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Development Of A Product Remanufacturing Assessment Tool Based On Part Attributes And Features

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Abstract: Automotive waste is one of the main problems that can be found in waste management especially in developing countries. The purpose of this study is to evaluate the factors and criteria that influence remanufacturing process and to build an assessment tool that can provide a performance index for automotive parts to undergo the remanufacturing process. Analytic Hierarchy Process (AHP) was used in this study in data collection and analyzing data. A questionnaire was produced by three main factors and fifteen sub-criteria criteria, which were subsequently prioritized using the AHP technique. Fourteen participants were involved in answering the questionnaire to evaluate the importance level between all the factors. The participants involved are engineers and academicians. The result finds out that Product development factors gain the highest weightage score which is 0.770, followed by External factors with a score of 0.127 and Internal Factors got the lowest weightage score which is 0.103. Then, the data from the analysis will be used to developed an assessment tool. The assessment tool was validated by three academicians and the tools were found helpful and acceptable. The tools might be used for remanufacturing industries to be used as a guideline to evaluate the automotive parts before undergoing remanufacturing process and improve the remanufacturing process.

Keywords: Remanufacturing, Analytic Hierarch Process, Automotive

1. Introduction

These days, end-of-life items may be returned to their original form through remanufacturing process. The current industry aims at protecting and greening the environment, promoting and recycling economy, saving and making full use of energy [1]. Remanufacturing process able to changes the product to their original state with less energy use and can minimize the waste of the material. The other names for remanufactured products also known as refurbished, reconditioned and recertified [2]. The introduction should describe general information on the subject matter area of study. It is usually arranged in such a manner to gradually bring to focus the specific motivations of the current study, the research questions, the problem statements, the hypotheses, the objectives, as well as the expected outcome.

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Although remanufacturing is not a new concept or strategy to enhance the product to be returned for remanufacturing purposes, but at most of the time manufacturers or industry practitioner still facing the difficulty to decide whether a product is suitable for remanufacturing. This scenario raised because , there are lack of assessment to assist and help the practitioners in remanufacturing decision making. For that reason, this study is needed objectives is to develop an assessment tool to evaluate automotive products for remanufacturing purposes.

2. Material and Methods

2.1 Definition of Remanufacturing

Remanufacturing is an industrial process that applies to use product to make it return to like new or better performance product [3]. Moreover, Remanufacturing is also known as the procedure that brings end of life products return to good as new products [4]. The increasing of end of life products will become waste and the products come with many bad effects. With remanufacturing, the end of like products can return into new products with the same quality, functionality and warranty [5]. Remanufacturing is an industrial process turning used products into a condition of like new or better [6]. Table 1 below shows the summary of definition of remanufacturing.

Table 1: Summary of definition of remanufacturing

Definition of Remanufacturing	Author
• Process of bringing end-of-life products back to good-as-new	[7]
• Series of manufacturing steps applied to an end-of-use part or product in order to return it to like-new or better performance, with warranty to match. Remanufacturing challenges and possible lean improvements	[3]
• Industrial process turning used products into a condition of like new or better.	[6]
• Industrial process that turns used products into products with the same quality, functionality and warranty as new products.	[5]

2.2 Industry that practicing Remanufacturing

In the last decade, industrial actors, policymakers and researchers shows increasing in amount for the sustainable management of waste (Adamo & Rosa, 2016)[7]. Remanufacturing became an important component in many sectors such as automotive, communication, aerospace, medical equipment's, and many more sectors. Remanufacturing also involving in the different product such as machinery, photocopies, automobile parts, single-use cameras and furniture (Matsumoto et al., 2016) [5].Not all products can undergo remanufacturing process due to short of technological. Table 2.3 below shows the products successfully remanufactured classified by field of activities.

2.3 Factors to influence in Remanufacturing

In product remanufacturing, understanding the criteria or factors that influence remanufacturing actitivires are important. According to [8], there are 3 technical factors to succeed high quality of remanufacturing products which are design requirement, material and damage. In design aspect, the used products need to meet design requirements to make sure the products have capabilities to do remanufacturing reconditioning process. As for the material aspect, the used products needs to be analyzed first to make a high quality of remanufacturing products. Lastly, the level of damage of the material also needs to examine to ensure the capabilities of the material to do the remanufacturing process.

