

QUALITY ASSURANCE OF REMANUFACTURED COMPONENTS OF END-OF-LIFE VEHICLE: A LITERATURE REVIEW.

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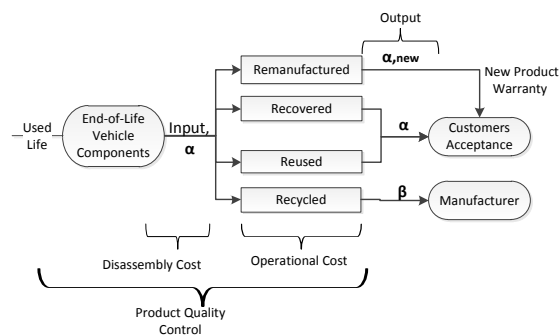
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Graphical abstract



Abstract

This objective of this work is to investigate the quality assurance of remanufactured ELV components by distinguished with other sustainable manufacturing stakeholders, 6Rs. The study is focused on developing countries such as China, India, Malaysia, and Brazil as the authors determine whether remanufactured ELV components are significant to the respective countries. Implications of this study are the three remanufacturing research areas classified and discussed: Remanufacturing Process, Remanufacturing Supply Chain, and Sustainable Remanufacturing Industry. The most significant findings in this study classified quality of remanufactured ELV components in terms of quality assurance and quality after business.

Keywords: remanufacturing, end-of-life vehicle, quality assurance, developing country

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1.0 INTRODUCTION

In recent decades, sustainability and greening concept has been the most interesting research area for End-of-Life vehicles (ELV) all over the world. Interest in End-of-Life Vehicles started for the past two decades by developed countries such as in Europe and United States. Started from 3Rs concept to 6Rs concept in product life cycle, End-of-Life (EOL) activities becomes more interesting when it comes to the ultimate 6Rs stakeholder which is remanufacturing. Remanufacturing processes are like giving new life to ELV components.

Remanufacturing is always hardly distinguished from recovering activities such as reconditioning and refurbishing. A clear processes and framework have to be done in order to establish remanufacturing activities to quantify the reliability, quality and safety standard are at par with the Original Equipment Manufacturer (OEM) components.

As we realized through recycling, reusing, recovering and remanufacturing activities are highly promoted in order to achieve a sustainable industry and

preserved of environment for next generation. However, literature reviews have indicated that there were no significant criteria presented among the sustainable manufacturing stakeholders in term of quality. This study is reviewed and focused the area should be tackled in order to present remanufacturing quality is differ from other stakeholders.

Consequently, after study is carried out a clear remanufacturing overview also presented to expedite remanufacturing research for further discussion.

2.0 END-OF-LIFE VEHICLES ACTIVITIES

2.1 Developed Countries vs. Developing Countries

The necessity of remanufacturing passenger cars or other vehicles may not be too significant to a developed country because reconditioned vehicles and reused parts are marketable as second-hand

goods in other countries, specifically among most developing countries. Most developed countries are trying to get rid of vehicle scrap to comply with legislation and regulations.

There is high demand of used cars from Japan, including older models with low mileage that represent good value in developing nations [1]. Same goes to others developed country such as Europe and the United States. This might be the biggest reason why developed countries did not carry extensive study on remanufacturing activities because most of second-hand cars or parts being exported overseas.

According to [2], in importing countries, the vehicle pricing structure is likely to create a relatively low cost of second-hand vehicle use and strengthen incentives to demand second-hand vehicles from other countries. This vehicle price structure is defined by the low or non-existent safety, environmental and fuel regulations. This scenario goes for second-hand imported vehicle component in Malaysia. If consumers face no regulations, they have no reason to spend extra money to acquire a component that meets minimum quality standards. Instead, consumers can freely choose among all the available options such as reused parts and imitation parts disregarding the reliability of products assurance. In addition, many broken and unwanted vehicles are abandoned all around the country with no further action, proving the necessity on conducting remanufacturing research to another level. [3] listed five barriers for the success of China agenda for ELV recycling: i) Imperfect legal system; ii) Incomplete recycling system; iii) A few numbers of small remanufacturers; iv) Backward remanufacturing technologies; and iv) Consumption attitude. By far, developing countries like Malaysia are facing the same problems as China on handling these issues.

