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Determining Factors of Quality Uncertainty and Its Control Analysis in Remanufacturing System

Mohamad Imron Mustajib[ab]*, Udisubakti Ciptomulyono[a] and Nani Kurniati[a]

[a] *Department of Industrial Engineering, Institut Teknologi Sepuluh Nopember. Surabaya, Jawa Timur 60111, Indonesia.*
[b] *Department of Industrial and Mechanical Engineering, Universitas Trunojoyo Madura. Bangkalan, Jawa Timur 69162, Indonesia.*

Abstract: Remanufacturing is a major area of interest within the field of sustainable manufacturing. Since remanufacturing has widely recognized as a strategy to recover of used products. This recovery means that salvaged values in the used products can be generated again in multi-lifecycle of product through many operations in remanufacturing system. Previous research has established that there are many challenges in remanufacturing practices. The crucial challenge is a shortcoming of control respecting uncertainty in quality, quantity, and return time of a used product. The existence of quality uncertainty incurs risks to incoming core, to remanufacturing planning, and to remanufactured product itself. This uncertainty, if unmanaged correctly, could lead to high cost of quality and remanufacturing operations. Therefore, the main problem is how to analyze the causes of quality uncertainty in remanufacturing activities. In this work, the factors of quality uncertainty were investigated using a fish bone diagram as a tool for cause and effect analysis. This tool is particularly useful in investigating factors and root causes of the quality uncertainty problem in remanufacturing system. In the first step we show that the factors exist in core acquisition and remanufacturing activity. The next step, we propose a quality control framework for reducing quality uncertainty. The framework characteristic in this paper is generic in nature, so that it can be potential for general applicability in remanufacturing industries.

Keywords: Core acquisition; remanufacturing operations; core acceptance condition.

1. Introduction

The fast development of global industry has generated manufacturing strategies were increased significantly, due to tight of product quality requirements, lower cost emphasis, on-time delivery and shorter lead time, and high flexibility also customization, as well as a trend of the shorter product life cycle. In addition, products that are resulted from environmentally conscious manufacturing have attracted attention to many customers. The manufacturing strategy have been started from the traditional manufacturing system which is only focuses on creating product value added in the manufacturing process phase so that the presence of production waste was not considered as an element of the problems in the industry. Then, a lean manufacturing strategy was developed to pay great attention to reduce waste of physicals and activities that do not contribute to added value during the all of manufacturing phase. After that, green manufacturing strategy was proposed as a methodology to improve the efficiency of resource uses and reduce environmental impacts by applying the 3R principle; reduce, reuse and recycle. Finally, the latest strategy that was quite popular for saving resources and reducing

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environmental impacts is sustainable manufacturing. This strategy used 6R principle; Reduce, Reuse, Recycle, Recover, Redesign and Remanufacture to maximizing value recovery from end-of-life products [1]. Sustainability in the manufacturing system is able to be realized when a closed systems exist in which resources are recovered over the life cycle of a product from pre-manufacturing to post-use phase.

Remanufacturing is a powerful strategy to obtain a valuable product in a closed-loop production system. The purpose remanufacturing is to renovate and to recondition the used product so that productive life is able to be extended as good as new condition [2]. Therefore, there are many benefits of remanufacturing in economic, environmental and social dimensions. Remanufacturing not only reduces manufacturing costs and disposal costs but also minimizes environmental impacts like emission to air, energy consumption, and resource use. These advantages were addressed by Ijomah [3], Ilgin and Gupta [4]. Meanwhile, the social benefits obtained from the remanufacturing industry are able to expand the creation of new jobs, because remanufacturing is labor intensive [5].

Although these benefits able to improve the performance of remanufacturing system, there remain difficulties to operate remanufacturing system. The first is regarding material supply are difficulties and high costs during the acquisition process of used product from consumers and collectors hands [6]. The second is the uncertainty in quality and volume of the core, also arrival time of used product [7, 8]. The existence of uncertainty incurs risks to incoming core, to remanufacturing planning, and to remanufactured product itself. These uncertainty, if unmanaged correctly, could lead to high cost of quality and remanufacturing operation. Regarding these uncertainties, few researchers have identified the cause of quality uncertainty factors of core over the activities in remanufacturing system. On the other hand, remanufactured products are not adequately competitive in the marketplace, as cannot always meet customer requirements for the technological reasons. This indicates the quality problem rather than customer satisfaction. The variance of products and processes that make quality to be uncertain are always exist not only in manufacturing [9], but also in remanufacturing. Up to now, far too little attention has been paid to factors cause quality uncertainty in remanufacturing activities.

