ANALYSIS OF PRODUCT DISASSEMBLABILITY USING THE DISASSEMBLY EVALUATION CHART METHODOLOGY

WIWIEK FATMAWATI

UNIVERSITI TEKNOLOGI MALAYSIA

Dedicated to my beloved family and my institution, UNISSULA

ACKNOWLEDGEMENTS

With the highest gratitude to the Almighty ALLAH S.W.T. for all the blessings and for giving me the patience and strength to complete this project.

Then, I would like to express my sincere appreciation to my supervisor Dr. Ariffin Haji Abdul Razak, for his critics, advices, support and encouragement which have contributed to the success of this project. His invaluable advice and suggestion has been a source of inspiration whenever I encountered certain problems in carry out this project.

My grateful thanks also go to my institution, Universitas Islam Sultan Agung (UNISSULA) for giving me the chance and the financial support throughout the length of my study. And also for my colleagues in Fakultas Teknologi Industri UNISSULA, thank you for all supports which have given to me.

Special thanks to all of my course mates and lecturers at the Advanced-Manufacturing Technology Programme, UTM, I would like to thank you all for your help, support and friendship.

At last, my tribute goes to my beloved family, Mas Imam and Azka, Solo and Jogja big family, who taught me patience, possibility and hope in my life with their endless love and spirit that I could not do without.

ABSTRAK

Mereka bentuk produk yang selamat untuk persekitaran serta memudahkan produk dan bahagian-bahagiannya menjadi mudah untuk diguna semula, kembali dikilangkan atau dikitar semula di akhir hayatnya menjadi semakin penting. Salah satu aspek pembangunan produk yang menjadi tumpuan pemulihan sumber pada akhir masa kitaran hayat produk adalah reka bentuk untuk leraian (DFD). Carta kaedah penilaian reka bentuk ceraian (DECM) merupakan suatu kaedah yang boleh didapati dari pelbagai kaedah dalam DFD yang boleh digunakan untuk menilai kebolehleraian satu produk dengan menggunakan satu lembaran sebaran dengan memperhatikan tingkat kesulitan untuk satu kerja operasi reka bentuk leraian yang diterbitkan daripada sistem Maynard Operation Sequence Technique (MOST). Matlamat DECM adalah untuk menjadikan produk lebih mudah untuk dileraikan. Keputusan penilaian seperti kecekapan kebolehleraian, anggaran masa dan anggaran kos akan dikira dan kemudian dinilaikan untuk mengenalpasti apa yang harus diperbaiki. Pengoptimuman reka bentuk boleh dicapai dengan menyemak hasil penilaian, membuat pembaikan terhadap reka bentuk dan menilai semula reka bentuk. Pengesahan DECM adalah dibuat dengan menggunakan satu kajian kes produk dan membandingkan hasil daripada perancangan asal untuk cadangan reka kes kajian produk. Keputusan didapati daripada kes kajian yang menunjukkan bahawa kaedah boleh mencapai objektif daripada kebolehleraian produk.

ABSTRACT

Designing product which is safe for the environment and facilitate the product and its parts to be easily reused, remanufactured or recycled at its end of life is becoming increasingly important. One of the aspects of product development which focus on the recovery of resources at the end of the product lifecycle is Design for Disassembly (DFD). Disassembly evaluation chart methodology (DECM) is one of the various available methods in DFD which can be used to evaluate the disassemblability of a product by using a spreadsheet-like chart with the respect to the disassembly difficultness for each task of the disassembly operation which is derived from the Maynard Operation Sequence Technique (MOST) system. The goal of DECM is to make products easier to disassemble. The evaluation result such as disassembly efficiency, disassembly time and disassembly cost estimation are calculated and then evaluated to identify what should be improved. The design optimization is achieved by reviewing the evaluation results, making improvements on the design and re-evaluates the design. Validation of DECM is done by using a product case study and comparing the result from the original design to the proposed design of product case study. Results obtained from the case study showed that the method is able to achieve objectives of the product disassembability.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	TITLE	i
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENTS	iv
	ABSTRAK	v
	ABSTRACT	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xi
	LIST OF FIGURES	xiii
	LIST OF APPENDICES	xv
I	**INTRODUCTION**	1
	1.1. Introduction to the Problem	1
	1.2. Objective of Study	3
	1.3. Scope of Study	4
	1.4. Methodology of Study	4
	1.5. Significance of Study	6
	1.6. Report Structure	6
	1.7. Summary	7
II	**LITERATURE REVIEW**	8
	2.1. Introduction	8
	2.2. Design for ‘X’	10
	2.3. Design for Environment	11

