DEVELOPMENT OF REMANUFACTURING QUALITY PRACTICES FRAMEWORK FOR MALAYSIA AUTOMOTIVE INDUSTRY

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DEDICATION

To the man I missed the most.... my beloved Abah, Mohamed Bin Juhari. I kept my promise to you, Abah. Special dedication to my mum, my husband and kids, for being by my side along the journey through thick and thin.

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ABSTRACT

Remanufacturing is the ultimate process of recovering old products to function like new products in its original condition. One interesting research area for remanufacturing is in the automotive industry. This is because it is a known fact that there are components/parts from end-of-life vehicles that are being reused while others are dumped into landfills, causing a major issue in all countries including Malaysia. One of the most significant discussions found in this area is the quality distinction between reused and remanufactured products of used vehicle components called the 'core'. Reused is a weak traditional approach that brings back the value of 'core' without guaranteeing quality and safety. However, there is no established framework for remanufacturing product that takes into account quality and safety aspect for the 'core'. The aim of this study was to develop a Remanufacturing Quality Practices Framework (RQPF) for Malaysia automotive industry. Both qualitative and quantitative data were collected and analysed sequentially to achieve the research objectives. Hence, the RQPF and criteria for the Malaysian automotive industry were established. A focused group discussion was held at the Malaysia Robotic and IoT Institute (MARI) to get experts' views on the criteria to develop the RQPF. Ten factors and 38 items that affect the quality of remanufacturing to be certified are key instruments for subsequent quantitative measurement. The respondents comprised of industrial players, policy makers and academicians who have experience in automotive, marine and heavy machinery. Purposive sampling survey using a questionnaire was conducted to confirm the final factors and underlying items to interpret the current best practices on remanufacturing 'core' which ended with the snowball effect at the end of the survey. Important factors and items were then finalised through exploratory factor analysis and confirmatory factor analysis (EFA-CFA). The data was then filtered to strengthen the model. Next, a program consists of nine factors and 21 items was conducted to rank the importance of the factors and items towards the needs of the remanufacturing industry in Malaysia through the analytical hierarchy approach (AHP). Finally, the RQPF framework for the automotive industry in Malaysia was proposed. The produced framework is expected to assist the Malaysian government and industry to draft possible regulations that will help regulate remanufacturing practices.

ABSTRAK

Pembuatan-semula merupakan proses tertinggi dalam memulih produk terpakai untuk berfungsi seperti baru dalam keadaan asal. Salah satu bidang penyelidikan yang menarik dalam pembuatan-semula adalah dalam industri automotif. Ini kerana terdapat komponen/bahagian daripada kenderaan akhir-hayat yang digunakan-semula manakala ada juga yang dibuang ke tapak pelupusan dan ini telah menjadi isu utama di semua negara termasuk Malaysia. Salah satu perbincangan yang paling penting yang ditemui dalam bidang ini adalah perbezaan kualiti antara produk guna-semula dan buat-semula bagi komponen kenderaan yang disebut sebagai 'core'. Guna-semula adalah pendekatan tradisional yang lemah untuk mengembalikan semula nilai 'core' tanpa jaminan kualiti dan keselamatan. Walau bagaimanapun, tiada kerangka kerja yang dihasilkan bagi produk pembuatan-semula yang mengambil kira aspek kualiti dan keselamatan terhadap 'core'. Oleh itu, kajian ini dijalankan bertujuan untuk membangunkan kerangka kerja kualiti praktik pembuatan-semula (RQPF) bagi industri automotif Malaysia. Kedua-dua data kualitatif dan kuantitatif telah dikumpulkan dan dianalisa mengikut turutan untuk mencapai matlamat penyelidikan. Oleh itu, RQPF dan kriteria untuk industri automotif Malaysia telah dibangunkan. Perbincangan dalam kumpulan fokus telah dijalankan di Malaysia Robotic and IoT Insitute (MARI) untuk mendapatkan maklumbalas pakar mengenai kriteria (faktor/elemen) untuk membina RQPF. Sepuluh faktor dan 38 elemen yang memberi kesan kepada kualiti pembuatan-semula yang perlu diperakui menjadi instrumen utama dalam pengukuran secara kuantitatif. Responden kajian terdiri daripada pakar dari pengamal industri, pembuat dasar dan ahli akademik yang berpengalaman dalam bidang automotif, marin dan jentera berat. Pensampelan purposive melalui kajian soal selidik telah dijalankan untuk mengesahkan faktor-faktor akhir dan eleman-elemen asas dalam pembuatan-semula 'core' yang mana ianya berakhir apabila terjadinya kesan bebola salji di akhir tinjauan. Faktor-faktor dan elemen-elemen utama kemudiannya dimuktamadkan melalui exploratory factor analysis dan confirmatory factor analysis (EFA-CFA). Data seterusnya ditapis untuk mengukuhkan model. Seterusnya, program mengandungi sembilan faktor dan 21 elemen telah dijalankan untuk mengira sejauh mana kepentingan faktor-faktor dan elemen-elemen terhadap keperluan industri pembuatan-semula di Malaysia dengan melalui proses analisis secara hierarki (AHP). Akhir sekali, satu kerangka kerja RQPF bagi automotif industri di Malaysia telah dicadangkan. Kerangka kerja yang dibangunkan diharap dapat membantu kerajaan Malaysia dan pihak industri untuk merangka peraturan yang akan membantu mengawal selia amalan pembuatan-semula.

