The ease of replacing components of electronic products: A systematic literature review and case study

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Introduction

Electronic devices such as laptops, desktops, display monitors, smartphones and tablets are a major source of electronic waste, known as a waste of electrical and electronic equipment (WEEE) or e-waste. An estimated 57.4 million metric tonnes (Mt) of e-waste were generated in 2021 and is forecasted to reach 74.7 Mt by 2030 (Misra et al., 2021; Tian et al., 2022). On average, the lifespan of most electronic devices is 3 years (Forti et al., 2020). When an electronic product reaches its end of life/end of use, the users or owners are faced with the decision of how best to dispose of the item. Appropriate means of disposing of e-wastes are noted to be by returning it to the retailer or manufacturer, sending it to a third-party recovery agent (for repair, refurbishment or remanufacturing), or sending it to a specialised recycling facility (Kumar & Singh, 2014; Nagajothi & Felixkala, 2015). However, they are often indiscriminately disposed of as part of general waste or shipped to developing or under-developed countries for further use (Awuchi et al., 2020; Rao, 2014). However, in 2019 only 17.4% of the global e-waste generated was collected and recycled appropriately (Mohammed & Sindhu Vaardini, 2021).

Used electronic devices may be recovered through direct reuse, repair, reconditioning, refurbishment or remanufacturing (Curvelo Santana et al., 2021; Ijomah & Danis, 2019; Steuer, 2016). During product recovery (either through repair, refurbishment or remanufacturing), a critical stage is the replacement of dysfunctional components either with new, refurbished, reconditioned, repaired or remanufactured equivalents. However, a component replacement can only be performed after the product has been assessed and disassembled. This process is complex and time-consuming, and the decision of which components to replace, repair or recycle often relies on historical data, experience and the expected quality of returned items (Jaeger-Erben et al., 2021; Makov & Fitzpatrick, 2021).

However, significant literature gaps exist in the assessment of the techno-economic feasibility of replacing components of waste electronic products. To date, the complexity of electronic components and the potential viability of replacing dysfunctional components to give electronic devices a second or third life has been under-researched. This study attempts to fill this gap by presenting the state-of-art decision-making for component replacement during electronic product recovery either through repair, refurbishment, or remanufacturing. The study combines insights from exploratory research on understanding the different components and materials that are contained in the different components in electronic products, specifically laptops, tablets and smartphones, with data from an IT asset disposal (ITAD) company.

Methods

A systematic evidence mapping of the literature on electronic device assembly and characteristics was performed, using Scopus and ProQuest databases. Different combinations of specific keywords are used as search strings on the databases to generate the results. The initial search results were analysed in four stages. Duplicate (697) articles were removed, followed by the screening of titles where 10,146 were removed. Then, 332 articles were removed after screening the abstracts. Finally, full texts of the remaining articles were screened to remove 168 articles which were unrelated to the overall aims of this study. Subsequently, 55 articles were analysed and included in this study. Data from an IT asset disposal company was used to supplement the findings of existing literature. The data was collected through interviews with company employees, observations, and relevant documents in line with (Yin, 2014). This aided in the understanding of the nature of components and component replacement decision-making during the recovery of used electronic products. The company, which is 4 years old, specialises in the collection, recovery, and redistribution of used electronic products. This combination of data collection approaches increases the credibility of the outcome and enhances robust interpretations of the obtained data (Yin, 2014).

Results

Nine key electronic device component categories were identified and analysed. These are the: 1) battery unit; 2) data storage unit (e.g., hard drives or solid-state drives); 3) mechanical package and support (e.g., the hinges, screws and bolts); 4) display unit; 5) core electronic units (made of the capacitors, resistors and transistors); 6) integrated peripherals (e.g., keypads, touchpads, charging ports, USB ports etc); 7) cooling unit; 8) enclosure (or the back cover); and 9) printed circuit boards (PCB). As discussed in the literature the decision of which components are replaced in an end-of-use (EoU)/end-of-life (EoL) electronic product to give a second life, depends on sustainability considerations, product technical specifications and the quality of the EoU/EoL item. Sustainability considerations include the environmental, economic and social viability assessment, whereas the product technical specifications include the product design and the technological capability of the company to perform the component recovery. The quality of the returned product includes the condition of the returned item, quantity and timing of return. The component replacement decision-making at the company level was assessed to identify the economic viability and technical feasibility as the main considerations. The company relies on the experience of its technicians and historical data on component replacements and ease of recovering specific product models. Combining the data and evidence collected the electronic devices components, are clustered into three (3) types based on economic viability and technical feasibility. The typology developed is shown in table 2.

Table 2: Description of clusters of electronic components

S/N	Cluster	Description	Components
1	Repairable or replaceable without any economic constraints	Components that are easily accessible in electronic devices and are easily repairable. The environmental and economic rationale for repairing (if possible) these components or replacing them to return the product to usable standard is usually high.	Battery units Data storage units Mechanical package & support
2	Repairable or replaceable following detailed economic viability assessment	Components that can be repaired or replaced, following a comprehensive techno-economic viability assessment. This involves an assessment of the technical expertise needed to access, repair or replace components, availability of replacement parts, costs associated with repair or replacement, and associated environmental impacts. When costs outweigh benefits components are not repaired or replaced and the product may go down the recycling pathway.	Display unit Core electronic units Integrated peripherals
3	Not usually repaired or replaced	Components that are usually not repaired or replaced in electronic devices. This may be due to the design of the product, the technical feasibility of accessing the component, costs of repair or replacement and the associated environmental impact of repairs. In most cases, it is difficult to justify the rationale for a full repair or replacement of these parts.	Cooling unit Enclosure Printed Circuit Boards (PCB)

The results of this study indicate the significant emphasis placed on the assessment of the techno-economic feasibility and viability for component replacement during product recovery. The findings will be of interest to both practitioners in the IT asset disposal industry as a necessary knowledge to improve their decision-making on component replacement. It also presents the state-of-art which will be of keen interest to academics.

Conclusions

This study informs the techno-economic feasibility and viability of repairing and refurbishing electronic devices. Using evidence from the literature and the business sector, the study clustered electronic product components and created a typology for rapid decision-making processes for practitioners working in the field of electronic device repair and refurbishment. The findings from this study add to the rapidly expanding field of e-waste management. Although this study focuses on component replacement decision-making, the findings may well have a bearing on the environmental, economic and social impacts of improving e-waste management, informing on future circularity pathways.

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