	2.3.1. Design for Recycling	11
	2.4. Design for Disassembly	12
	2.4.1. Definition of Disassembly	13
	2.4.2. Principles of Design for Disassembly	13
	2.4.3. Design Guidelines for Design for Disassembly	14
	2.4.4. Advantages of Design for Disassembly	16
	2.5. Disassembly Time Evaluation Methodologies	16
	2.5.1. The Hitachi Disassemblability Evaluation Method	17
	2.5.2. The Disassembly Evaluation Chart Method	18
	2.5.3. Work Factor Method	19
	2.5.4. Reversibility and Connection Method	20
	2.5.5. The Symbolic Methodology	21
	2.6. Summary	22
III	**DISASSEMBLY EVALUATION CHART METHODOLOGY**	24
	3.1. Introduction	24
	3.2. Outline of Disassembly Evaluation Chart Methodology (DECM)	25
	3.2.1. Aims of DECM	25
	3.2.2. Procedure of DECM	26
	3.3. The Evaluation Method	27
	3.3.1. Evaluation Chart	27
	3.3.2. Difficulty Rating	32
	3.3.3. Derivation of Difficulty Score	34
	3.3.4. Disassembly Estimation Time	36
	3.3.5. Design Efficiency	37
	3.3.6. Disassembly Cost	37
	3.4. Summary	38

IV	**PRODUCT CASE STUDY**	39
	4.1. Introduction	39
	4.2. Product Case Study	39
	4.2.1. Product Description and Specification	40
	4.2.2. Product Structure	41
	4.2.3. Bill of Materials	43
	4.2.4. Identify the Function and Weakness of Each Part	45
	4.3. Summary	52
V	**EVALUATION OF THE ORIGINAL DESIGN**	54
	5.1. Introduction	54
	5.2. Difficulty Rating	54
	5.3. Disassembly Evaluation Chart Worksheet	62
	5.4. Disassembly Time Estimation	67
	5.5. Disassembly Cost Estimation	68
	5.6. Original Design Efficiency	68
	5.7. Summary	70
VI	**DESIGN MODIFICATIONS AND IMPROVEMENTS**	71
	6.1. Introduction	71
	6.2. Redesign of Product Case Study	71
	6.2.1. Major Improvements	75
	6.2.2. Minor Improvements	81
	6.2.3. Exploded View of Redesign Product	94
	6.3. Product Tree Structure of Redesign Product	95
	6.4. Bill Material of Redesign Product	97
	6.5. Summary	98

VII	**EVALUATION OF REDESIGN PRODUCT**	99
	7.1. Introduction	99
	7.2. Difficulty Rating of Redesign Product	99
	7.3. Disassembly Evaluation Chart Worksheet of Redesign Product	104
	7.4. Disassembly Time Estimation of Redesign Product	108
	7.5. Disassembly Cost Estimation of Redesign Product	108
	7.6. Design Efficiency of Redesign Product	109
	7.7. Summary	110
VIII	**REDESIGN PRODUCT VALIDATION**	111
	8.1. Introduction	111
	8.2. Comparison Between Original and Redesign Product	111
	8.2.1. Total Number of Parts	112
	8.2.2. Product Disassembly Time	112
	8.2.3. Product Disassembly Cost	112
	8.2.4. Design Efficiency	113
	8.3. Discussion	113
	8.4. Summary	114
IX	**CONCLUSIONS AND FUTURE RECOMMENDATIONS**	115
	9.1. Introduction	115
	9.2. Conclusions	115
	9.3. Future Works Recommendations	117
	REFERENCES	119
	APPENDICES	122