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LIST OF ABBREVIATIONS

AHP	-	Analytical Hierarchy Process
AIJ	-	Aggregation of Individual Judgement
AIP	-	Aggregation of Individual Priorities
AM	-	Arithmetic Mean
AVE	-	Average Variance Extract
CFA	-	Confirmatory Factor Analysis
CA	-	Cronbach Alpha
CR	-	Consistency Ratio
CR	-	Composite Reliability
CI	-	Consistency Index
CKD	-	Complete Knocked Down
EOL	-	End-of-Life
EFA	-	Exploratory Factor Analysis
ELV	-	End-of-Life-Vehicle
IER	-	Independent Equipment Remanufacturer
OEM	-	Original Equipment Manufacturer
OER	-	Original Equipment Remanufacturer
NAP	-	National Automotive Policy
PCM	-	Pairwise Comparison Matrix
PLS	-	Partial Least Square
Reman	-	Remanufacturing Industry
RQPF	-	Remanufacturing Quality Practices Framework
RI	-	Random Consistency Ratio
SEM	-	Structural Equation Modelling

LIST OF SYMBOLS

F	-	Factor
S	-	Item
E	-	Element
E	-	Number of Participant (Expert)
A	-	Pairwise Comparison Matrix
W	-	Normalize Weighting
R	-	Normalize Priority Ratio
n	-	Number of Respondent
n	-	Number of Element (Factors/ Item)
GM	-	Geometric Mean
AM	-	Arithmetic Mean

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Traditionally, the configuration of supply chain for product lifecycle is known as the opened-loop supply where in the beginning of the manufacturing stage, the only consideration is on how to reduce cost and waste. Total Quality Management (TQM) and Lean Manufacturing (LM) traditional concepts have been used in monitoring the development of products in terms of quality, processes and services with economic strategy as the pillar addressed. In the recent world, the greening concept and achieving a sustainable manufacturing supply chain under the closed-loop life cycle are the focus of research. The evolvement from the 3R to 6R concept is the new era for the cradle-to-cradle life cycle under the closed-loop life cycle which will be explained in Chapter 2. Figure 1.1 depicts the evolution of the opened-loop to closed-loop lifecycle and the pillars addressed (Duxes Reman Series, 2016). The evolution bring to remanufacturing approach in cradle-to-cradle concept as ultimate form of recycling to remanufacturing (Abdulrahman, Subramanian, Liu, & Shu, 2014; Errington, 2009; Saavedra, Barquet, Rozenfeld, Forcellini, & Ometto, 2013; Sundin, 2004).

