engineering proceedings

MDPI

Proceeding Paper

Monitor Redesign Based on the 3R Principles (Reduce, Reuse, and Recycle) for Environmental Sustainability †

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† Presented at the 9th Mechanical Engineering, Science and Technology International Conference (MEST 2025), Samarinda, Indonesia, 11–12 December 2025.

Abstract

The rapid growth of electronic waste has created an urgent need for more sustainable product design. Current monitor designs often prioritize aesthetics and performance over repairability, reusability, and recyclability, leading to unnecessary material consumption and short product lifespans. This study focuses on redesigning a 24-inch monitor using the principles of reduce, reuse, and recycle (3R) to enhance environmental sustainability. The research examines five commercially available monitors. The redesign reduces material complexity, enhances modularity, and increases recyclability. The final concept features a lightweight structure (2.4 kg) made from 90% recycled plastic, magnetic bezel attachments for easy disassembly, and clear resin coding for material recovery.

Keywords: monitor; redesign; 3R

1. Introduction

Today's global patterns of production and consumption are causing serious and often irreversible social and environmental damage. If these patterns are not addressed promptly, their negative consequences may become permanent [1]. Design plays a vital role in reducing these impacts, as designers' decisions largely determine the effects of the goods and services we use [2]. In fact, approximately 80% of a product's environmental impact is determined during the early stages of the design process [3]. Designers influence key factors such as material selection, raw material processing, packaging, distribution, usage (to some extent), and disposal. Every decision made in designing a product or product–service system has a direct social and environmental impact, either positive or negative, on people and the planet [4].

The electronics industry is the largest and fastest-growing sector globally. Modern life depends heavily on technology to support a comfortable lifestyle, leading to a significant increase in the demand for and consumption of electronic devices worldwide. As a result, electronic waste (e-waste) is rising sharply, growing at a rate of 20–25% annually [5]. The combination of widespread use of electronics and their short lifespans has made e-waste the fastest-growing waste stream [6].

Consumers also need assurance that their products can be repaired when necessary, often through repair warranties. However, these warranties are frequently unfriendly to consumers, either due to restrictive terms or the high cost of repairs. Manufacturers often take deliberate steps to prevent non-experts from repairing electronic devices. These measures include restrictive product design, limiting repairs to authorized service centers, sales

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Academic Editors: Rusandi Noor, Sigiet Haryo Pranoto, Arbansyah, Sarjito, Waluyo Adi Siswanto, Agus Dwi Anggono and Taghfirul Azhima Yoga Siswar

Published: 20 May 2026

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tactics that discourage third-party repairs, and the use of intellectual property protections to block access to repair information [7].

Monitors are among the electronic devices that have seen rapid technological advancement, with manufacturers offering a wide range of features and improved performance. However, from a product design perspective, the monitor market has made limited progress toward environmentally sustainable design. Current designs often prioritize aesthetics, performance, and cost over sustainability, overlooking the environmental impact across the product's life cycle. Many monitors are built with components that are difficult to recycle or repair, contributing to the growing problem of unmanaged electronic waste. In addition, manufacturers frequently use internal components that cannot be easily replaced or repaired by consumers, reinforcing a disposable consumption model. This approach runs counter to sustainability principles, which emphasize waste reduction and the extension of product lifespan.

Most modern monitors prioritize aesthetic appeal and compactness, often at the expense of serviceability. A common issue is the use of plastic clips instead of screws to secure the casing. Although this design choice may enhance visual simplicity and reduce manufacturing costs, it makes disassembly difficult and risky. These clips often break easily, rendering the product effectively non-repairable once opened. Internally, many monitors contain integrated components that cannot be replaced individually. For instance, control boards or power supply units are sometimes embedded or soldered directly onto larger assemblies, requiring the replacement of entire modules rather than specific faulty parts. This design increases electronic waste and drives up repair costs, often making it more economical to replace the unit entirely rather than repair it. In addition, ports and connectors are frequently placed in inaccessible or non-standard locations, complicating routine servicing and cable replacement.