LIST OF TABLES

TABLE No.	TITLE	PAGE
Table 2.1	Design for disassembly principles	14
Table 2.2	Design for disassembly guidelines	15
Table 2.3	Design for disassembly methodologies	17
Table 2.4	The relationship of joining method to disassembly time and its reversibility	21
Table 2.5	Tool categories and symbols for disassembly operations	22
Table 3.1	Structure of disassembly evaluation chart	27
Table 3.2	The standard disassembly task and their code	29
Table 3.3	The standard disassembly tool and their code	30
Table 3.4	Three main sequence models used in Basic MOST	35
Table 4.1	Product specification	41
Table 4.2	Bill of Material	43
Table 4.3	The function and weaknesses of each part	46
Table 5.1	Parameter allocation for each part	56
Table 5.2	Component times (in TMU) for each part	59
Table 5.3	The difficulty score for dismantling each part	61
Table 5.4	The disassembly evaluation chart for CPU	63
Table 6.1	The proposed improvement for product case study	72
Table 6.2	Bill of material of redesign product	97
Table 7.1	The generation of the difficulty rating score of redesign product	101
Table 7.2	The TMU time for each pat of redesign product	102
Table 7.3	The difficulty score for each part of redesign product	103

Table 7.4	The disassembly evaluation chart of redesign product	105
Table 8.1	Original design and redesign product comparison	113

LIST OF FIGURES

FIGURE No.	TITLE	PAGE
Figure 1.1	Project flowchart	5
Figure 2.1	Product life cycle	9
Figure 3.1	Aims of DECM	25
Figure 3.2	Disassembly evaluation procedure	26
Figure 4.1	The product case study	40
Figure 4.2	Product tree structure	42
Figure 6.1	Casing box	76
Figure 6.2	Casing cover	77
Figure 6.3	Casing cover with its ribs	78
Figure 6.4	CD ROM rack	79
Figure 6.5	Detailed view of HDD rack	80
Figure 6.6	HDD rack	81
Figure 6.7	Protrude holes	83
Figure 6.8	Detailed USB slot	84
Figure 6.9	The USB slot with the inserted USB board	84
Figure 6.10	The front view of USB slot	85
Figure 6.11	CPU cable speaker	86
Figure 6.12	Expansion slot	87
Figure 6.13	Extra CD ROM cover	88
Figure 6.14	Extra CD ROM cover in detail	89
Figure 6.15	How to insert the button and the switch	90
Figure 6.16	Power-reset button	91
Figure 6.17	Rubber base	93

Figure 6.18	Exploded view of redesign product	94
Figure 6.19	Redesign product	95
Figure 6.20	Product tree structure of redesign product	96

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
Appendix A	General Move Data Card	122
Appendix B	Controlled Move Data Card	123
Appendix C	Tool Use Data Card for Fasten or Loosen	124
Appendix D	Tool Use Data Card for Cut, Surface Treatment, Measure, Record and Think	125
Appendix E	Exploded View of Redesign Product	126

CHAPTER 1

INTRODUCTION

1.1. Introduction to the Problem

In recent years of environmental awareness, the steadily increasing consumption of industrial product is facing with the environmental issue for both consumer and manufacturer. Huge amounts of products are now manufactured and sold to consumers every year. These products sooner or later have to be dumped in landfills after their life cycle are over. Furthermore, their life cycle become short not only because they fail but also because they go out of style or become technologically obsolete. However, the biggest damage to the environment occurs when the product completes its useful life.

This trend is most apparent when the environmental impact of worn-out products is considered. The disposal of this product by conventional means, such as landfill or incineration, represents an unsustainable loss of raw material resources and poses another problem because the product does not simply disappear after disposal. The extremely high and ever-increasing annual disposal rates of solid waste have caused a big problem. Disposal of used product in landfills can affect the environment by the loss of natural resources and contamination of the environment with hazardous substance.

Since the value of preserving the environment and natural resources may soon predominate the cost of recycling, then it is expected to face a growing demand to dispose of old products in constructive way by removing hazardous materials, retrieving reusable components and recycling. Because the products to be disassembled a few years from now are the ones that designed and built today, thus it is needed to account the recyclability in current design practices (Carver et al., 1999).

The concerns about the environment have spurred designers to consider the product life cycle, from initial conceptual design, through normal product use, to the eventual disposal of the product. It is widely acknowledged that the most ecological way to treat the obsolete product is by recycling. Although it is rarely possible to recycle a product completely, it would be noteworthy to maximize the recycled resources and to minimize the rubbish of the remaining product. Products are expected to derive minimal energy and resources from the environment and discharge minimal amount of waste during and after their life cycles.