In the automotive manufacturing industry, the rising numbers of automobiles produced and sold every single year triggered a global concern over environmental issues, take-back obligation of used products and green consciousness on product recovery activities such as reusing, recycling and remanufacturing. European countries and several states of USA have stringent laws on the 3R activities stated on End-of-Life Vehicles (ELV) on take-back programmes at End-of Life (EOL) such as in Denmark, Germany, the Netherlands, Norway and Switzerland. In the Asian region, China and Malaysia are expanding knowledge and practice to 6R for remanufacturing

ELV as its new focus. China has become the largest vehicle market in the world, and it will retain that position for a long time. Recently, Malaysia together with their recycler's associated members such as Japan, New Zealand, Korea, and South Africa have been looking deeply to all 6R activities and have seriously considered to venture into the remanufacturing industry.

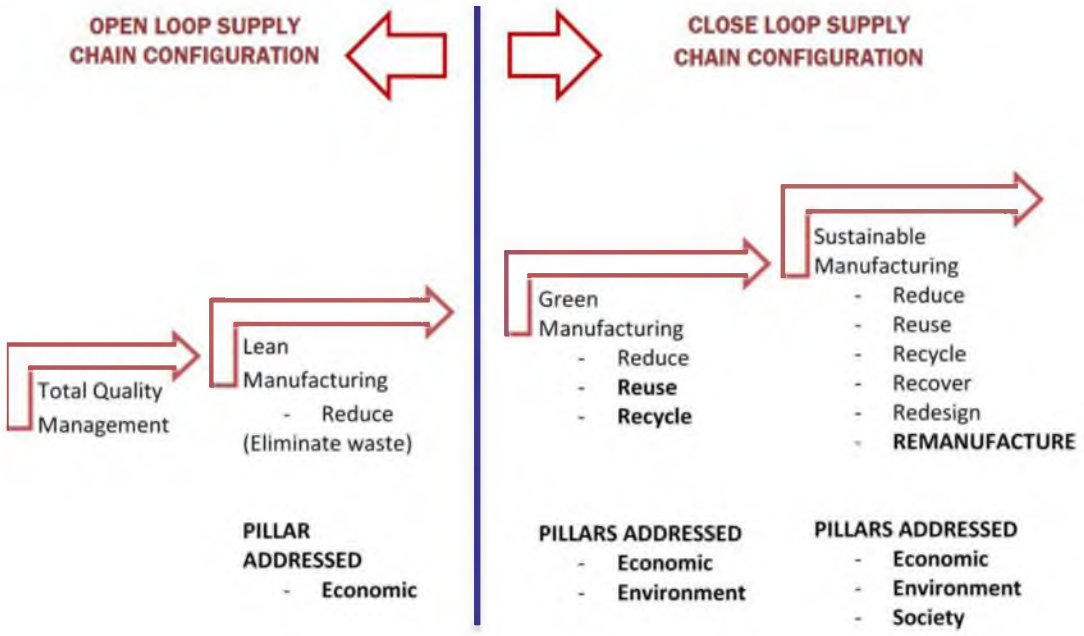

Figure 1.1 Evolution from Traditional and Sustainable Manufacturing (Duxes Reman Series, 2016; Jawahir & Dillon Jr., 2007)

Despite having two national car producers, PROTON and PERODUA, and a national motorcycle producer, MODENAS, Malaysia is a becoming hub for other makers to expand their business and production. Honda, Toyota, Naza and Inokom are among the vehicle-makers (passenger cars and commercial vehicles) with huge assembly plants in Malaysia that produce vehicles with lower costs in production. These local assembly units are marketing in Malaysia and delivering to the Asean region with very competitive prices. Significantly, semi knocked down (SKD) and complete knocked down (CKD) vehicle units are starting to increase in numbers. The

buying power of Malaysia's purchasing vehicles, especially international cars, has steeply increased with the existence of these brands and types.