Given these challenges, there is an urgent need to reconsider how electronic products, particularly monitors, are designed, with a focus on enhancing their repairability, reusability, and recyclability. This research aims to apply the 3R framework as a design strategy to develop a more environmentally friendly monitor. By integrating sustainability principles into the early stages of product development, this study proposes a redesigned monitor that minimizes material waste, supports modular repair and maintenance, and facilitates end-of-life recycling. Ultimately, the goal is to contribute to broader efforts in sustainable product innovation and the advancement of circular economy practices. It is important to note that the redesign in this study focuses exclusively on the casing of the monitor rather than its electronic systems. This scope was chosen to target the structural and material aspects most directly influencing product sustainability, while acknowledging that future work could address internal electronics and power efficiency.

This research also aligns with the IEEE 1680.1-2018 standard, which provides criteria for the environmental and social responsibility assessment of computers, tablets, and monitors. The standard addresses aspects such as energy efficiency, sustainable material selection, design for disassembly, end-of-life management, and recyclability [8]. By referencing this standard, the redesigned monitor aims to meet globally recognized benchmarks for environmental performance, ensuring that the sustainability improvements are supported by established technical requirements while maintaining market relevance. This study is also aligned with the United Nations Sustainable Development Goal (SDG) 12, responsible consumption and production, which emphasizes the need to reduce resource consumption, improve product longevity, and promote material reuse and recycling [9]. An effective 3R implementation considers technical, economic, and environmental aspects in balance, thereby supporting circular economy principles and reducing negative environmental impacts [10].

https://doi.org/10.3390/engproc2026137003

2. Materials and Methods

2.1. Case Study

This research examines five monitors presented in Figure 1, each with a 24-inch screen size. This size was selected because 24-inch monitors are among the most commonly used in everyday activities. They are widely adopted for personal use, such as work and home multimedia, and are also prevalent in professional environments, including cashier stations in convenience stores, bank teller desks, customer service centers, and office workspaces. Their popularity stems from the balance they offer between screen size and usability, providing a comfortable viewing experience while remaining versatile across different settings. This makes them particularly relevant as research subjects in efforts to apply sustainable design principles to monitor redesign. In addition to screen size, brand popularity reflected in sales volume was also a key criterion in selecting the monitors for this study.



Figure 1. Case studies.

The five monitors share several common features, including slim bezels for an immersive viewing experience, matte plastic casings, and rear-positioned connectivity ports that contribute to a minimalist design. Models from brands such as LG, Dell, and ASUS reflect current design trends that prioritize aesthetics. One of the most notable features is the use of matte plastic as the primary material for both the casing and the stand, giving the monitor a modern look while keeping it lightweight. The stands are generally designed to be simple yet stable, although certain models, such as those from Dell, offer greater flexibility in screen positioning. Connectivity ports are typically located at the lower rear of the monitor, which contributes to a clean front appearance but can sometimes reduce accessibility.

2.2. Research Process

The study began with an evaluation of the case study designs using the 3R framework to assess their alignment with sustainable design principles. The 3R analysis helps identify weaknesses in existing designs while also revealing opportunities for sustainable innovation.

2.2.1. Reduce

The 'reduce' principle focuses on minimizing the use of materials and energy throughout a product's life cycle. This includes reducing the consumption of non-renewable resources through input substitution, process improvements, and more efficient management of production and consumption stages [11]. In practice, this means designing monitors with smaller footprints, fewer components, and lower power requirements. For example,

a monitor with a thinner, lighter bezel and only essential components helps reduce both material and energy use [12].

2.2.2. Reuse

The 'reuse' principle focuses on extending the lifespan of products by using them for the same or a similar purpose without major modifications [13]. Products that are easy to disassemble tend to have higher rates of reusability, helping to reduce waste and conserve resources [12]. In short, reuse involves designing a monitor to be durable, repairable, and appealing enough to remain in use rather than being discarded and sent to landfill.

2.2.3. Recycle

The 'recycle' principle involves processing spent products into raw materials for the creation of new products. It includes reprocessing waste materials into products, materials, or substances, whether for their original use or for other purposes [11]. In the context of computer monitor design, this means that when a monitor reaches the end of its life, its glass, plastics, and metals can be efficiently recovered and reprocessed into new electronic devices.

Table 1 summarizes the definitions of each 3R principle, along with key indicators used to evaluate the sustainability of a product's design, specifically in the context of monitor redesign. These indicators are organized to support both qualitative and quantitative assessments in a systematic way.