According to [9], there are two types of factors that need to be fulfilled before running remanufacturing process which is essential factors and supportive factors. Essential factors is a factor that must be accomplished to allow remanufacturing process running. There are 4 essential factors which is remanufacturing process and technology, labor skill and availability, facilities of remanufacturing and core acquisition and reverse logistics. While supportive factors is a factor that may boost the remanufacturing efficiency and system's capabilities but this factors is not essential for the running of remanufacturing process. There are 5 supportive factors which is remanufacturing market knowledge, organization, planning and control, remanufacturing process improvements, design for remanufacturing and information feedback.

China is one of the countries that actively in remanufacturing activities. Because of that, there are some factors that needed to fulfil to achieve and improve the remanufacturing process in China. According to [10], there are two types of factors that will improve the remanufacturing activities in china which are external factors and internal factors. The external factor consists of completed legislation system, policy guidance, OEMs information sharing, Sustainability and growth public awareness while internal factors consists of advanced remanufacturing technology and quality management of remanufactured products. To achieve all of this factors, government, OEMs, remanufacturers, consumers and other stakeholders need to involve. Government may legislate about policies to toughen the public awareness about remanufacturing and to control the activities and action about remanufacturing stakeholders. Remanufacturers also should use the modern and new remanufacturing technologies to promote resource conservation and to improve the quality of product.

In a study done by [11], there are major and minor factors that influence the remanufacturing process. The minor factors are green benefits and production planning and control while the major factor are consumer acceptance, return tendency and government regulations and incentives. Government should take part by form policies about sustainable technologies and should offer incentives to the organizations that interested in remanufacturing activities. Government and non-government organizations (NGO) also must inspire and encourage consumers to buy remanufactured products by make advertisement about green environment to increase the awareness about environment among consumers. Table 2 below shows the summary of factors influence in remanufacturing.

Table 2: Summary of factors influence in remanufacturing

Group	FACTORS	Author
• Material	• Design requirement	[8]
	• Type of material of used parts	
	• Condition of used parts	

• Machine and labor	• **Essential factors** ➢ Remanufacturing process and technology ➢ Labor skill and availability ➢ Facilities of remanufacturing ➢ Core acquisition and reverse logistics • **Supportive factors** ➢ Remanufacturing market knowledge ➢ Organization, planning and control ➢ Remanufacturing process improvements ➢ Design for remanufacturing ➢ Information feedback	[9]
• Law Regulations and technology	• External factors ➢ Policy guidance ➢ Completed legislation system ➢ OEMs information sharing • Internal factors ➢ Advanced remanufacturing technology ➢ Quality management of remanufactured products	[10]
• Market demand	• Major factors ➢ Consumer acceptance ➢ Return tendency ➢ Government regulations and incentives • Minor factors ➢ Green benefits ➢ Production planning and control	[11]

3. Methodology

In this study, the info about remanufacturing were extracted from the past literatures, it followed by AHP approach for data collection and analysis purpose. Lastly, the findings from AHP were used for the assessment tool developments. The details of flow is shown in Figure 1 below.