According to Asia-Pacific Economic Cooperation (APEC) Malaysia does not have specific regulation on remanufactured goods and same import term is charged on remanufactured and new products. Under the Malaysian tariff classification, there are no specific tariff lines for the importation of remanufactured/used products. They share the same tariff as new products, except for a few products such as used tires and motor vehicles. This has been supported by a survey done by [4] in which End-of-Life Vehicle Management in Malaysia still under study and not yet established.

3.0 6R STAKEHOLDERS VALUE THROUGH END-OF-LIFE

For more recent sustainable manufacturing, 6R concept has formed the basis for sustainable manufacturing categorized by reduce, reuse, recycle, recover, redesign and remanufacture which classified as the key ingredient of the material flow in product life-cycle [5]. Sustainable manufacturing is

the latest era in manufacturing industry after traditional, lean and green manufacturing, where it countered the economic issue, environment issue and social welfare. There is misconception between sustainability and green manufacturing. Both are direct to a better ecological environment, but social welfare and economic issues are two additional key points in terms of sustainability.

The 6R name was inspired by work done at Center for Sustainable Manufacturing, University of Kentucky in United State. The institution has performed research and conducted many events for promoting sustainability to be applied in manufacturing industries. The Sustainability concept is held within three pillars; economic, environment, and social. None of the pillars should be missed in applying the sustainability concept and here where many misconceptions happened in some studies. Being green is not sustainable enough. Sustainability scope is huge enough to explore from the beginning of pre-processing the material until post-used. 6Rs Manufacturing can be thought of as an environmentally benign, closed-loop manufacturing system that creates durable goods without negatively impacting the environment. Generally, the 6Rs supply product line is applicable to many industries, especially the automotive industry, and has the potential to be implemented effectively by many entities.

Reduce;

Reducing or preventing of hazardous materials being discharged to the environment.

Reuse;

Reusing components or parts without going any technical or recondition processes.

Recycle;

Deal with the recycling materials at the EOL into new raw material for new product development.

Recover;

In depth, authors agree on setting conditions for parts that are reconditioned, refurbished, repaired, replaced, or even painted. After the recovery process, components are free to be used without warranty. Recovering processes restore components to working order.

Redesign;

Act of redesigning products to simplify future post-use processes through the application of techniques to make products more sustainable.

Remanufacture;

A process of recapturing the value-added to the material/ component when a product was first manufactured, to at least OEM original performance specification and warranty with lower resell value. Remanufacturing is part of product sustainability components. It may be concluded that there are six

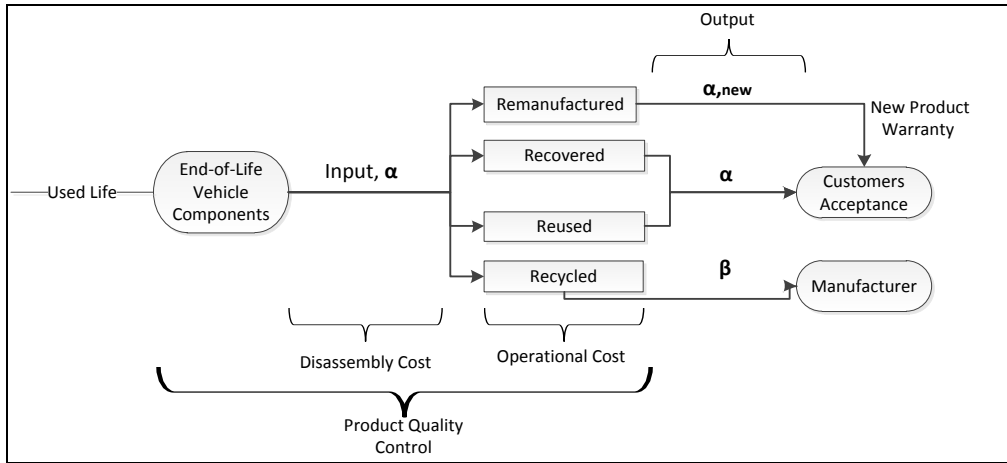


Figure 1 Overview on Stakeholders of End-of-Life Vehicle Components Endeavor.

elements affecting product sustainability, one of which is recyclability/remanufacturability [6];

- i) Environmental impact
- ii) Function
- iii) Resources utilization and economy
- iv) Manufacturability
- v) Recyclability/ Remanufacturability

After all components are discussed, it may be concluded that reuse, recycling, recovering, and remanufacturing play important roles for end-of-life vehicle components strategies per Figure 1. As shown, the output (α , α_{new}) of three stakeholders which is reuse, recover and remanufacture is same as input, α component. Detailing of each processes under each stakeholder and warranty given will distinguished them. Due to intensive remanufacturing, operational flow remanufacturing is promoted on prolonged components life span as the quality of remanufactured components is tested as described in Figure 2.

