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A preliminary study of technical feasibility for mobile phone remanufacturing in Indonesia Yopi Y. Tanoto1, Shu-San Gan2, Didik Wahjudi3, and Juliana Anggono4 1,2,3,4 Mechanical

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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 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.
Key Words: 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** 5

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. Remanufacturing has been applied in some

developed countries, such as the United States, Germany, Japan, **and** 8

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]. Raw Materials Parts Products Disposal Material Processing Assembly Distribution Landfill Repair/Reuse Remanufacturing Scrap -Material Recycling Figure 1: Product life cycle [5] 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 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** **2**

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

X 1 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** **1**

product for this case study product 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** 6

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 about 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 city of 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 technician, head of 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 is described in Figure 2. From the information gathered, we observed in which condition a 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 7

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. Disassembly Cleaning Inspection and sorting Recondition Reassembly 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 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 mobile phone are snap fit and nut-and-bolt. During the disassembly process, a 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 damage part cannot be fixed, the final solution is to replace that component. The cleaning process on mobile phones involves mechanical and chemical cleaning. Mechanical equipments 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 dusts and dirts 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 cleansed 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 Table 2 Result of the Survey Process A B C D Disassembly time required connection type special tools to disassembly action when there is a difficulties 2 minutes and 6 minutes for non-removable battery snap fit and bolt nut plunger and heater for non- removable create a new groove on the bolt 15 minutes snap fit and bolt nut lever for open the casing brake the casing 10 minutes and 15 minutes for waterproof snap fit bolt nut and adhesive tweezers, steam solder and press tool drilled and replace with the new one 60 minutes for all process snap fit and bolt nut plunger create a new groove on the bolt Cleaning parts that are often cleaned connector, mainboard and connector and casing casing, connector battery, front and main camera, LCD LCD, PCB and LCD tool for cleaning brush, thinner, blower, cleaner, contact cleaner, alcohol 90%, static brush alcohol, special cloth , tissue blower, thinner, microfiber razor blade and pen eraser components that can be socket and antenna nope broken PCB path lens (scratch) damaged when cleaned action when damage occurs replace component - connected with wire replace component when cleaned Testing (Inspection and Sorting) methods or tools standard examples in testing visual and USB doctor for battery testing Maximum death pixel on LCD are 5 points visual, avotester, hard lock and power supply refers to consumer convenience press *#*#7378423#*#* on the mobile phone, avotester and magnifier refers to *#*#7378423#*#* Avotester and magnifier 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 number of manpower how to test the condition after reassembling is there a special tool standard in testing standard examples in testing if it fails during final test 5 minutes and for some type more than 5 minutes 1 people press 12345=+ none yes the line drawing on the LCD should fit retest and if still fail, replace component 15 minutes 1 people manual testing power supply yes There is no dead pixel replace mother board or trade-ins 10 minutes and 15 minutes for waterproof type 2 people (troubleshoot and repair) press *#*#7378423#*#* magnifier and avotester yes With compressor and refers to *#*#7378423#*#* informed to consumer 30 - 60 minutes 1 people with compartner none yes refers to compartner repair again and antennas so as not to separate them. 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 by the help of a dedicated software. The battery condition is tested using a tool calls USB-doctor. Repairs that are frequently done on the cellphone 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 other 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 a damage or error is found on 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 for remanufacturing process. 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 need). All brands replace the whole motherboard (PCB) in case of damage one of electronic component only. This makes the replacement cost is more expensive. It is necessary to study further to find which parts that have highest fail rate. It is necessary to design motherboards with modular systems. So if there is a 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 labor 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 is 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 mother board 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 mother board time to remove casing time to remove battery time to open bolt nut numbers of step to access mother board number of tool used number of fastener removed number of steps Access to repairable parts

reach repairable items number of steps number of part 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 Table 8 List of Preferred Qualities and Metrics List of Preferred Qualities and Metrics Disassembly time required connection type special tools to disassembly Existing 2 - 15 minutes various, depend on the type of battery and special feature steam solder, plunger and heater. Recommendation 2 - 10 minutes snap

fit and bolt nut (limited to removable battery) 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 Repair components replacement limited to the performance of mobile phones (software) Thorough to each electronic component and physical checking each part a whole mother board Just a damaged modular Reassembly time required 5 - 15 minutes 2 - 10 minutes Repair time to repair V. CONCLUSION number of tool used From the qualitative survey and analysis, it can be standard for repair concluded that mobile phones remanufacturing in Indonesia spare part availability 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 Table 7 remanufacturing, such as the selection of phone types and Design Attributes for Reassembly the meticulousness in every step to avoid damage during the Reassembly remanufacturing process. Moreover, the design of the time to assembly mobile phone needs to consider its remanufacturability for maximum remanufacturing benefits. number of step number of tool used ACKNOWLEDGMENT time to final test We are grateful for the research grant provided by Ministry of Research, Technology and Higher Education through a E. Preferred Qualities and Metrics research scheme of “Penelitian Unggulan Perguruan The results of remanufacturing assessment of mobile Tinggi.” We also thank the Institute for Research and phone are shown in Table 8. The table shows the current Community Outreach of Petra Christian University that has conditions that are less supportive of the mobile phone supported the implementation of this research grant. remanufacturing process. Several recommendations are given to get a low cost and quality assured remanufacturing. The recommendations involves the time is made to a REFERENCES minimum, no damaged material, efficient in component replacement and testing done thoroughly.

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