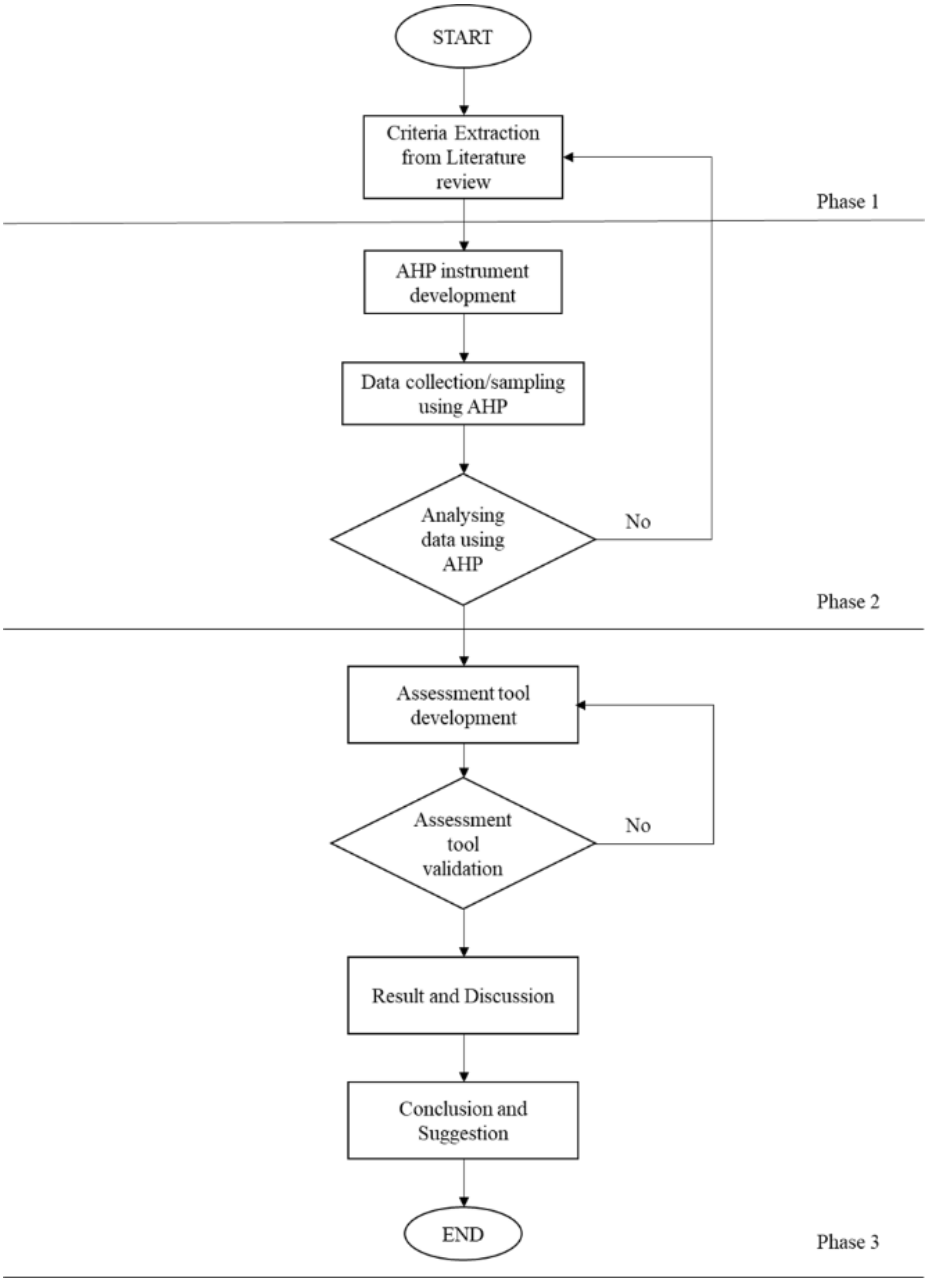

Figure 1: Research flow chart

3.1 AHP Framework and questionnaire design

AHP survey is used for data collection, particulatly the on the criteria extracted from the literature. The participant of this study are those selected respondents that fulfilled the criteria such as 5 years working experience, involve in remanufacturing industry/research and at least got a degree in engineering.

During the data collection, the criteria of remanufacturing were structured accourding to the the AHP framework. In the AHP framework (refere Figure 2), there are 5 main factors which are product development, external factors and internal factors. Besides that, there are total 15 sub-criteria which categories under the three main factors.

Pairwise comparisons was used in the AHP to combine all the criteria and mixed the result into a decision matrix. The analysis process was conducted before gained the final result. The analysis was done using Expert Choice software. The software able to produce the value of weightage for all the

factors including main factors and sub-criteria and consistency ratio of the pairwise judgments. The consistency ratio must be less than 0.1 to make the data acceptable.