Table 1. The indicator of the 3R Framework.

3R	Definition	Indicator
Reduce	Designing products to use fewer materials and resources	• Reducing material quantity and diversity while maintaining full functionality. • Minimizing environmental impacts throughout the product life cycle by means of design. • Minimizing the number of components and simplifying connections.
Reuse	Designing products to support the reuse of both the product and its components	• Improving product durability through material selection or design. • Enabling repair and maintenance throughout the product's usage period. • The product's design supports extended use through maintenance and repair.
Recycle	Designing products to enable material recovery after disposal	• Selecting materials that are reusable or recyclable. • Ensuring that product materials can be identified, sorted, disassembled, and separated for recovery. • Enable material recovery through reuse, biodegradation, recycling, upcycling, downcycling, or energy recovery.

Source: [7,14–16].

In the next stage, a new monitor was developed using the product development process outlined by Ulrich et al. [17]. Needs statements were collected through interviews with technicians and repair professionals who had direct experience with monitor repair. The interviews focused on common issues in existing designs, challenges during disassembly and repair, and whether components could be repaired or required replacement. Based on the evaluation results and the identified needs, product specifications for the new monitor

were established. These specifications guided the development of three alternative design concepts, from which the most suitable option was selected.

In the final stage, the new design was evaluated by comparing its performance with the case study designs using the 3R principles and consumer feedback. Consumer feedback was gathered through a survey designed to assess the design's performance in relation to user expectations and sustainability goals. The respondents were 100 university students and office professionals, as 24-inch monitors are widely used in both academic and office environments. Their regular experience with this monitor size ensured that the feedback provided was practical and relevant to the study.

3. Results

3.1. Evaluation Results of the Case Study Designs

This section presents the results of the design evaluation of five 24-inch monitors using the 3R framework. Each principle is qualitatively assessed to identify key limitations and opportunities for sustainable redesign as presented in Table 2.

Table 2. Findings from the 3R-based evaluation of the case study designs.

Case Study	Reduce	Reuse	Recycle
Acer Nitro XV252Q_F (Acer Inc., Xizhi—New Taipei City, Taiwan)	Overuse of layered plastic components, decorative, non-functional elements	Semi-integrated ports; poor modularity	No material labeling for mixed plastics
LG 24QP500-B (LG Electronics, Seoul, Republic of Korea)	Uses multi-layered plastic casing	Permanently integrated HDMI/USB ports	Virgin PC/ABS blend with no recycled content
ASUS VZ249HFA-G (ASUSTeK Computer Inc., Taipei, Taiwan)	Use of adhesives and unnecessary structural layers	Low accessibility and uses plastic clips on the bezel	Mixed plastic with painted logo
Alienware AW2521H (Alienware/Dell Technologies, Miami—FL, USA)	Over-engineered body with non-functional decorative parts	Internal parts sealed with metal casing	No recyclable composite layers
Samsung S31C 75Hz (Samsung Electronics, Suwon, Republic of Korea)	Simpler material use but still virgin plastic	Plastic clips on the bezel increase the risk of cracking during disassembly	20% recycled plastic content and left unpainted

Across the five models analyzed, most did not optimize material use. The Acer and Alienware models feature layered decorative elements and thick casings, resulting in unnecessary material consumption. The ASUS model makes extensive use of adhesive and internal reinforcements, which complicates manufacturing and disassembly. Samsung shows better material efficiency with a simpler design, although it continues to use a bezel panel with clips. Technicians noted that complex internal layering and bezel designs are difficult to manage during repair and offer little benefit to structural strength.

Modularity is a major issue across the case studies. LG and Alienware have sealed ports and components, making them nearly irreparable. ASUS lacks tool-less access and uses adhesives that discourage disassembly. Acer allows some access but still lacks a clear separation between parts. Samsung offers slightly easier opening via rear screws, but component replacement is still limited.