The fast depletion of the raw materials and an increasing amount of different forms of waste such as solid waste, air and water pollution leads the manufacturer to create environmentally friendly products and develop techniques for product recovery and waste management. Product recovery usually performed in two ways: recycling and remanufacturing (Gungor, et al, 1999). Disassembly has proven its role in material and product recovery. However, in the process of disposing and recycling old product which include the cost of handling, sorting and disassembly will play an important role. The cost effectiveness of recycling will be increasing if disassembly is made easier.

Some manufacturers now inlaid their take-back legislation on their product to make them responsible for the environmentally safe recycling or disposal of their end-of-life products. The legislation is designed to create an economic incentive for manufacturers to design more environmentally friendly products, and to reduce the environmental impact of waste by increasing the volume that is recovered and recycled. Again, the design for disassembly plays an important role.

Product disassembly is motivated to obtain the pure secondary material and to isolate environmentally relevant materials from other materials (Rose, 2000). Disassembly a product into separate part or material is just one of may possible end-of-life treatment options for obsolete product. Even though the disassembly approach may seem to provide a way to minimizing the environmental problems, it should be mentioned that the cost of disassembly and the market process for recycled materials are less than the environmental benefits.

The problem statement of this project is defined as “how to evaluate the certain product to make it ease to disassemble by determining the disassembly time estimation”. Product life cycle can be extended by good maintenance and servicing, these activities usually require partial disassembly in order to replace or repair parts that are embedded with other parts in the product structure. The main issue is how to redesign a product in such way to make it ease to disassemble with the minimum cost. It is due to the cost of handling, sorting and disassemble time which plays an important role in process of disposing and recycling old product.

1.2. Objective of Study

The time taken to disassemble the product is the important factor due to aspect of remanufacturing, reuse and recycles. The objective of this project is to evaluate the disassembly time estimation of a case study product using the disassembly evaluation chart method in order to improve the product disassemblability.

1.3. Scope of Study

The scopes of this project consist of:

1. Review on literature of disassembly time estimation.
2. Study only on disassembly analysis tool.
3. Study on the concept of disassembly evaluation chart method as a disassembly analysis tool.
4. The disassembly time analysis is based on case study example by analyzing the result and redesigns the product.

1.4. Methodology of Study

This project is proposed in 2 consecutive semesters. For the first semester the task that should be proceeded are project definition, literature review and determining the methodology for disassemble the product case study, including the disassembly evaluation and the proposed improvement of the original product.

For the second semester the task is done to evaluate the disassemblability of the proposed design. This task comes up with the proposed improvement design for ease of disassemble in detail, and the evaluation is based on results gained from the disassembly evaluation chart which included the disassembly time estimation, disassembly cost estimation and disassembly efficiency. The flowchart of this project is shown in Figure 1.1.