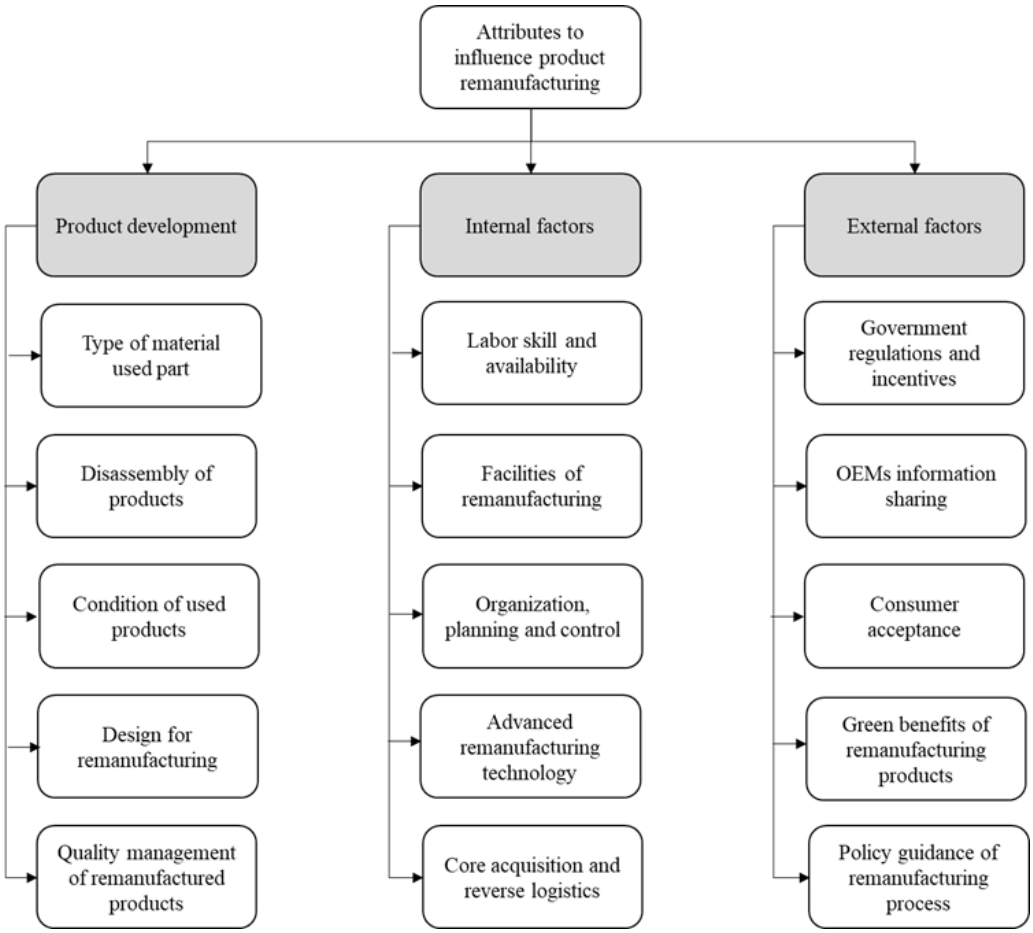

Figure 2: Hierarchy structure framework

3.2 Assessment tool development

After the result was obtained after AHP analysis, an assessment tool was developed using Microsoft Excel. The weightage value for each factor and sub-criteria was used to build the assessment tools. The factors served as the questions, while the sub-criteria served as the answers. Therefore, there are 15 questions in the assessment tool that need to be answered by users with the score provided in the range of 1 to 5. After the users answer all the questions provided, the tool will provide an overall index and performance for the products to undergo remanufacturing process. The performances will be categorized into several categories based on the score obtained such as Excellent (100-80 %), Good (84-70 %), Average (50-69 %) and Poor (Below 50%).