This study investigated potential factors cause quality uncertainty in remanufacturing activities by means a cause and effect diagram. The importance of using fishbone diagram for identifying root causes of problem in remanufacturing has been demonstrated by Nasr et al [10], Sakao and Sundin [11], Kosacka [12], Soeseno and Kusumastuti [13]. One study by Nasr et al [10] have explored in their empirical research that remanufacturing barriers consists of factors: technology, operations, workforce, core/design, market/environment, and management. Meanwhile, Sakao and Sundin [11] have proposed seven m's factors; measurement, material, human, method, machine, marketing, and maintenance in order to improve the customer value in remanufacturing system. Moreover, in her case study of automotive parts remanufacturing, Kosacka [12] identified five main categories of threats to health and life problem of workers in remanufacturing, namely: employee, machines, remanufacturing process, core, and management. In a recent study, Soeseno and Kusumastuti [13] identified the main causes of the problem of delays in remanufacturing processes mainly due to uncertainty in the time of arrival, quantity and quality of the core. For this purpose, they developed a fish bone diagram which shows that delays problems are caused by the four main factors: the late arrival in quantity of incoming cores; inaccurate information of reusable parts; incompatible with incoming core with the manufacturing requirements; and the difference between the reassembly and disassembly schedules. As the solutions they proposed improving in core acquisition activity, separating job orders for disassembly and recovery, and reassembly processes. These studies clearly show that there is a need to solve various problems in remanufacturing systems using a systematic approach. One of them is a systematic approach to improving the quality of remanufacturing activities is still needed to improve the performance of the remanufacturing system. This research aims to contribute to quality in research remanufacturing by identifying factors of quality uncertainty in core acquisition and remanufacturing operations. After that, we propose a framework for controlling this uncertainty. Controlling uncertainty refers to a mechanism used to overcome sources of quality uncertainty in remanufacturing activities. Therefore, our works are differ from previous researchers in identifying the factors that are generated the problems in remanufacturing and the proposed solution by using a framework.

This paper begins by an introduction section for establishing the importance of remanufacturing topic, describing both of the benefits and the challenges of remanufacturing practices, and establishing a problem of quality uncertainty in remanufacturing, also identifying lack of previous research. It will then go on to section 2 provides the description of remanufacturing system and its activities. In this section also discusses the causative factors for quality uncertainty in the activities. After that, we proposed a framework for quality control in remanufacturing system in section 3. Finally, section 4 concludes the resulted study.

2. Remanufacturing system

A remanufacturing system can be viewed as collection of elements that have technical and economic aspect relationship to obtain common goals by cooperation between them. The vital aspect of remanufacturing system is the relationship between the elements and the activities of the system to transform used product (at the end of life) into remanufactured product (as good as new condition). Three main activities in remanufacturing system are: core acquisition, remanufacturing operational, and (re)marketing or demand development. All the causative factors for quality uncertainty in the activities are will be discussed in the next section. In this context, uncertainty refers to variations from desired ideal condition of perfectly deterministic information of the relevant systems.

2.1. Core acquisition

The first activity in remanufacturing system is core acquisition as front-end component. Core acquisition is analogous to the procurement of materials in foward manufacturing system. This activity plays a basic role in remanufacturing system, due to it interfaces a remanufacturing company to material supply side, in order to acquire used product from end users hand or collectors. The methods for collecting core can be done by direct or indirect collection. In direct collection, remanufacturer collects cores directly from end users, while in indirect collection a remanufacturing company in closed loop supply chain involves complex reverse logistics network to obtain cores from end users.

There are two mechanisms for acquiring cores from the end users for remanufacturing

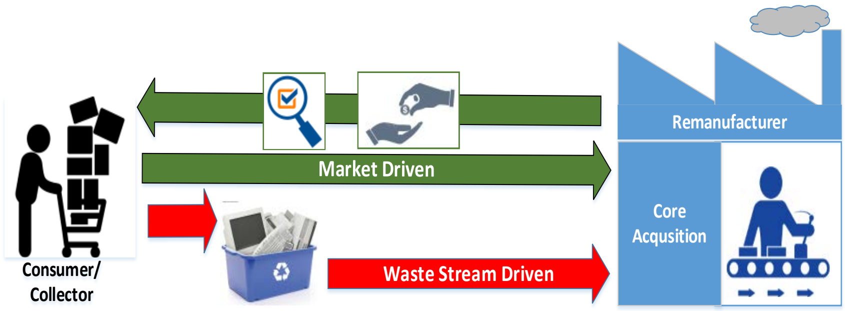

Figure 1. Description of core acquisition mechanism in remanufacturing system.

