		Extremely strong

RESOURCE USAGE CRITERIA

1. Resource usage criteria against technical criteria, how strong is the resource usage criteria:

1	2	3	4	5	6	7	8	9
Equal		Margin strong		Strong		Very strong		Extremely strong

2. Resource usage criteria against financial criteria, how strong is the resource usage criteria:

1	2	3	4	5	6	7	8	9
Equal		Margin strong		Strong		Very strong		Extremely strong

3. Resource usage criteria against environmental criteria, how strong is the resource usage criteria:

1	2	3	4	5	6	7	8	9
Equal		Margin strong		Strong		Very strong		Extremely strong

Part Two

THE ALTERNATIVES

In this part (two), you are simply filling the tables with numbers 1 – 9 based on each criteria

a. REGARD TO TECHNICAL CRITERIA

In this technical aspect, it needs to know your opinion about the technical complexity of each option, including the aspects like reliability, availability and efficiency of each energy option.

Alternative	Fossil fuel	Wind power	Solar Power	Hydropower
Fossil fuel	1	2	2	2
Wind power	0.2	1	6	6
Solar Power	0.5	0.166	1	5
Hydropower	0.5	0.166	0.2	1

1	2	3	4	5	6	7	8	9
Equal		Margin strong		Strong		Very strong		Extremely strong

b. REGARD TO FINANCIAL CRITERIA

In this financial aspect, you can consider costing which may include capital, O&M costs, labor cost, profit for contractors and maybe compensation as well as legal and permit costs of each option.

Alternative	Fossil fuel	Wind power	Solar Power	Hydropower
Fossil fuel	1	2	3	2
Wind power	6	1	8	7
Solar Power	0.33	0.12	1	0.166
Hydropower	0.5	0.142	6	1

1	2	3	4	5	6	7	8	9
Equal		Margin strong		Strong		Very strong		Extremely strong

c. REGARD TO <u>RESOURCE USAGE CRITERIA</u>

In this resource usage aspect, it is about required resources for the option, for example: the need of water for cooling, size of land for building plants etc.

Alternative	Fossil fuel	Wind power	Solar Power	Hydropower
Fossil fuel	1	2	2	2
Wind power	8	1	7	7
Solar Power	0.5	0.142	1	0.125
Hydropower	0.5	0.142	8	1

1	2	3	4	5	6	7	8	9
Equal		Margin strong		Strong		Very strong		Extremely strong

d. REGARD TO <u>ENVIRONMENTAL CRITERIA</u>

In this resource environmental aspect, think about the amount of carbon emissions that may pump from the option to the atmosphere (from raw material extraction, component production, transporting, and construction till operation), wasting issue and noisy level.

Alternative	Fossil fuel	Wind power	Solar Power	Hydropower
Fossil fuel	1	2	2	2
Wind power	0.142	1	6	6
Solar Power	0.5	0.166	1	7
Hydropower	0.166	0.166	0.142	1

1	2	3	4	5	6	7	8	9
Equal		Margin strong		Strong		Very strong		Extremely strong