3.3 Validation

Upon completion of the tool development, the assessment tool was validated by academicians and engineers to ensure the tool feasibility performance. To make sure the tool was correctly validated, the selected experts are those a with Ph.D. holder and has knowledge about remanufacturing

4. Result and discussion

4.1 AHP Result

An AHP analysis was made to sort out and organize the data by calculating the priority weight for the each criteria and factors that influencing the remanufacturing process. Upon completion of AHP analysis, the priority weight was classified based on the criteria level. Firstly, the main criteria that influence remanufacturing process was obtained. There are three main criteria for this study which are Product Development, Internal Factors and External Factors. From there, the weightage for each of sub-criteria was obtained. There are 15 sub-criteria in total and each main criteria consists five sub-criteria. For product development, the sub criteria are type of material of used part, disassembly of products, condition of used products, design for remanufacturing and quality management of remanufactured products. For Internal Factors the sub-criteria are labor skill and availability, facilities of remanufacturing, organization, planning and control, advanced remanufacturing technology and core acquisition and reverse logistics. As for the external factors, the sub-criteria are government regulations and incentives, OEMs information sharing, consumer acceptance, green benefits of remanufacturing products and policy guidance of remanufacturing process.

Table 4.1 below displays the priority factors that influence the remanufacturing process for automotive parts. Results from analysis showed that the Product development had the highest weight of 0.770 followed by External factors with score 0.127 and Internal factors with score 0.103. Overall inconsistency ratio for this analysis is 0.02 that fulfil requirement which need to be less than 0.1.

For Product development, design for remanufacturing was found out as the most important factor with score 0.494 followed by four other factors which are type of material used part with 0.178, quality management if remanufactured products with 0.127, condition of used products with 0.106 and disassembly of products with score 0.095. Meanwhile, for internal factors, the main criteria is advanced remanufacturing technology with score 0.387 followed by labor skill and availability with 0.327, facilities of remanufacturing with 0.145, organization, planning and control with 0.072 and core acquisition and reverse logistics with score 0.069. For external factors, consumer acceptance was determined as the most important criteria with score 0.316. The second most important criteria is green benefits of remanufacturing products with score 0.262 followed by government regulations and incentives with 0.261, policy guidance of remanufacturing with score 0.095 and OEMs information sharing with score 0.066. The overall ranking of the criteria can be determined by using the global weight as showed in Table 3.

Table 3: Grouped Priority Factors That Influence Remanufacturing process for automotive parts

Criteria	Local weight of criteria	Sub-criteria	Global Weight	Local weight of sub-criteria	Rank
Product Development	0.770	Type of material used part	0.125	0.178	2
		Disassembly of products	0.067	0.095	5
		Condition of used products	0.074	0.106	4
		Design for Remanufacturing	0.346	0.494	1
		Quality management of remanufactured products	0.089	0.127	3
		Labor skill and availability	0.039	0.327	10

		Facilities of Remanufacturing	0.017	0.145	11
Internal Factors	0.103	Organization, planning and control	0.009	0.072	14
		Advanced remanufacturing technology	0.046	0.387	9
		Core acquisition and reverse logistics	0.008	0.069	15
		Government regulations and incentives	0.047	0.261	7
External Factors	0.127	OEMs information sharing	0.12	0.066	13
		Consumer acceptance	0.057	0.316	6
		Green benefits of remanufacturing products	0.047	0.262	8
		Policy guidance of remanufacturing process	0.017	0.095	12

4.2 Automotive product remanufacturing assessment tool

Based on the AHP analysis, an automotive remanufacturing assessment tool was developed to evaluate the suitability of automotive products to undergo remanufacturing process. Figure 3 below shows the main page of the tool and its instruction.