system [14]: waste stream system and market-driven system. It can be seen from the illustration at Figure 1 that in the waste stream system, remanufacturing company passively receive all used product from the waste stream. By using this system, remanufacturer tends to not able to control the quality and quantity of incoming cores, so that they to focus on the development of minimizing cost of operations. On the other hand, in a market-driven system, end-users are driven to return used products' quality level in numerous ways: for instance, by offering financial incentives particularly for better quality returned products, or by using deposit systems, credit, or cash paid for a certain level of quality. Hence, remanufacturer have strong power to control return rate, timing and quality of core due to acceptance of returns is determined by controllable variables. Overall, market-driven system has several operational advantages. Incoming cores will be sorted and classified based on quality condition before entering remanufacturing processes. High quality class of core increases yield of remanufacturing processes. Therefore, the variability of routings and processing times required can be classified based on its quality grade of incoming core. As a result is better resources utilization and cost-effective.

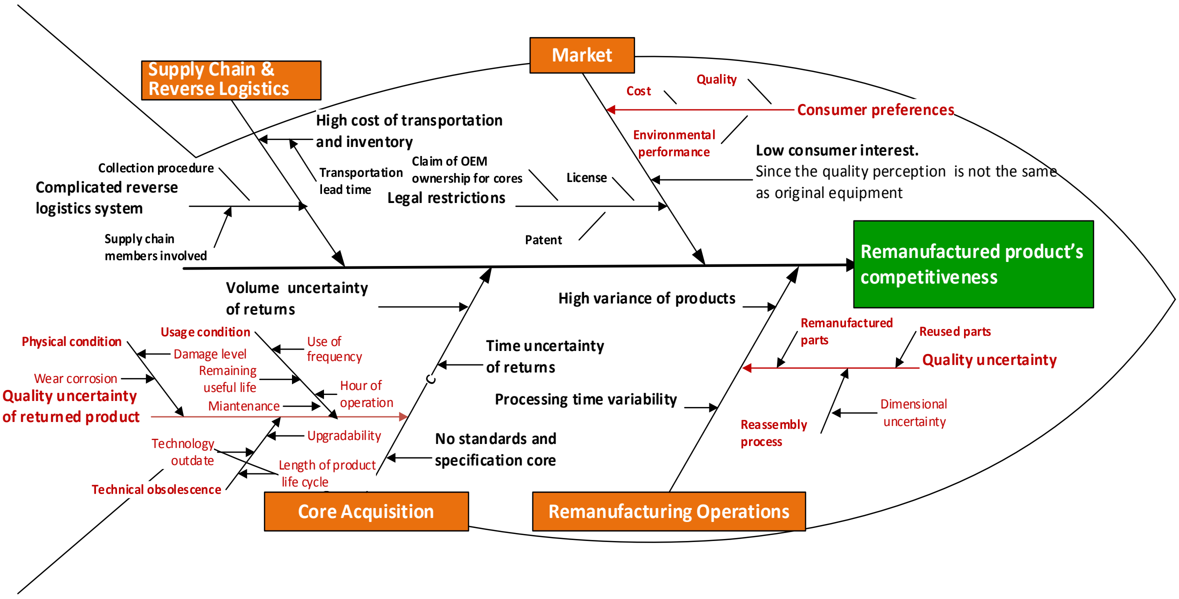

Figure 2. The fishbone diagram for identifying quality uncertainty in remanufacturing activities.

