A Preliminary Study of Technical Feasibility for Mobile Phone Remanufacturing in Indonesia

Yopi Y. Tanoto, Shu-San Gan, Didik Wahjudi, and Juliana Anggono
Mechanical Engineering Department, Petra Christian University, Indonesia.
yopi.tanoto@petra.ac.id

***Abstract*—Remanufacturing is an important element in making sustainable production and consumption in our society. Unfortunately, remanufacturing is not well-developed in Indonesia yet, especially compared to developed countries. To start a remanufacturing process, it is necessary to know the feasibility technically, economically and environmentally. This paper aims to find out whether the remanufacturing of mobile phones is technically feasible to be done in Indonesia. Mobile phone is chosen because it is one of the biggest e-waste takers lately. Four mobile phone brands are selected for this purpose. The method used in this research was a qualitative survey, which was conducted at the service center of each brand. From this research we find some barriers and facilitators in the remanufacturing implementation. In addition, we propose some attributes in every step of the remanufacturing process. It can be concluded that technically, remanufacturing of mobile phones in Indonesia can be implemented. There are notable processes in every step of remanufacturing that affect the feasibility of mobile phone remanufacturing, such as the selection of phone types and the meticulousness in every step to avoid damage during the remanufacturing process.**

***Index Terms*—Mobile Phone; Remanufacturing; Technical Feasibility.**

I. INTRODUCTION

In 2008 globally, the production of mobile phones was 1.18 billion units in total, of which 48% were produced in China [1]. In 2015 Global smartphone sales reached 1500 million units [2]. In 2011, J, Yin *et al* found that more than 70% of the population in China claimed that the service life of their mobile phone was 1-3 years. Usable mobile phones (resold or recycled) was only about 21% [3]. In Indonesia, it is recorded that 25% of the total population, which is about 65 million people, have used mobile phone [4]. It makes mobile phone one of the biggest contributors of e-waste when its life cycle has ended. Wastes from mobile phones contain some valuable materials (e.g., gold, copper and silver), but also contains toxic and hazardous metal waste (e.g., Cd, Hg, Pb, As, Cr, and Ni) [1].

Increased carbon emissions, limited energy, limited natural resources and strict government regulations have created a concern or focus on how to dispose end-of-life products, and it has become stronger larger over the past few decades [5]. Many ways have been done by the government and private sectors to cope with waste, especially e-waste, in addition to incineration. These ways include reuse, recycle and remanufacturing. Remanufacturing is a process to restore the physical condition and function of used-product to be the same as new, which is also called as the highest form of recycle [6], [7]. The position of remanufacturing in a product life cycle can be seen in Figure 1.

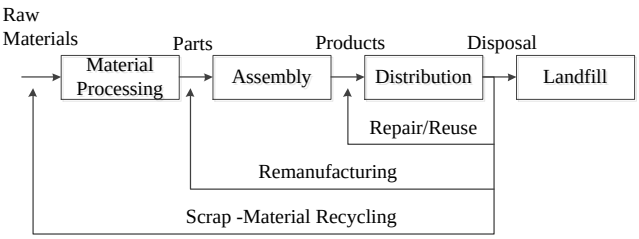

Figure 1: Product life cycle [5]

Remanufacturing has been applied in some developed countries, such as the United States, Germany, Japan, and United Kingdom. Products that are often involved in remanufacturing are electronic devices such as photocopiers, automotive parts and heavy equipment. In Indonesia, remanufacturing has not been applied widely. When it is implemented, it is usually performed by third party, not by OEM, and only limited to reconditioning or refurbishing [8].

Lund has developed 7 criteria for the remanufacturability, one of which is that remanufacturing is suitable to be applied to technologically stable products [9]. Mobile phones are products that do not belong to this category, but from the amount of e-waste generated, remanufacturing mobile phones deemed necessary to be studied. There are also several studies that support the remanufacturing of electronic products, such as Steinhilper [7], claiming that within the increasing volume of electronic products disposals, 80% of them look like new and are still working properly. Also, Guide *et al.* [10] show that remanufacturing of the short life-cycle product is not only feasible, but also can be profitable, when product acquisition is well managed. This paper is addressing empirically the technical feasibility of mobile phone remanufacturing in Indonesia, based on a qualitative study, to find the technically preferred quality and metrics that support successful remanufacturing implementation.