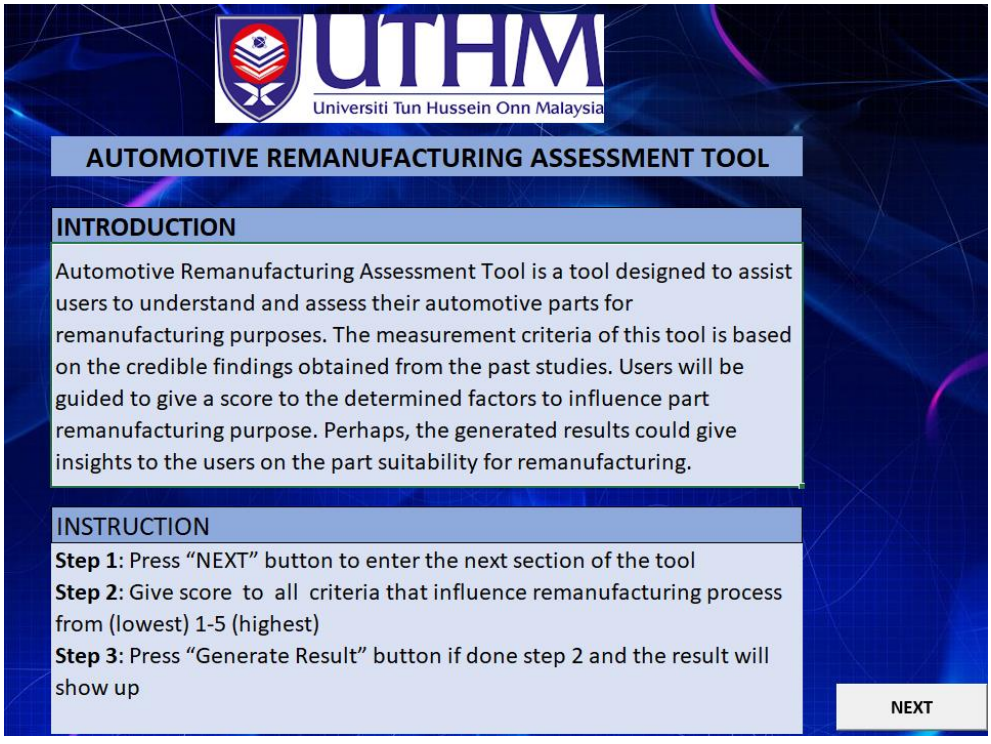

Figure 3: Homepage of the assessment tool

Figure 4 below shows the questions that provide in the assessment tool. There are 15 questions in the tool that needs to be answered with the specify its score. Upon completion of the criteria assessment by the users, an overall index will be showed. Figure 5 below shows an example of the result obtained in the tool. In addition, the assessment tool could provides recommendation based on different categories scored obtained. Figure 6 below shows an example of recommendations generated in the tool.

Factors	Criteria	Score
Product Development Factors	Type of materials used part	0
	Disasembly of products	0
	Condition of used products	0
	Design for remanufacturing	0
	Quality management of remanufactured products	0
Internal Factors	Labor skill and availability	0
	Facilities of remanufacturing	0
	Organization, planning and control	0
	Advanced remanufacturing technology	0
	Core acquisition and reverse logistics	0
External Factors	Government regulations and incentives	0
	OEMs information sharing	0
	Consumer acceptance	0
	Green benefits of remanufacturing products	0
	Policy guidance of remanufacturing process	0