We identified four activities caused remanufactured product competitiveness (Figure 2); supply chain and reverse logistics, and the three main activities in remanufacturing system (core acquisition management, remanufacturing operational, remarketing). In this work we focused on quality uncertainty in three main activities in remanufacturing system. Quality aspects are one of the important parts in determining the competitiveness of remanufactured products, because by definition the quality of remanufactured products is compared to new products. Unfortunately, the natures of incoming core in acquisition process are always uncertain in quality due to many factors. As is shown by the cause and effect diagram in Figure 2, the first factor is is technological condition. The rapid change in information and communication technology has caused the product life cycle becomes shorter and the technology of product to be outdate. In addition, the increasing of consumer needs complexity also caused technology of products are required to be upgraded according to the specifications set by consumers.The second factor is physical condition of used product. The quality of core is affected by various damage condition of used product such as crack, corrosion, and fatigue. Quality variation also triggered by the different “customer-use” of the products stage and thus leads to different levels of damage of components [15]. The condition of damage reveal the physical characteristics of used product and it can be classified based on the size of a fault [16]. The third factor factor is usage condition. This factor includes [17]: number of uses, duration time of operation, age, and maintenance. Maintenance is defined as a collection of activities taken during the use of a product to keeps or restores into a state in which it can perform as predetermined design function. Maintenance also be considered as a series of reliability improvement actions, and its quality output can be controlled. In determining the proper maintenance strategy, usually information about product reliability or failure distribution is needed. Hence, maintenance strategy plays an important role in determining quality level of used product. The reliability of equipment and failure statistics are related to its age. Generally speaking, quality level of used product is a function of the equipment age.

2.2.Remanufacturing operations

A general activity in remanufacturing operations is a series of process: disassembly, cleaning, inspection and sorting, reconditioning, upgrading, reassembly, and testing. A common issue in remanufacturing processes is how to determine the sequence of process under quality uncertainty of incoming core. Due to the quality variance of incoming core also induces a variance in the processing time and routing. The uncertainty in quality not only regarding the acquired core, but also the variability between remanufactured part, reuse part, new or upgraded part, and dimensional tolerance lead to complexity in reassembly process of remanufactured product. Remanufacturing with part upgraded can be better solution for overcoming the quality uncertainty on used product obsolescence since rapid changes in product technology and customer choices [18].

A vital aspect in guaranteeing the remanufactured product to be as good as new product is quality control of the assembly process in remanufacturing operation. It is about how to optimize the use of remanufactured component variable quality class and to improve the performance of remanufactured product in order to meet quality standard [19, 20, 21]. Where the total quality variance of these components must not exceed the variance of remanufactured product assembly.

2.3. Re-marketing

The back-end component of remanufacturing activities is re-marketing of remanufactured products. In remarketing activity not only consider reselling process for remanufactured products, but also generating consumer demand which depend on factors; selling price strategy, product quality, and greening level of remanufactured product. These factors influence the consumers' willingness to pay decision and remanufacturing company's sales. One of the main obstacles of remarketing is the uncertainty from the demand side which is faced with the issue of pricing, quality, and environmental aspects based on consumers preferences for remanufactured products. From the costumers' perspective, many of them still have perceive that remanufactured products to have lower quality than new products. Although, there are adequate evidences to prove that these typically have similarity of performance characteristics as new products. A strategy to overcome this problem, remanufacturing company may remarketing the remanufactured products and encouraging customers by offering product quality insurance through warranty policy on remanufactured products.

In balancing demand with the supply side related to core acquisition, remanufacturing planning is needed, which can be the interface of supply and demand side. Then, an optimization model for remanufacturing planning is needed to obtain appropriate decision variables with the right quantity and quality of remanufactured product and reasonable price offered to the market, so that remanufacturing company is profitable. This view is supported by Cui et al. [22] who stated that although improving quality has an impact on increasing the number of customers and improving the reputation of remanufacturer, the company need to calculate the quality costs spent. When the condition of the cost variable increased, the strategy of reducing price of remanufactured product will be more suitable for remanufacturers to obtain optimal profits under quality constraint.

2.4. Supply chain and reverse logistics

The emergence of closed-loop supply chain was triggered by the value recovery of used products using reverse supply chain process; recollecting, repairing, remanufacturing, recycling, and disposing. This process also are known as a closed-loop economy or circular economy (CE), as opposite of forward supply chain processes, which is called linear economy. Meanwhile, "the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing or creating value or proper disposal" is called as reverse logistics [23]. Both of closed loop supply chain and reverse logistics play an important role for moving the used product from end user to a final destination in a complex system for product recovery options. This complexity is caused by the used product flowing in a reverse logistics system by involving many stakeholders (supply chain members), such as remanufacturing company, retailer, customer, collector / broker, recycled center, service center and distribution center that forms a network with high cost of transportation and inventory. Cost of transportation also generated by length of transportation lead time. In general, transportation lead time and collection procedure have made reverse flow is the major factor in terms of closed-loop supply chain uncertainty [24]. In reverse logistics network, collector managed the collection activities of used product and inspected the quality of it. The collection activity is analogue to purchasing and procurement in the forward logistics activities. Overall, set of operational reverse logistics functions are collection, inspection/sorting, reprocessing, and redistribution.