The Malaysian Automotive Association (MAA) reported that the number of registered vehicles in Malaysia is 576,635 units in 2017 and has very significantly increased in 10 years between 2007 and 2016 by 16.02%. To hypothesise, the rise of vehicle sales may also increase the number of vehicles scrapped. Furthermore, the volume of total passenger cars and commercial vehicles produced and assembled in Malaysia has increased year by year (Yusop, Wahab, & Saibani, 2016) and increasing to current years as shown in Table 1.1. Current ELV practices are more focused on reusing and recycling ELV components to support recovery activities. The 3Rs initiatives are aimed at supporting the maximum use of reusable components and improvement of material recycling. However the safety and quality of reused parts and components are uncertain and has given no warranty.

Table 1.1 Total Industry Volume 2018 versus 2017 (MAA, 2018)

Segment	2018	2017	Unit Variance
Passenger Vehicles	523,000	514,679	8,321
Commercial Vehicles	62,000	61,956	44

Source: http://www.maa.org.my/pdf/Market_Review_First_Half_2018.pdf

On the other hand, Malaysia has shown much interest on buying reconditioned and refurbished vehicles imported from developed countries. This is another issue in bringing reconditioned vehicles into the second-hand market. These types of vehicles will go to local workshops for service and repair because the authorized dealers usually do not entertain reconditioned or refurbished vehicles in the market. The current situation promotes reusing imported vehicles' components in the market due to demand from customers. In addition, imitation parts and components entering the Malaysian automotive market without any fear in the black market would offer lower

prices. Surprisingly, new imitation parts are the cheapest in price compared to original reused parts. The quality of original parts is everlasting, whether new or used, without compromise as stressed by the General Motor (GM) Company.

Through outlooks and responses taken from various stakeholders, a new National Automotive Policy was presented in 2014. The development of NAP 2014 (Ministry of International Trade and Industry, 2014) had taken many engagements from various stakeholders to benefit the automotive industry as a whole. It focused on structural issues affecting the domestic automotive industry and outlined measures to meet global quality, cost and delivery requirements. Besides that, to align with United Nation's safety regulations of vehicles, it looks at issues affecting consumers and puts forth mechanisms as the following:

i. To promote a competitive and sustainable domestic automotive industry including national automotive companies;
ii. To make Malaysia the regional automotive hub in energy-efficient vehicles (EEV);
iii. To promote an increase in value-added activities in a sustainable manner;
iv. To promote an increase in the exports of vehicles and automotive components;
v. To promote participation of Bumiputera companies in the total value chain of the domestic automotive industry; and
vi. To safeguard consumers' interest by offering safer and better quality products at competitive prices.

The NAP 2014 objectives are supported by six roadmaps and action plans. It serves as the guideline in transforming the local automotive industry. The following are the NAP 2014 roadmaps:

i. Malaysia Automotive Technology Roadmap (MATR);
ii. Malaysia Automotive Supply Chain Development Roadmap;
iii. Malaysia Automotive Human Capital Development Roadmap;

iv. Malaysia Automotive Remanufacturing Roadmap;

v. Development of Automotive Authorized Treatment Facilities (ATF) Framework; and

vi. Malaysia Automotive Bumiputera Development Roadmap.

Item no. (iv) listed among all the roadmaps is the major concern for this research. There is an urgency that remanufactured vehicles parts and components should take place over reused, reconditioned or refurbished products to achieve the ultimate success of ELV in order to sustain a longer life-span. This will eventually abolish the grey market and black-market goods or competition of grey market with the remanufactured goods (Ijomah, McMahon, Hammond, & Newman, 2007). However, according to APEC (2015) Malaysia, there is no specific regulation on remanufacturing goods. For the Malaysian automotive industry itself, there are no standards for remanufacturing components or imported or exported parts.

1.2 Problem Statement

Sustainable and greening concepts are a relatively slow-growing industry in Malaysia, especially in remanufacturing vehicle components. Reusing automotive goods face problems with the environmental, safety and quality issue and here comes remanufacturing offering better standard as the safety is tested and quality is guaranteed. At the same time, it will reduce environmental issues on recycling. Realising Malaysia is one of dumping fills of second-hand parts and reconditioned vehicles from developed countries, turning the imported second-hand goods as cores to be remanufactured is an advantage to establish remanufacturing industry.