Figure 4: Example assessment tool 1

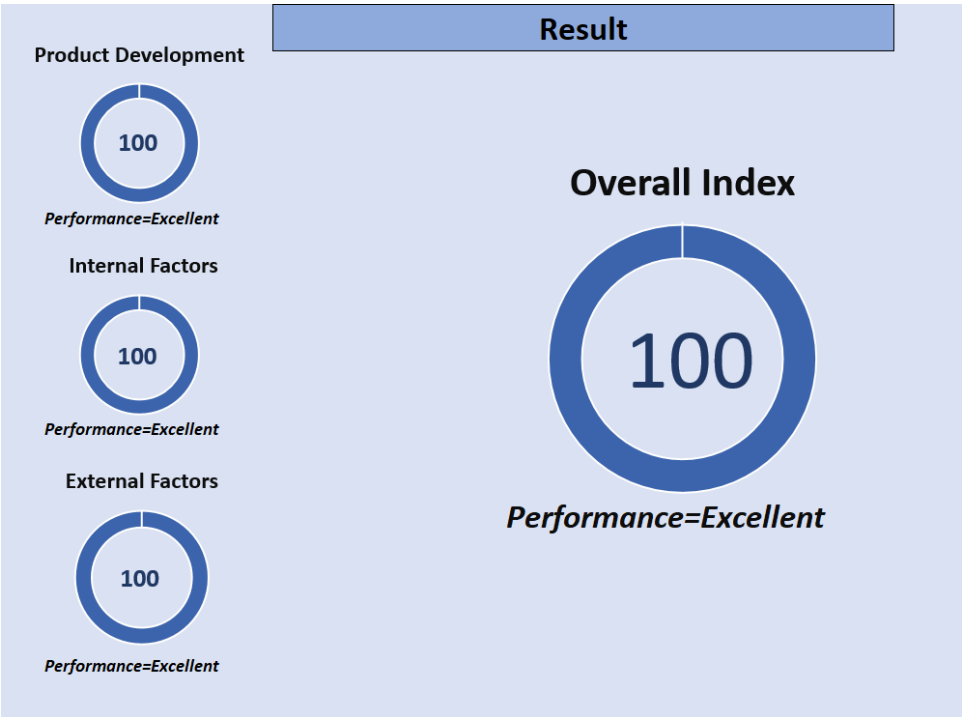

Figure 5: Example assessment tool 2

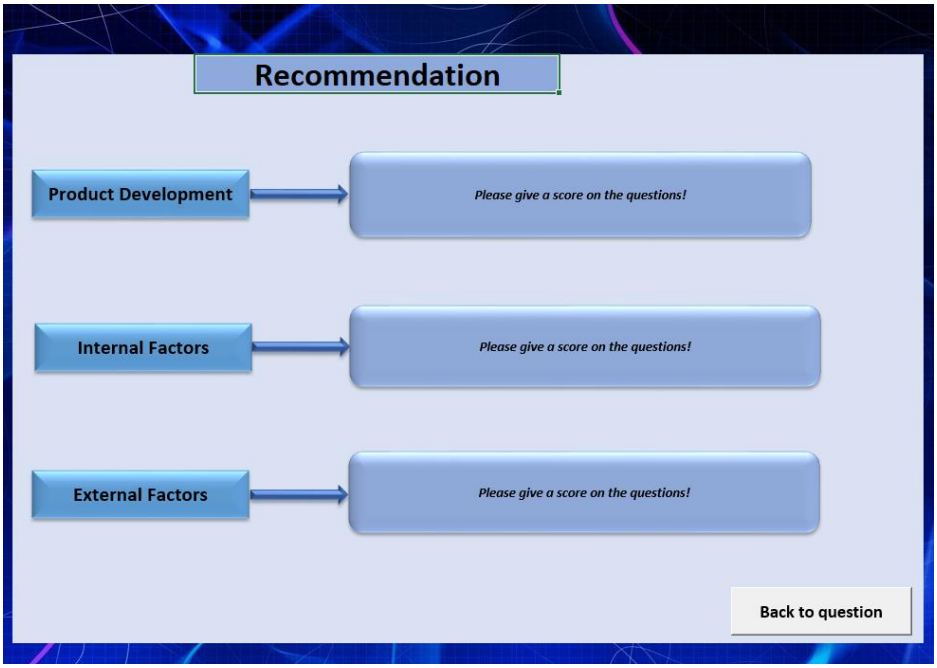

Figure 6: Example assessment tool 3

4.3 Discussion

For this study, in order to build an assessment tool that able to evaluate the product to undergo the remanufacturing process, there are three main factors that need to be focused on. The three main are Product development, Internal factors and External factors. Product development plays a critical role in order to produce high-quality remanufactured products [12]. Internal factors and external factors also important in remanufacturing process. In China, these two factors are important to improve the remanufacturing process. According to 10], external factors and internal factors are the two sorts of factors that will boost China's remanufacturing operations.