3. Framework of quality control in remanufacturing system

To develop a framework of quality control for reducing uncertainty in remanufacturing system we need to identify its system's elements. As explained in the previous section, it is clear that crucial activities in remanufacturing system are core acquisition, remanufacturing operations, and remarketing. These activities are system's element that carry out transformation process of used products into as good as new of remanufactured products. In this transformation process, value added occurs by reprocessing, reconditioning, and part replacement or upgrade technology so that the remanufactured product has a higher value than the value of used product. Therefore, commitment to product quality must be implemented at each stage of activity by implementing quality control principles with the aim of ensuring the quality of remanufactured products is not lower than new products.

In Figure 3 we present a framework for quality control in remanufacturing systems. Although, quality control principle employ by inspection and measurement on the product quality characteristics by using equipment and some procedures [25], there are two steps to apply quality control in remanufacturing that we are propose; short term and long term strategy. To employ an efffective quality control system we need to prepare a mechanism. An useful example of quality control mechanism are: by person, facility/equipment, financial, or by information [26]. These were done to ensure the quality of the remanufactured products produced would have high quality at an affordable price, as well as environmental friendly for remanufactured product competitiveness.

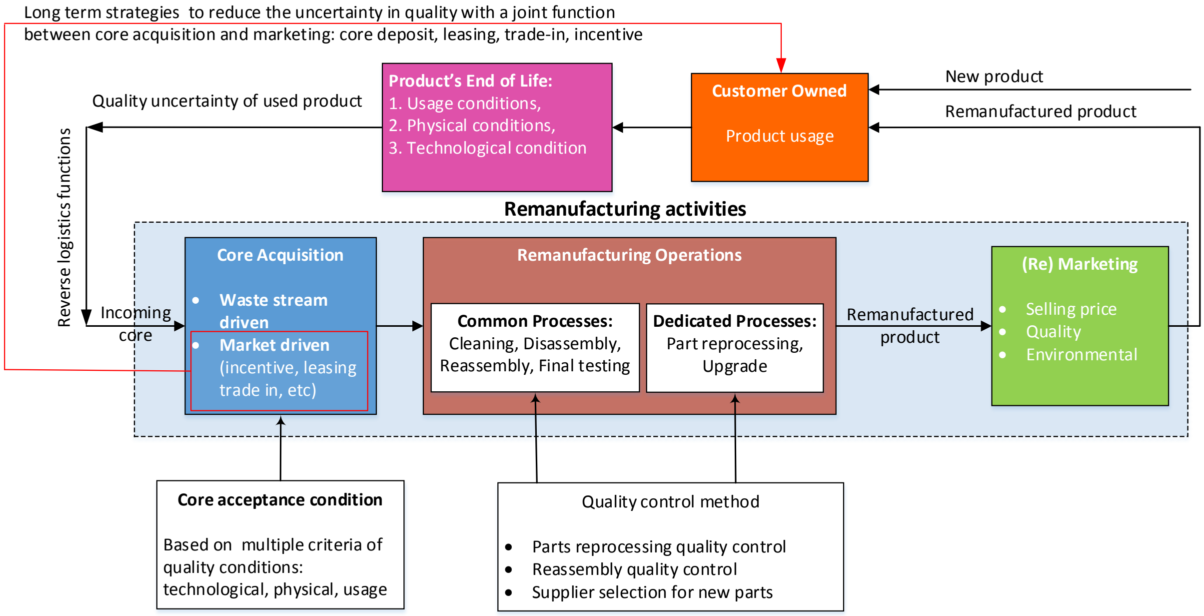

Figure 3. The proposed framework for quality control in remanufacturing system.

In short term strategy, inspection for core acceptance condition and grading of incoming cores quality are fundamental quality control at the first step of remanufacturing processes series are needed to make condition the used product to be remanufactured product as a good as new condition to meet the demand.Therefore, quality control at the beginning incoming core should be done by inspecting and classifying into several grades based on initial quality condition of core. The short term is covered by operational planning with time horizon in hour, day, 1 week to 1 month. A major current focus in inspection and grading of incoming cores tend to consider on single justification only. For example, based on economic criteria the purpose of inspection for incoming core is to discard cores that will be not economical or not possible to remanufacture, receiving only those thought to be feasible [5]. There remains a need for an efficient method that can solve the problem of core acceptance condition by considering multi-criteria quality condition, such as technological condition, physical condition, and usage condition, where are among these criteria can be represent core (used product) quality dimension that are conflicting each others.