The interaction on aftermarket management between the OEM, recycler and independent remanufacturer on remanufacturing industry in Malaysia has yet to be established. The recycler, parts dealer or even workshop foreman are often confused between reusing, reconditioning, refurbishing or remanufacturing parts and components, and even the consumer does not acknowledge those criteria. Affirmative

practices in order to certify the quality of second-hand goods at the premium level is also not a concern. To date, the Malaysian Automotive Institute (MARI) supported by the Ministry of International Trade Industry (MITI) are working to align regulatory and business practices to boost the remanufacturing industry in Malaysia as highlighted in the fourth roadmap under NAP 2014. Reusing, recycling and remanufacturing practices to the current ELV practices should be clearly distinguished in order to certify a premium in remanufacturing goods.

Overall, the euphoria of bringing back goods into remanufactured parts and components has led to problems with warranty issuances, where remanufacturers usually do not give warranty to the remanufactured component as they would with the first OEM components. This drawback brings about a low acceptance of remanufactured products, with customers having a sceptical attitude about buying these products and remain doubtful of their quality (Saavedra et al., 2013; Yusop et al., 2016). Prior to this, remanufactured components must be certified in order to get the consumer's attention and acceptance. Product attributes that reflect the remanufacturing of automotive parts and components is the concern here. Identified factors and items underlying under each process will help aftermarket industrial practitioners to bring out a premium quality of remanufactured products to function at par to the new one.

According to APEC (2015) there is no specific regulation on remanufactured goods in Malaysia, and for the automotive industry itself as whole, there are no standards for remanufacturing imported or exported components or parts. Knowing Malaysia is a developing country which imports tons of second-hand goods inclusive of black market goods entering the country without any barriers, establishing a remanufacturing industry is thus a wise action. These circumstances need very clear guidelines in order to establish the remanufacturing industry and ensure valued output as the premier one. Output from various stakeholders in the aftermarket industry is very important to achieve the goals concerning the welfare for every stakeholder. The

perception from industrial practitioners, authorized agencies and research associates with the remanufacturing industry and products' quality is thus significant.

Reviewing on work done from previous study shown nothing much on remanufacturing except on the supply chain, process and decision making to remanufacture in very huge scope of remanufacturing industry (from IT, Electronic, Automotive and etc). In automotive, most developed framework on ELV are directed on achieving zero wastage in recycling framework and every single counties are establishing own framework to suit their ELV environment. This study stepped forward a pace on digging into automotive remanufacturing criteria in term of quality of remanufactured components/ parts as to bring out reuse goods to be in ultimate form (remanufactured).

In conclusion, the establishment of a remanufacturing quality practices framework for certifying remanufactured products is very significant and will motivate automotive recyclers to upgrade their grey market of reused parts and components as certified goods and to secure the safety of prolonging the life cycle of parts/components. The establishment of remanufacturing quality practices framework which complies with the needs of the current situation of aftermarket practices in Malaysia is aligned with the fourth roadmap under NAP 2014 where the idea is to make Malaysia the centre of automotive remanufacturing for South East Asia (APEC, 2015).

1.3 Research Questions

A study that can enhance the effectiveness of the ELV's reusable goods through remanufacturing practices should implemented to reinforce the premium quality of second-hand parts for local and imported parts/ components. Based on the current situation, the remanufacturing quality criteria that are required to ensure the quality and safety of second-hand parts/ components that are feasible for the establishment of the automotive remanufacturing industry, especially in Malaysia, has been identified by this study through the following questions:

i. What are the existing practices of reused and remanufactured parts of automotive parts/components in Malaysia being addressed, whilst ensuring quality and safety factors?

ii. What would be the factors affecting the remanufacturing quality and safety of automotive parts/components and what are the key elements underlying each factor for the composition of the remanufacturing quality practices framework?

iii. How can the factors and items be confirmed as significant to represent the automotive remanufacturing industry?

iv. What would be the best composition for the remanufacturing quality practices framework to ensure the best remanufacturing automotive part/components practice in Malaysia?