4.3.1 Product Development

From the analysis, it shows that Product development got the highest weightage which is 0.770. This might be due in order to undergo remanufacturing process, the main factor or condition is to look at the products itself. For example, DfRem (design for remanufacturing) is important criteria for certain products to undergo remanufacturing process. DfRem includes many things such as disassembility of products, type of material, the lifespan of the products and many more. According to [9], DfRem (design for remanufacturing) is a factor that can boost remanufacturing efficiency. Because of this explanation, it's the reason why design for remanufacturing criteria obtained the highest weightage in Product Development which is 0.494. While other four criteria which are the type of material used part, disassembly of products, condition of used products and quality management of remanufactured products got lower weightage with 0.178, 0.095, 0.106 and 0.127 respectively.

4.3.2 External Factors

It is found that the external factors also play a role to influence remanufacturing process with the second highest score of 0.127. Consumer acceptance of remanufactured items is a big concern for businesses because customers believe that the performance and quality of remanufactured items are inferior to brand new items [11]. Government regulations and incentives also important in order to promote and motivating the consumers to use and purchased remanufactured products. Furthermore, customers' purchasing intentions toward remanufactured items are positively driven by perceived green benefits and adversely influenced by perceived quality and performance risk. [11]. As a result of this

reasoning, it is the reason why consumer acceptance has the highest weightage with score 0.316 followed by green benefits of remanufacturing process with score 0.262 and government regulations and incentives in the third with score 0.261. The other criteria which are policy guidance of remanufacturing process and OEMs information sharing were placed in fourth and fifth place with scores 0.095 and 0.066 respectively.

4.3.3 Internal Factors

From the results, it shows that Internal Factors obtained the lowest in the local weight of criteria which is 0.103. The highest weightage for sub-criteria in Internal Factors is advanced remanufacturing technology with score 0.387. According to [10], advanced remanufacturing technology able to improve remanufacturing process by enhancing the recovery and reuse ratio of cores and exploit clean materials to realize clean production. Next, labor skill and availability is one of the important factors in remanufacturing industries. The complicated and unpredictable nature of remanufacturing demands a high level of skills on the part of remanufacturing employees [9]. Other than that, advanced remanufacturing equipment or technologies able to reduce emissions and achieve cleaner production in remanufacturing process. As stated in studies in China, in order to improve remanufacturing process, one of the factors is related to improving remanufacturing facilities [10]. Due to that, it's the reason why labor skill and availability got the second-highest weightage with score 0.327 followed by facilities of remanufacturing with score 0.145 and followed by two others which are organization, planning and control and core acquisition and reverse logistics with score 0.072 and 0.069 respectively.

4.3.4 Assessment tool validation

This assessment tool was validated by 3 academicians. Table 4 below shows the result for the validation of the assessment tool. Based on the table below, it indicated that consistent results which are good performance and average performance on the most aspect. Based on the feedback from the academician, one of them commented to improve the presentation of the result to make it more interesting. Other than that, one of the academicians commented to increase the criteria to make the result more accurate. Due to that, a little change has been made regarding the presentation of the result.

Table 4: Result for Assessment Tool Validation

Aspect	Respondent 1	Respondent 2	Respondent 3
User interface	Good	Excellent	Good
Presentation of result	Excellent	Good	Good
Reliability of result	Good	Average	Average
Flexibility of the tool	Average	Average	Good
Knowledge-based System	Good	Good	Good
Usefulness level	Average	Average	Average
Informative level	Good	Average	Good

5. Conclusion

In conclusion, this study is aims to develop an Automotive Product Remanufacturing Assessment Tool based on product remanufacturing attributes. The tools was developed by using the factors that influencing remanufacturing process in the literatures. There are three main factors that influencing remanufacturing process which are Product Development, Internal Factors and External factors and in under each factor, there are five sub-criteria. This tool was developed by using Microsoft Excel because the software able to offer fast and simple evaluation on automotive product remanufacturing. The validation process has been done for this tool to make sure this tool is helpful and functions. Hopefully, this tool able to be one of the options to help industry or practitioners to evaluate automotive parts to undergo the remanufacturing process.

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