Further, we propose a hierarchical model for prioritizing quality of cores acceptance conditions during core acquisition activity based on these three citeria as shown in Figure 4. In this model a high priority quality cores implies minimum remanufacturing operation (means lower costs). The first criteria, the term technological condition refers to technology characteristics of used product shows the expiration rate, due to the product age is longer than the design age (obsolescence), or the emergence of new technological innovations. Whereas upgradablity of technology refers to upgrade possibility above the initial condition to meet costumers' quality grade needs. Second, the term physical condition is generally understood to mean a property that indicates the appearance of the core and basic functions to meet its functional requirements. The evidence of physical condition can be clearly seen in the case of appearance of damage, completeness of components, product identity, and dimensional tolerance. For example the physical condition of worn out tire is determined by thickness tolerance of its tread. Finally, in the literature [17], the term usage condition tends to be used to refer the characteristics that are caused by users during the product use phase. Important sub criteria of usage condition are: frequency of use, operating hours, distance traveled. The remaining useful life (RUL) also vital aspect to determine used condition of a used product.

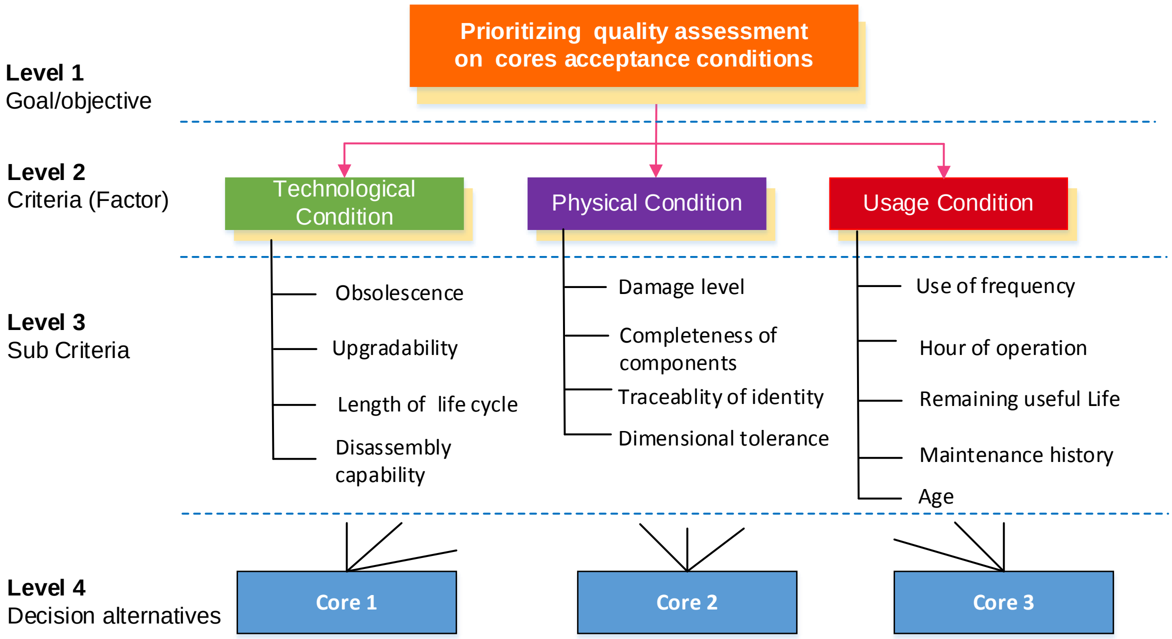

Figure 4. Hierarchical model for prioritizing quality of cores acceptance condition.

Overall, their prioritisation can be done using an analytical hierarchy process (AHP) approach to select the relative importance of criteria (factor) and sub criteria in core acceptance condition. The results will help decision maker in remanufacturing company to work upon them based on their relative importance to select the better quality of accepted core.