3.1 Remanufacturing Process Chain

The product recycling also called remanufacturing or refurbishing has the aim to refabricate used products (cores) to a like new condition to give them a further life cycle [7]. This is a common misconception in defining remanufacturing and other recovering elements such as reconditioning and refurbishing. The term remanufacturing cannot be associated with a complete vehicle. It is hardly possible to remanufacture a whole vehicle as a unit, but to remanufacture a single automotive product or component is promising. That is why recovering activities such as reconditioned and refurbished are more suitable in defining imported second-hand vehicles which have undergone specified checking and recovering processes. The execution modes of remanufacturing techniques are including replacement, repair, refurbish and reconditioned which are parts of remanufacturing conditions. Remanufacturing required more work and intensive

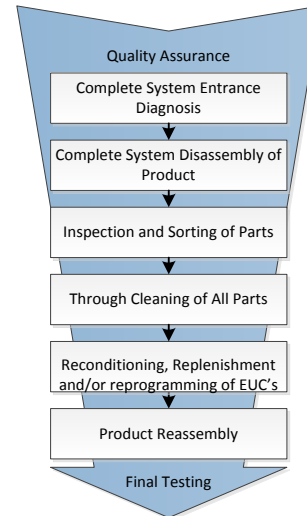


Figure 2 Remanufacturing Process Chain of Mechatronic System [7]

testing. Referring to Figure 2 from [7] and [10], processes of remanufacture ELV components are described in the following steps; complete product entrance diagnosis, total disassembly of the product, parts cleaning, inspection and storage of parts, recovering processes, reassembly of the product and final testing.

To conclude, remanufacturing is the ultimate stakeholder value in end-of-life vehicle processes and is affirmative (not at par) with other execution modes. That is why remanufacturing brought recovered activities to the highest level which at par to the OEM products standard where quality of remanufactured components should be guaranteed and certified. This is where legislation is needed for certifying the remanufactured components or products. Certified remanufactured components are reliable and safe for use regardless of component history.

4.0 OVERVIEW OF REMANUFACTURING RESEARCH AREA IN DEVELOPING COUNTRIES

Presented here are the three main research areas in remanufacturing to be established in the case of remanufactured ELV components: i) Remanufacturing Processes; ii) Remanufacturing Supply Chain; and iii) Sustainable Remanufacturing Industry. Once all the three criteria are established, the remanufacturing industry will become a larger consumer resource, and their existence will bring a new grown and green industry to nations.

4.1 Remanufacturing Processes

Figure 2 shows that quality assurance of remanufacturing products is defined by the process flow of total processes from used components entrance to final testing procedure. It is clearly defined in that remanufacturing requires completing total processes to meet the requirements of remanufactured components. A survey done by [11] has indicated that the remanufacturing process may give some impact towards the level of quality assurance of the part itself. In this case, the author assumed that the quality of remanufactured component is reset to nil because the component goes to the stage of remanufacturing process, which can be classified as production of product or component.

To distinguish and give more value to remanufactured products, a quality trademark is very significant to distinguish between remanufactured or recovered products based on processes and testing done. The research to date has tended to supply proof in terms of economical remanufacturing processes regardless of quality verification.

4.2 Remanufacturing Supply Chain

In a study by [8], in order to provide reliable remanufacturing service, the case company already set up three remanufacturing plants so far, located in China, Japan, and Singapore, to cover demand in Asia. It was demonstrated by [8] that remanufactured products are accepted by consumer and the demand are getting higher because the price and reliability. However the management and supply chain in remanufacturing products are hardly able to meet the demand. One of the key challenges is effective management of used products or components within reverse logistics [12] which interferes with the production run of dismantlers, remanufacturers, or suppliers who have to depend on outside brokers for their supply of used products or components [10].