1.4 Research Objectives

The objectives of the research are:

(a) To clarify the current practices of reused and remanufactured automotive in bringing quality and safety to ELV components/ parts.

(b) To examine the factors and items on performing qualified remanufacturing components on quality (warranty) and safety (guarantee).

(c) To establish the factors and items required to construct a remanufacturing quality practices framework for ELV components.

(d) To develop a remanufacturing quality practices framework for ELV components in Malaysia.

1.5 Scope

To conduct this research, the perspective of remanufacturing quality on any mechanical part of most automotive industries (passenger vehicle and commercial vehicles) must be considered. The focus is on components or parts (called core) that have reached end-of-life to be remediated and the remanufactured cores are endorsed to be certified for quality and safety. Remanufacturing experts from three remanufacturing sectors which coordinate with each other and reliable for research purpose is identified. The three sectors are most dealing with mechanically operated moving components and parts. There are from automotive, industrial machinery and marine sectors. Table 1.2 is the illustration of research scope under this study.

Table 1.2 Research Scope

End-of-Life sustainability procedures	Remanufacturing definition	Malaysia remanufacturing sectors to be focused	Expert feedback associated with aftermarket
Remanufacture	Warranty same as OEM	Automotive and Heavy Duty/ Off Road Vehicles	Legislators
	Function as good as new.	Industrial Machinery and Equipment	Remanufacturing Experts
		Marine Equipment	Remanufacturing Researchers
			Recycler Association Members

1.6 Significance of Research

The research of remanufacturing in sustainable manufacturing is to prolonged the life span of automotive components or parts of in reliable form with affirmative quality condition. The project's goal in this research is develop a Remanufacturing Quality Practices Framework factors and items that importance to achieve the ultimate form of remanufacturing quality in focusing of mechanically operated automotive goods. The framework could help practitioners, researchers, legislator or any entity in automotive sectors to get a benchmark of criteria of the important remanufacturing factors and items in order to make a distinction from the form of reusing and recycling. The chaos of end-of-life vehicle secondhand goods (cores) in term of reuse, recycle or remanufacture entering new life cycle is preset under remanufacturing.

1.7 The Thesis Structures

The research is enclosed within 7 chapters in this thesis. At first, the Introduction chapter explain how this research emerge begin with research background, problem statement, research questions, research objectives, scope, significance of research, the thesis structure and challenge embedded in research. It is followed by Chapter 2 that contains literature review of theory, concept, and industrial practices. It explains the concept of sustainability and greening concept in Manufacturing, remanufacturing policy and standard, review the current ELV recovery practices, review of remanufacturing industry, and the modelling the quality remanufacturing framework. The Chapter 3 is Methodology of research which comprised with method structure and justification, data collection, measurement and scaling, data analysis using Exploratory Mixed-method Design, validation of framework, analytical hierarchy approach, summary of RQPF development, and benefits of study.

The next chapter is the beginning of preliminary Development of Remanufactured Quality Framework and The Elements. In this Chapter 4, the process

of selecting the elements (factors and items) for the RQPF is explained. Through qualitative methods of literature study, field work activities, interview and focus group discussion, the primary dimensions consist of factors and items that might significant on certifying remanufactured components and parts was finalized. This followed with the process of establishing the factors and items for the RQPF which explained in Chapter 5 under topic Result and Analysis. Under this topic result from questionnaire is used on completing the statistical analysis for data reduction, exploratory factor analysis (EFA) for exploring the underlying theoretical structure of each dimension and confirmatory factor analysis (CFA) for whole model-fitting of the RQPF. Finally the importance of factors and items is ranked using priority ranking process by analytical hierarchy process (AHP).

In Chapter 6, the findings of this research is discussed accordingly with some review of achievement and limitations of the research. Finally, Chapter 7 concludes the research, listed the contribution of the research and provides some recommendations for future research.

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