Having inspected, then the core to be graded into several classes. For instance three classes of quality level; good, better, worst. Many studies in recent years determined quality classification methods are to justify the economic feasibility of remanufacturing operations. Unfortunately, it is not always proper to use only economic feasibility criteria in selection of quality classification method. Due to technical feasibility is also an important criteria for determining cores that it can be remanufactured or not. At the same time, the criteria of resource consumption are also important to be considered in determining the quality classification method. So that the method to be chosen could be efficient in resource uses during remanufacturing operation. Once the incoming cores are classified, each of quality level of cores is ready to be processed in remanufacturing operation. In general, we divide the processes into two groups; common process (cleaning, disassembly, reassembly, final testing) and dedicated process (part reprocessing, upgrade). This grouping is needed to reduce variability in the process routing, as well as make it easier for the quality control of process. Due to remanufactured products are composed of remanufactured parts, reused parts and new parts, it is important to develop quality control based its parts characteristics. In case remanufactured and reused part, the quality control method will be different. Meanwhile, for new parts are proper to use supplier selection for controlling quality of purchased parts. Meanwhile, for new parts are proper to use suppliers selection for controlling quality of purchased parts. At the end of remanufacturing operation there were need for quality control for reassembly process to assure the remanufactured products fitted to the standard requirement or it specification

Another important strategy to reduce the quality uncertainty of remanufacturing system is long term strategy. In long terms, to reduce the quality uncertainty of incoming core needs to operate a joint function between core acquisition activity and marketing activity to make joint decisions (as illustrated in Figure 3) by using: core deposit, leasing, trade-in, incentive, etc. The literature on [27, 28] has highlighted several types of the joint decisions to end consumers or collectors. Firstly, leasing product can broadly be defined as ownership-based relationship when the product is operated by the consumer but it is still owned by the manufacturing company. A rental of equipment is a good illustration of leasing which is product-service offer. Based on contracts agreement, the quality control of leasing equipment can be strictly regulated. So that, manufacturer/remanufacturer mostly have more data on the quality of leasing equipment (used products). A notable example of leased products in remanufacturing business is heavy equipment. Secondly, trade-in can be loosely described as returning a used product by consumers as a buying discount when they buy a new or remanufactured product. This discount is based on the quality level of the used product are returned. An important example of trade-in policy are tire remanufacturing, mobile phone, washing machine. Thirdly, in a market driven remanufacturers, end users are motivated to return products that are already in the end of life phase. They use financial incentives in order to improve return rates and better core quality, so that remanufacturing companies can indirectly control core quality levels.

Together the description of framework provide important insights into fundamental approach of quality control in remanufacturing system. This framework has important implications for developing both of quality control model and remanufacturing planning model in remanufacturing system. Consequently, a further work with more focus on these models are therefore suggested.

4. Conclusion

This study has identified the factors of quality uncertainty in core acquisition, remanufacturing operations, and remarketing activities in remanufacturing system. Prior works have identified the factors in remanufacturing barriers [10], and seven m's with recommended action to remanufacturing practices [11], also the delays problem in remanufacturing processes [13]. However, their study have not focused on quality uncertainty in remanufacturing which has an impact on the control quality needs for improving competitiveness of remanufactured products. This product competitiveness refers to perceived equal or better of remanufactured product quality relative to new product from the costumers' perspective.

In this work, we are not only studied the cause and effects of quality uncertainty in remanufacturing system, but also developed a framework for controlling quality uncertainty. Our results are different significantly from previous works. Which is according to our perspective, the issue of competitiveness of remanufactured products comes from quality uncertainty in core acquisition activities, remanufacturing operations, and remarketing activities. To overcome this problem, we propose a quality control framework. Therefore, this study makes a major contribution to research on remanufacturing by identifying the quality uncertainty in remanufacturing activities and developing the framework for controlling this uncertainty. The framework presented in this paper is appropriate for the general remanufacturing system. Therefore, our results should be encouraging in a specific remanufacturing system. For instance: remanufacturing to order, remanufacturing to stock, and hybrid remanufacturing system.

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References

[1] Badurdeen, F. and Jawahir, I. S. 2017. *Procedia Manufacturing*, *8:* 20–27. http://doi.org/10.1016/j.promfg.2017.02.002.

[2] McConocha, D. M. and Speh, T. W. 1991. *The Journal of BUsiness and Industrial Arketing*, *6*: 23–37.

[3] Ijomah, W. L. 2010. *Proceedings of the ICE - Waste and Resource Management*, *163*: 157–163. http://doi.org/10.1680/warm.2010.163.4.157.

[4] Ilgin, M. A. and Gupta, S. M. 2012. *Remanufacturing modeling and analysis*, Taylor & Francis Group.

[5] Errington, M. and Childe, S. J. 2013. *Journal of Remanufacturing*, *3*: 7. http://doi.org/10.1186/2210-4690-3-7.

[6] Matsumoto, M. and Nasr, N. 2016. *Services And The Green Economy*, London: Palgrave Macmillan. http://doi.org/10.1057/978-1-137-52710-3.