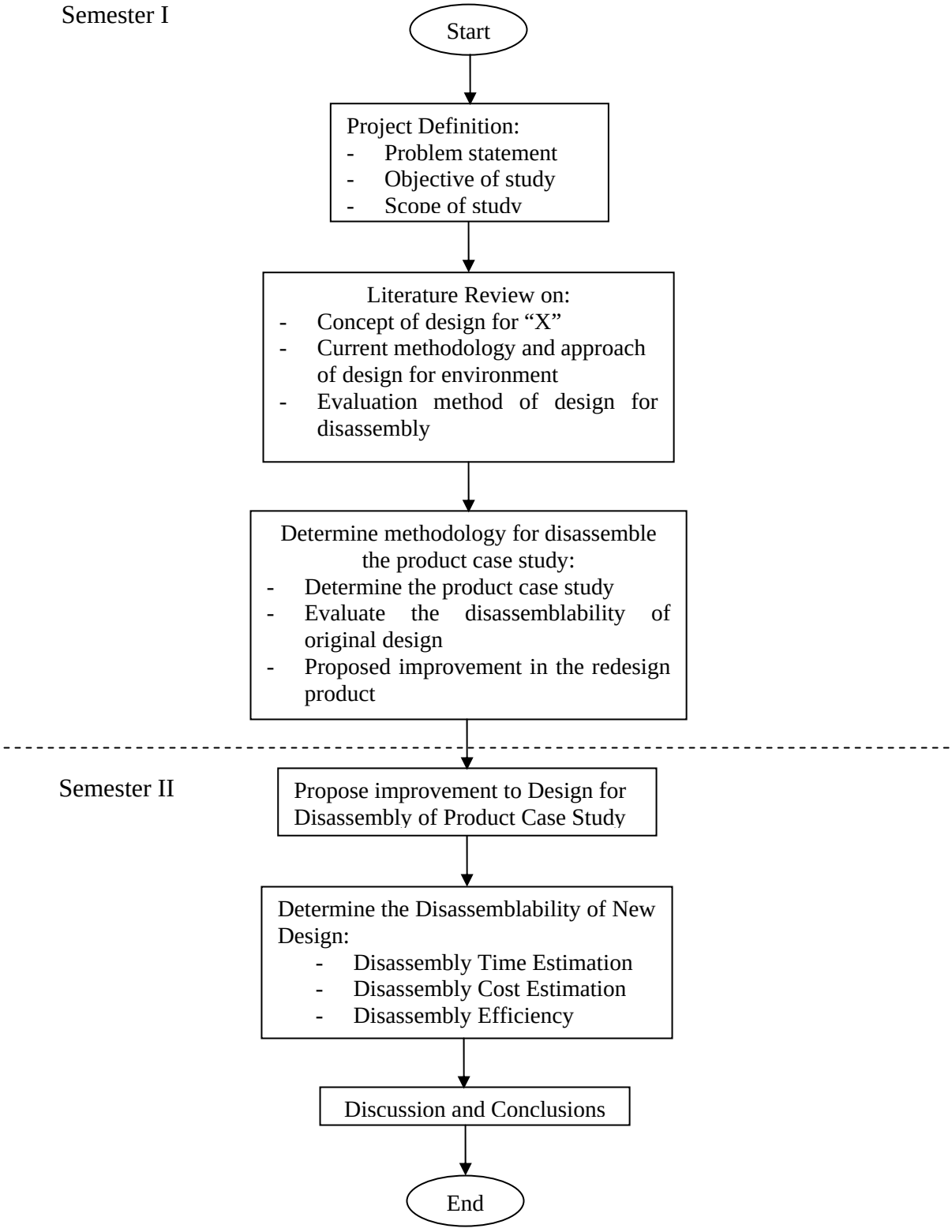

Figure 1.1: Project Flowchart

1.5. Significance of Study

The motivation of carry out this project is to evaluate the design of a certain product on the ease of disassemble point of view. The advantage of designing a product which was easy to disassemble is to give the simplicity to service or to maintain the product in order to extend the product life cycle. Furthermore, the product then can be reused, remanufactured, recycled and/or recondition without or with less damages to product's component.

The significance of the disassembly evaluation chart method is to simplify the evaluation method of manual procedures of disassembly operation using a spreadsheet-like chart. The difficulty parameter in disassembly operation is also determined through this study. The improvement of the product disassemblability will be compare through the disassembly estimation time, disassembly cost and disassembly effectiveness. However, if the improvement design only gives a small increasing in disassemblability parameter, it is still consider acceptable, because it would be significant over large production volumes.

1.6. Report Structure

This report consists of nine chapters. The organization of this report is as follows: Chapter 1 is an introduction to this thesis which contains introduction to the problem, objective, scope and project methodology and significance of the study. Chapter 2 discusses the literature review of the relevant disassembly methodology and evaluation, and the past work done by the previous researcher which is related to the study. Chapter 3 will discuss detail about the disassembly evaluation chart methodology which is used to evaluate the design for disassembly and will explained more by using product case study as an example. Chapter 4 explains about the product case study where Central Processing Unit (CPU) of a Personal Computer

(PC) is carried out. The evaluation of disassemblability of the original design is discussed in Chapter 5. Chapter 6 discusses about the design modification and improvement to the original design. The proposed improvements of the original design are also discussed. The evaluation of the redesign product is discussed in chapter 7. Chapter 8 discusses about the validation of redesign product. This chapter explains about the comparison between the original and the improved design. Finally, the conclusions and recommendations of this project will be presented in chapter 9.

1.7. Summary

This chapter presented the overview of the entire project. Introduction to the problem, objective of study, scope of study, project methodology and significance of study were discussed in detail. The whole project was to analyze the design for disassembly using disassembly evaluation chart methodology. It is hoped that the methodology would encourage the disassemblability of product.