According to [8] three ideas of remanufacturing supply chain are presented: i) remanufacturing is not an isolated process and an integrated approach is

necessary to be implemented; ii) the remanufacturers are encouraged to charge at different rates according to the services provided; and iii) a decision support system can also contribute to promote improved sustainability for the company or the supply chain, based upon remanufacturing defective products for service and aftermarket parts. These findings are supported by [12], who concluded that the uncertainty in used components and products availability can negatively impact the aftermarket business if it is discovered during the implementation phase that cores are unavailable for parts with high volume demand.

In a larger scope, remanufacturing supply chain in Malaysia will involve not only dismantlers, remanufacturers, or suppliers but other entities such as OEM, local workshops, service centers, government bodies and also consumers. How components are to be conveyed in an integrated manner is essential to determine.

4.3 Sustainable Remanufacturing Industry

From the literature, the authors propose six key factors to establish a Sustainable Remanufacturing Industry:

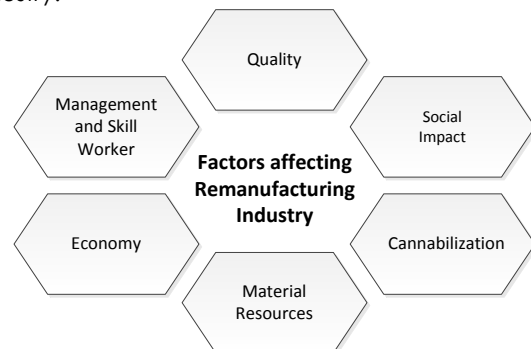


Figure 3 Important components highlighted to set up a remanufacturing industry in Malaysia.

4.3.1 Quality;

Expectations for the remanufacturing business need to be closer to the definition. One of the most significant criteria in remanufacturing is quality, in terms of quality assurance and quality after business. Quality assurance is for certified remanufacturing components, as reliable output is the same as new OEM components. The remanufacturing process is a crucial area to be researched. In the meanwhile, quality after business ensures that the remanufacturing industry is a sustainable industry to be developed for the future because only with great quality offered a business will be sustain for a long run. A survey done by [13] referring to the Malaysian environment found that different levels of complexity for the demands and preference by each customer, along with uncertainties about the quality of any remanufactured products and their output yields, are among the variables that need to be taken into account.

4.3.2 Social Impact;

Design for remanufacture of both product strategy and detailed product design can lead to reduced carbon emissions and secure, skilled employment [14]. There are many studies regarding impact of sustainability and greening technology to nations which make these areas so significant to be established at early design stage or at the end-of-life especially focused on environment, safety, and health.

Another significant finding by [14] is skilled employment. The finding is consistent with one of Malaysia Automotive Recyclers Association (MAARA) points to secure the Malaysian local workshop business and other players, with Malaysia developing the National Automotive Policy 2009 and 2014. MAARA countered NAP 2009 with an argument that prohibiting used parts worsens the welfare of the industry players and consumers. One of the actions should be taken is gradually phase-out used components and offered remanufactured parts to the industry.

4.3.3 Cannibalization;

Even if remanufacturing is independently profitable, OEMs may still ignore this option due to concerns about the cannibalization of higher-margin new product sales [15]. OEM commitment and responsibility for sustainability applications is contributing a huge help. The entire components specification form original manufacturer is the material need for a remanufacturer. No interaction between OEM and independent remanufacturer is something can be working out in the future; this is where legislation and government entities act as bigger role play. OEM should not take remanufactured components as a rival to the new OEM's. The imitation components in the black market are the biggest thing to be resolved as Malaysian are offered with these types of components with questionable safety and quality.

4.3.4 Material Resources;

It can be argued that for the regenerated materials and parts, they might be sent to other manufacturers or material collectors as secondary materials for their manufacturing purposes [16] as they are going through the open loop system in which parts are disposed in landfills. Hence, products or components might not be reverted to their point of origin, but may be reverted to any point of recovery under EOL close loop system. Nevertheless, a continuous supply of used parts needs to be established because the remanufacturing business needs to keep running to fulfill demands while and the history of used components need to be identified as parameters in a check list before undergo remanufacturing processes.