II. LITERATURE REVIEW

There are many researches on remanufacturing. Du *et al*. implemented an integrated method to evaluate remanufacturability of a machine tool [11]. Factors that are integrated were technical, economic, and environmental factors [9]. Shu *et al*. [12] conducted a technical study of design applications for remanufacturing of fastening and connection selection. The selected product for the case study was Kodak copier and toner cartridge. From this research, it was found that connections that were designed for assembly and recyclability were not able to facilitate remanufacturing. In addition, the opportunities for and consequences of damage during dismantling and reassembly may increase the

cost of remanufacturing. Mabee *et al*. [13] developed a series of design charts that contained design attributes and metrics to evaluate remanufacturability. The product for this case study was the cooler assembly of Kodak paper copier.

Ijomah *et al*. [14] conducted a study which also related to the design for remanufacturing. The products were mechanical and electromechanical products. From the results of the study, the basic steps were generated to improve the toughness of DfRem that already made by previous studies. Fatimah and Biswas in 2016 [15] conducted an assessment of the sustainability of remanufactured computers. From their study, it was found that computer was technically, environmentally, economically, and socially suitable for remanufacturing as long as the availability of quality cores, skilled workers combined with standardized processes and the presence of sophisticated equipment to support remanufacturing process were available.

The technical feasibility factor is one of the most important factors. From technical feasibility we know whether a product can be reproduced effectively or not. In the research mentioned above there had been no technical discussion of remanufacture on mobile phones. Therefore, it is necessary to study the technical feasibility for mobile phone remanufacturing.

III. METHODS

Data were obtained by conducting interviews at mobile phone service centers. The service centers that were selected were based on the identification of brands and models of mobile phones that were potentially feasible for remanufacturing. We selected four service centers of four different brands, i.e. Unicom (Huawei), LG, Sonny, Asus. All service centers were located in Surabaya, Indonesia. The main activities of the interviewed service centers are usually checking and repairing (accompanied by component replacement if necessary). The interview was conducted in May and June 2017 which took place in Surabaya, Indonesia. It was organized in a semi-structured questions, face to face, and recorded. Table 1 shows the respondents' profile. The interviewee served as a supervisor, head of the technician, head of the service center and some were technicians.

Table 1
Data of Respondents

Brands	Positions of respondents
Asus	Head of technician
LG	Head of service center and technician
Sony	Technician
Huawei	Supervisor and technician

Interview questions were prepared according to the remanufacturing steps of Steinhilper [7] which are described in Figure 2. From the information gathered, we observed in which condition damage often happened, and how the process of disassembly, checking, repairs, re-assembly and final test were done. The remanufacturing steps by Steinhilper started from disassembly; cleaning; inspection and sorting; reconditioning; and reassembly. The interview questions were slightly different, because the service centers did not do the sorting process, so in the third step there was only the inspection process. Reconditioning was limited to a process of repair performed by the service center.

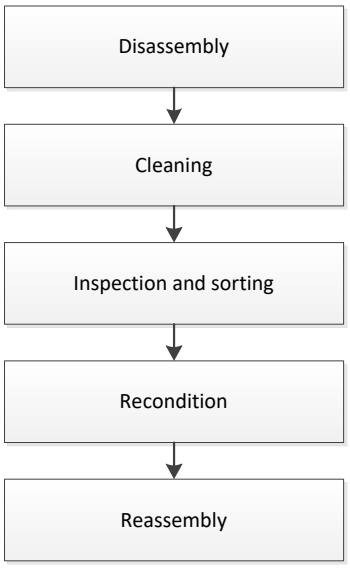

Figure 2: 5 Steps of remanufacturing process [7]

IV. RESULTS AND DISCUSSIONS

A. Interview Results

Interview data obtained from the service centers of those four brands can be seen in Table 2. The brand names are replaced with letters of A, B, C, and D which are written randomly for confidentiality of each brand.

B. Discussions

Disassembly process takes 2 - 60 minutes. It takes a longer time to disassemble and it also requires special tools on mobile phones with non-removable batteries and water-proof features. This could make the cost of remanufacturing higher. The joints used on a mobile phone are snap fit and nut-and-bolt. During the disassembly process, damage rarely happens. However if it does happen, there are ways to overcome it, for example by making a new groove on the bolt. If the damaged part cannot be fixed, the final solution is to replace that component.

The cleaning process on mobile phones involves mechanical and chemical cleaning. Mechanical equipment used include blower, brushes, pen erasers, fiber cloth or tissue, and razor blade. Chemicals include 90% ethanol and thinner. Blower is used to clean the fine dust and vulnerable-to-scratch parts like lens and parts that cannot be reached by a brush. However, brush is the most commonly used tool. Brushes can be used to clean dust and dirt on the connector, PCB and other parts. Microfibers and wipe cloth are used to clean the LCD and mobile phone casing. The use of wipe cloth is usually also accompanied by ethanol. Thinner is used to remove impurities that cannot be cleaned using ethanol or brush. Rust on the connector and PCB are removed using a razor blade. When cleaning the lens, it has to be done very carefully so as not to scratch them. Also, special attention needs to be paid when cleaning the sockets and antennas so as not to separate them.