3.2. New Monitor Design

3.2.1. Need Statements

The identification of need statements was carried out through interviews with technicians who have extensive experience in servicing and repairing monitors. The responses revealed several recurring issues that were consistently mentioned across respondents, highlighting key limitations in current monitor designs. Notably, the complexity of casing structures, restricted access to internal components, and the prevalent use of non-modular assemblies were identified as major barriers to efficient repair. In addition, technicians emphasized that the most frequent failures occur in the power supply units and input ports, while display panels, once damaged, are typically non-repairable and must be replaced entirely. These insights provide a valuable foundation for redefining user-centered design priorities in line with the principles of sustainability and serviceability. Table 3 summarizes the interpreted responses from the interviews, organized into five main thematic points. Each response is supported by a direct quotation to preserve the authenticity and practical relevance of the technicians' perspectives.

Table 3. Need statements.

No.	Interview Topic	Direct Quotation	Need Statements
1	Design issues in current monitors	"Nowadays, monitors mostly use clips instead of screws. So, when opened, they break easily."	The monitor enclosure enables safe and repeated access without damage.
2	Challenges during monitor repair	"Sometimes we have to disassemble the whole thing just to replace one cable. Wastes time."	The internal monitor layout allows individual components to be accessed and serviced without full disassembly.
3	Decision to repair or replace	"If the panel is damaged, we usually replace it with a new one. But if it's the power adapter or fuse, that can still be fixed."	Internal electronic components function independently and can be repaired or replaced without removing the display panel.
4	Most commonly damaged parts	"The most frequent damage I see is in the power supply or input port. Sometimes the screen is scratched or only half-lit."	High-risk components such as power ports and input connections are designed for durability and easy replacement.
5	Ease of disassembly and reassembly	"Disassembling is difficult, especially if the casing is thin. A wrong pry can easily crack it."	The monitor casing enables tool-friendly disassembly and reassembly without risk of structural damage.

3.2.2. Product Specifications

Following the identification of user needs and product limitations, this stage aims to define measurable and realistic design goals for the redesigned monitor. The target specifications serve as a foundation for guiding subsequent decisions in concept selection and product detailing, ensuring alignment with the 3R principles and technical feasibility. These specifications reflect critical factors such as material choices, component accessibility, ease of disassembly, modularity, and recyclability, each informed by technician feedback and sustainability benchmarks. Table 4 outlines the target specifications, including the ideal and acceptable values.

Table 4. Product specifications.

No.	Specification	Metric/Unit	Ideal Value	Acceptable Range
1	Total product weight	Kilograms (kg)	≤2.5 kg	≤3.0 kg
2	Number of casing components	Unit count	≤6 parts	≤10 parts
3	Number of screws on casing	Unit count (pcs)	≤10	≤15
4	Repair access to main components	Accessibility level	Tool-accessible and modular	Semi-integrated, accessible
5	Component modularity (panel, PSU, I/O)	Modular design criteria	Fully separable units	2 of 3 separable
6	Recyclability of all material components	Percentage (%)	≥80%	≥60%
7	VESA mount compatibility	Dimension standard	75 × 75 mm	Must meet standard
8	Surface marking for recycling (resin codes)	Present/not present	Clearly labeled	Present on all plastic parts

The target specifications listed in Table 4 were derived based on the evaluation of case study designs, key issues highlighted in technician interviews, and sustainability goals aligned with the 3R framework. These specifications guide the concept selection and detail design stages, ensuring that the redesigned monitor achieves both environmental and functional performance goals. Based on the design objectives and sustainability targets, the recommended material for the redesigned monitor casing is recycled acrylonitrile butadiene styrene (rABS) with a minimum of 90% post-consumer recycled content. This thermoplastic offers a balance of mechanical strength, impact resistance, and dimensional stability, making it suitable for protecting internal components while withstanding repeated assembly and disassembly cycles [18].

3.2.3. Concept Designs

This step is essential to systematically explore various combinations of design elements that align with the principles of reduce, reuse, and recycle. By generating multiple concepts with different configurations as presented in Table 5, the design team can compare their trade-offs in terms of sustainability and functionality. Each concept is formed through modular decisions across structural frame design, connection methods, stand configuration, and material strategies, all derived from insights gathered through 3R evaluation and technician interviews.

Table 5. Combination table for generating concept designs.