As the remanufacturing technology becomes more sophisticated, a single remanufacturing plant is not capable to encompass all the technologies. Each plant has its own remanufacturing rate to produce the remanufactured products. Some large incorporated companies may have difficulties in

distributing the accepted orders to the subsidiary plants, because of resource constraints [8]. Establishment of quantities of used components or products in a scheduled manner might be a challenge for this business to meet demand.

4.3.5 Economy;

As pointed out, remanufacturing industry offers a quality product with lower cost and creating a new industry for society, which is the remanufacturing industry itself. To bear in mind, everything comes with a cost. The head cost to establish and set up a real remanufacturing plant and develop skilled workers is very costly. Remanufacturing processes, logistics, and legislation are still misrepresented. Many researchers are working on this to provide beneficial findings to sustain the development of remanufacturing industry itself, to allow for a lower cost of remanufactured product.

4.3.6 Management and Skill Worker;

By referring to [17], [18], [19] certain the issue of management and technical feasibility are most drawback in running a remanufacturing plant. As [3] concluded, backward remanufacturing technologies is one of the barrier bringing success to China recycling industry. Even Malaysia Automotive Institute realizes about this issue and they planned to develop remanufacturing skill worker in

It was found that all the six factors affecting remanufacturing industry are coupled with the need of regulations/legislations to the industry and consumer acceptance. In developed countries, used components have good demand, which is the best argument why remanufacturing industry need to be established with support from industry players and government entities. This will result in bringing up Malaysia to another level as a sustainable region.

4.4 Summary

Malaysia has high potential to be a remanufacturing hub because Malaysia imports reused cars from many developed countries, which are then reconditioned and refurbished before entering the Malaysian market. However, to keep a business running in the long run, good quality products of remanufacturing industry must be proven and sustained. Together with that, awareness of the importance of safety and road issues has to be spread to consumers in order to make this remanufactured product getting more demand on market. Eventually, imitations and uncertified components or parts will be phase out from the market later on.

5.0 DISCUSSION

One of the most significant findings in this study is in terms of quality; quality assurance and quality after business. Quality assurance is to certify remanufacturing component as reliable output as

OEM new components, while the remanufacturing process is a crucial area to be researched. In the meanwhile, quality after business ensures remanufacturing industry is a sustainable industry to be developed for the future, because only with great quality component offers can business be sustained in the long run. Both of these issues need a legal authority to play part. Policy and legislation are needed to developing and established remanufacturing industry of ELV components especially in Malaysia.

Studies show that the public and even researchers are confused concerning reuse, recycling, recovering, and remanufacturing of vehicle components. The results of proper work flow make it clear once again: remanufacturing genuine component is reliable and safe. The idea is to make only genuine OEM component and remanufacturing OEM component used in a vehicle. Besides OEM components, a good quality of remanufactured component is the best offer to consumer due to price mark down. Quality assurance of remanufacturing components is assured by establishing proper processes from the ELV components spanning from the disassembly process until final testing is completed. More studies are required to identify the remanufacturing, recovering, recycling and reuse processes in more detail to make ELV component classified under the appropriate term and condition for better understanding as supported by [16].

This study indicates that aftermarket services for remanufactured component are a must for consumers because remanufactured components are issued a warranty just like OEM components at the first place. This study has gone some way towards enhancing our understanding to urge remanufactured components endorsed with a quality certification or benchmark.

6.0 CONCLUSION AND FUTURE RESEARCH

This study set out to determine that recovering processes such as reconditioning, refurbishing, repairing and repainting are part of remanufacturing procedures. Through the complete remanufacturing processes, the reliability and safety of used ELV components may be enhanced. Once processes are endorsed, the quality of remanufactured components are certified to meet minimum quality standard as same as OEM requirement. Quality assurance for remanufactured components refers to the remanufacturing processes carried out from the beginning of used products or components entrance diagnosis to the final testing. Considerably more work will need to be done to determine quality of remanufactured components by either quantitative or qualitative verification.

Implications of the findings indicate that further research should be undertaken in the following areas: remanufacturing processes' quality, reliability, and safety; remanufacturing supply chain definitions in terms of uncertainty about used components and products

availability; and sustainable remanufacturing establishing and catering to aftermarket business issues.

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