Table 2
Result of the Survey

Process	A	B	C	D
Disassembly				
Time required	2 minutes and 6 minutes for the non-removable battery	15 minutes	10 minutes and 15 minutes for waterproof	60 minutes for all process
Connection type	Snap fit and bolt nut	Snap fit and bolt nut	Snap fit bolt nut and adhesive	Snap fit and bolt nut
Special tools to disassembly	Plunger and heater for non-removable	Lever for open the casing	Tweezers, steam solder and press tool	Plunger
Action when there is a difficulty	Create a new groove on the bolt	Brake the casing	Drilled and replace with the new one	Create a new groove on the bolt
Cleaning				
Parts that are often cleaned	Connector, mainboard and LCD	Connector and casing	Casing, connector battery, LCD, PCB	Front and main camera, and LCD
Tool for cleaning	Brush, thinner, blower, tissue	Cleaner, contact cleaner, blower, thinner, microfiber	Alcohol 90%, static brush	Alcohol, special cloth , razor blade and pen eraser
Components that can be damaged when cleaned	Socket and antenna	Nope	Broken PCB path	Lens (scratch)
Action when damage occurs when cleaned	Replace component	-	Connected with wire	Replace component
Testing (Inspection and Sorting)				
Methods or tools	Visual and USB doctor for battery testing	Visual, avo-tester, hard lock and power supply	Press *#*#7378423#*#* on the mobile phone, avotester and magnifier	Avotester and magnifier
Standard examples in testing	Maximum death pixels on LCD are 5 points	Refers to consumer convenience	Refers to *#*#7378423#*#*	Refers to compartner
Repair (reconditioning)				
Damage/error that frequent repair	Replacement of connector and main board (PCB)	Error and off mobile phone	LCD and connector	Error and inaccurate GPS
Available of spare part	Yes	Yes	Yes only for new type	Yes
When spare part is not available	Sent from Jakarta (max 5 days)	Sent from other city service center (depend on location)	Depend on location	2 days
Is there a decrease in quality after repair	None	None	None	None
Components that are only disposable	LCD and place of sim card	Motherboard	Corrosion part (nut)	LCD, resistor and capacitor
Reassembly				
Time required	5 minutes and for some type more than 5 minutes	15 minutes	10 minutes and 15 minutes for waterproof type	30 - 60 minutes
Number of manpower	1 people	1 people	2 people (troubleshoot and repair)	1 people
How to test the condition after reassembling	Press 12345=+	Manual testing	Press *#*#7378423#*#*	With compartner
Is there a special tool	None	Power supply	Magnifier and avo-tester	None
Standard in testing	Yes	Yes	Yes	Yes
Standard examples in testing	The line drawing on the LCD should fit	There is no dead pixel	With compressor and refers to *#*#7378423#*#*	Refers to compartner
If it fails during final test	Retest and if still fail, replace component	Replace motherboard or trade-ins	Informed to consumer	Repair again

The inspection process (testing) is done visually and using some equipment such as magnifier and avo-tester. In some brands, standard testing is done by typing a specific code on the mobile phone. In other brands, testing is done with the help of dedicated software. The battery condition is tested using a tool calls USB-doctor. Repairs that are frequently done on the cell phone is on the connector, mainboard and LCD. After the repair, all brands claimed that there was no deterioration in the quality of the mobile phone, which meant the condition or performance was almost like a new one. Spare parts needed for the repair process are also available in the service center especially for the relatively new mobile phones. If the spare parts do not exist, then the service center will order from its center or another service center from another city. The spare part procurement period is about 2 to 5 days. There are some components that are only disposable when they are damaged. Those components are electronic component such as LCD and components that exist on the motherboard (diode, capacitor and others).

The reassembly process takes the same time as the disassembly process. The required workforce amounts to one person. The way of testing or final testing is the same as the methods in the inspection step. If damage or error is found in the final testing, the phone will be repaired again. If the phone still does not work, the customer service officer will offer component replacement to the customer. This most frequent component to be replaced is motherboard (PCB). The final test is done before the reassembly is finished, usually leaving the rear casing section.