[7] Wei, S., Tang, O. and Sundin, E. 2015. *Journal of Remanufacturing*, *5*: 4. http://doi.org/10.1186/s13243-015-0014-7.

[8] Kurilova-palisaitiene, J., Sundin, E. and Poksinska, B. 2018. *Journal of Cleaner Production*, *172*, 3225–3236. http://doi.org/10.1016/j.jclepro.2017.11.023.

[9] Mustajib M. I. and Irianto D. 2010. *Journal of Advanced Manufacturing Systems*, 9:1 31-48. http://doi.org/10.1142/S0219686710001788

[10] Nasr, N., Hilton, B., Haselkom, M., Parnell, K., Brun, V. and Hanson, F. 2017. *Technology Roadmap for Remanufacturing in the Circular Economy*, Rochester. https://www.rit.edu/gis/remanroadmap/docs/Technology roadmap for remanufacturing in the circular economy.pdf.

[11] Sakao, T. and Sundin, E. 2018. *Jounal of Manufacturing Science and Engineering*. http://doi.org/10.1115/1.4041746.

[12] Kosacka, M. 2018. Sustainability in Remanufacturing Operations. In K. F. Golinska-Dawson P. (Ed.), *Sustainability in Remanufacturing Operations*, London: Springer, Cham. http://doi.org/10.1007/978-3-319-60355-1.

[13] Soeseno, E. and Kusumastuti, R. D. 2019. *Logistics*, *3*: 1–15. http://doi.org/10.3390/logistics3010001.

[14] Guide, V. D. R. and Wassenhove, L. N. V. 2001. *Production and Operations Management*, *10*: 142–155. http://doi.org/10.1111/j.1937-5956.2001.tb00075.x.

[15] Jin, X., Hu, S. J., Ni, J. and Xiao, G. 2013. *IEEE Transactions on Automation Science and Engineering*, *10*: 76–85. http://doi.org/10.1109/TASE.2012.2217741.

[16] Jiang, Z., Wang, H., Zhang, H., Mendis, G. and Sutherland, J. W. 2019. *Journal of Cleaner Production*, 210: 419–431. http://doi.org/10.1016/j.jclepro.2018.10.316.

[17] Gavidel, S. Z. and Rickli, J. L. 2017. *International Journal of Production Research*, *7543*: 1–15. http://doi.org/10.1080/00207543.2017.1349954.

[18] Kwak, M. and Kim, H. 2012. *Journal of Mechanical Design*, *135*: 11007. http://doi.org/10.1115/1.4023000.

[19] Hatcher, G. D., Ijomah, W. L. and Windmill, J. F. C. 2011. *Journal of Cleaner Production*, 19: 2004–2014. http://doi.org/10.1016/j.jclepro.2011.06.019.

[20] Liu, M., Liu, C., Xing, L., Liu, Z., Li, X. and Lin, L. 2016. *International Journal of Advanced Manufacturing Technology*, 85: 1471–1481. http://doi.org/10.1007/s00170-015-8026-x.

[21] Ma, J., Wang, Q. and Zhao, Z. 2018. *Production Engineering*. http://doi.org/10.1007/s11740-018-0826-z.

[22] Cui, L., Wu, K. and Tseng, M. 2017. *Journal of Cleaner Production*, March: 1–9. http://doi.org/10.1016/j.jclepro.2017.03.056.

[23] Rogers, D. S. and Tibben-Lembke, R. 2001. *Journal of business logistics*, 22: 129-148.
[24] Goltsos, T. E., Ponte, B., Wang, S., Liu, Y., Naim, M. M. and Syntetos, A. A. 2018. *International Journal of Production Research*, 1–34. http://doi.org/10.1080/00207543.2018.1510191.
[25] Kurniati, N., Yeh, R. H. and Lin, J. J. 2015. *Procedia Manufacturing*, 4: 244-251. http://doi.org/10.1016/j.promfg.2015.11.038.
[26] Mustajib, M.I., Kurniati, N. and Ciptomulyono, U. 2017. *Proceedings of The 18th Asia Pasific Industrial Engineering and Management System Conference,* C5-C12 ISBN: 978-602-50913-0-8
[27] Östlin J., Sundin E. and Björkman M. 2008. *International Journal of Production Economics*, 115: 2, 336-348. http://doi.org/10.1016/j.ijpe.2008.02.020.
[28] Wei, S., Tang, O. and Sundin, E. 2015. *Journal of Remanufacturing*, 5: 1 4. http://doi.org/10.1186/s13243-015-0014-7.