C. Barriers and Facilitators

In the process of remanufacturing mobile phone, of course we will encounter things that inhibit or support the remanufacturing mobile phone in Indonesia. The main

technical obstacle is the initial design of the mobile phone which is not designed specifically for remanufacturing. This makes the disassembly process and component replacement process is not supported by remanufacturing process. The trend of mobile phone type with non-removable batteries is also increasing. In fact, there are some brands that almost all types of its mobile phones use non-removable batteries. As discussed earlier, the time to disassemble the mobile phone with the non-removable battery is longer and more difficult (a special tool is needed). All brands replace the whole motherboard (PCB) in case of damage one of the electronic component only. This makes the replacement cost more expensive. It is necessary to study further to find which parts that have the highest failure rate. It is necessary to design motherboards with modular systems. So if there is damage, we do not need to replace the whole motherboard, but only the damaged part. This can decrease the remanufacturing costs.

The condition of Indonesian society opens opportunities for the success of remanufacturing products. In Indonesia there are upper, middle and lower classes. The use of mobile phones has touched all circles. Mobile phone remanufacturing products of the premium type can be used by the middle class. In Indonesia there are also many abundant labours that when trained will become skilled. This is indispensable in the remanufacturing process. Used market, especially mobile phones in Indonesia has been developed. Many people, especially the lower middle class who is familiar to use a used phone. This may encourage or inhibit the use of remanufactured products. If the prices of remanufactured products are not competitive, people will prefer reused mobile phones rather than the remanufactured ones. But if the price is competitive and there are warranty and promotion from the OEM, the community will prefer remanufacturing products. On the other hand, government regulations are needed as they will greatly affect the sustainability of remanufacturing in Indonesia.

D. Design Chart

From observations during the interview, design attributes are made at every stage of remanufacturing. In disassembly, minimizing total disassembly time is the main objective. Time for reassembly is decomposed into two steps, i.e. time to access motherboard and time to reach repairable parts. The attributes are shown in Table 3.

For cleaning, testing, repair and reassembly, the relevant attributes can be seen in Table 4 to 7. The main objective of cleaning is to clean up the components into like new ones without destroying them with time efficient. Cleaning lens and electronic components on the motherboard need to be careful. In the testing process, a standard (method and time) is required for all test results to have the same standard. The selection of the components to be tested and the method of testing is important. Time is one important component in repair. Time depends on the availability of components and standards used. Standards also affect the use of equipment for repair. In disassembly process the main objective. On the reassembly process, the goal is to ensure that components can be assembled as early as possible. In addition, final testing is required to ensure the product works as new.

Table 3
Design Attributes for Disassembly

Disassembly
Access to motherboard
time to remove casing
time to remove battery
time to open bolt nut
numbers of step to access motherboard
number of tool used
number of fasteners removed
number of steps
Access to repairable parts
total number of parts
number of repairable items
time to reach repairable items
number of steps
number of parts reusable

Table 4
Design Attributes for Cleaning

Cleaning
time to clean
total cleaning material use
total cleaning tools use
numbers of parts need to be cleaned
cleaning without damage

Table 5
Design Attributes for Testing

Testing
time to test
total tool use to testing
test method
standard for testing
numbers of parts need to be tested

Table 6
Design Attributes for Repair

Repair
time to repair
number of tool used
standard for repair
spare part availability

Table 7
Design Attributes for Reassembly

Reassembly
time to assembly
number of step
number of tool used
time to final test

E. Preferred Qualities and Metrics

The results of the remanufacturing assessment of mobile phone are shown in Table 8. The table shows the current conditions that are less supportive of the mobile phone remanufacturing process. Several recommendations are given to get a low cost and quality assured remanufacturing. The recommendations involve the time is made to a minimum, no damaged material, efficient in component replacement and testing is done thoroughly.

Table 8
List of Preferred Qualities and Metrics

List of Preferred Qualities and Metrics	Existing	Recommendation
Disassembly		
time required	2 - 15 minutes	2 - 10 minutes
connection type	various, depending on the type of battery and special feature	snap fit and bolt nut (limited to removable battery)
special tools to disassembly	steam solder, plunger and heater.	none
Cleaning		
components that can be damaged when cleaned	scratched lens and the position of the socket and antenna is not fitting	use softer tools to clean lens and use jig when clean antenna
Testing		
scope	limited to the performance of mobile phones (software)	Thorough to each electronic component and physical checking each part
Repair		
components replacement	a whole motherboard	Just a damaged modular
Reassembly		
time required	5 - 15 minutes	2 - 10 minutes

V. CONCLUSION

From the qualitative survey and analysis, it can be concluded that mobile phones remanufacturing in Indonesia can be implemented from the perspective of technical feasibility. There are notable processes in every step of remanufacturing that affect the feasibility of mobile phone remanufacturing, such as the selection of phone types and the meticulousness in every step to avoid damage during the remanufacturing process. Moreover, the design of the mobile phone needs to consider its remanufacturability for maximum remanufacturing benefits.

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