Description	Concept A	Concept B	Concept C
Frame or chassis	Single thin wall	Three-layer system	Single thin wall
Connection type	Screws	Magnet	Screws
Stand design	Fully articulated with perforated	Integrated L stand	Tripod
Back door	Rectangle	U shape	Circle

As shown in Figure 2, concept A prioritizes material efficiency by minimizing the number of components and eliminating unnecessary features while still maintaining full usability through a fully articulated stand. The design uses a single-layer casing with minimal screws and a simple rectangular back cover secured with just two fasteners.

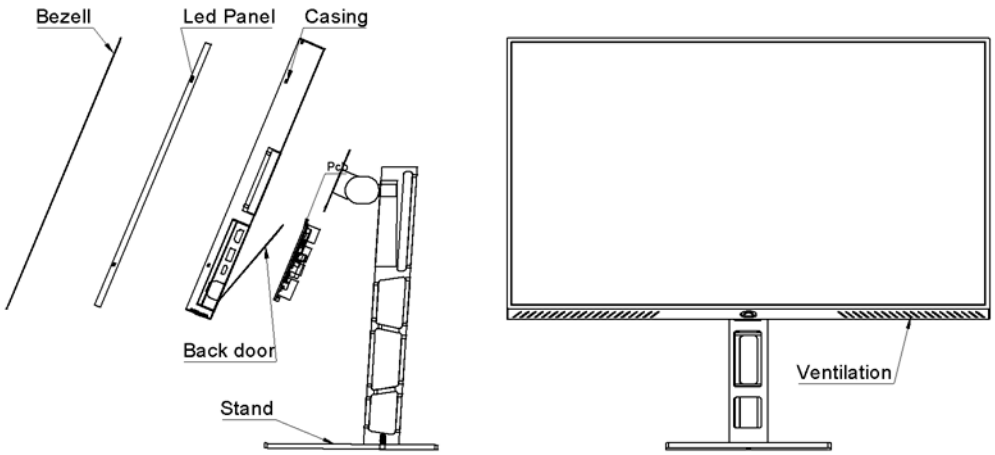


Figure 2. Concept A.

In contrast, concept B is illustrated in Figure 3, and it emphasizes serviceability, featuring a modular internal structure where components can be individually accessed and replaced. It incorporates magnetic attachments on the bezel and uses an integrated stand directly connected to the casing. However, this design results in a slightly heavier and more complex structure.

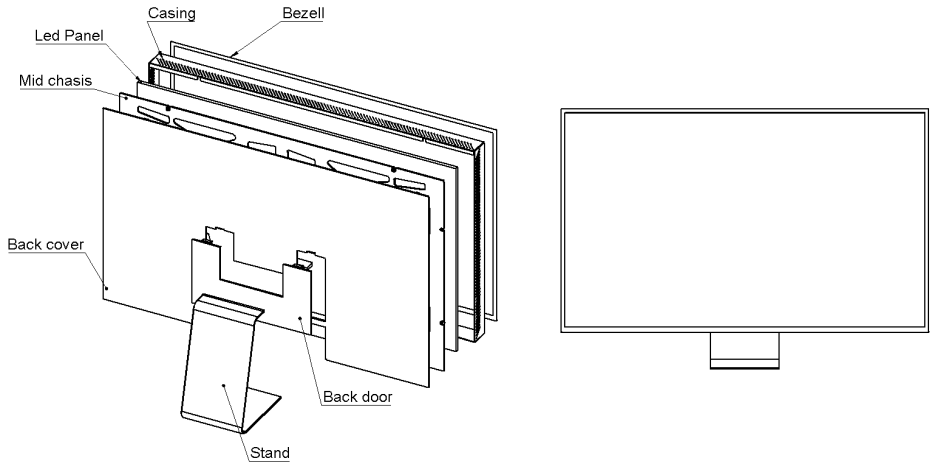


Figure 3. Concept B.

Concept C, presented in Figure 4, also focuses on material efficiency but with an even lighter and simpler casing. It features a circular back cover with a sliding mechanism for tool-less disassembly and uses a tripod-style stand. Additionally, ventilation slots are integrated into the lower bezel and stand to support internal airflow and thermal performance.

A concept screening matrix was used to evaluate each alternative against key criteria derived from Table 4, such as product weight, modularity, ease of disassembly, recyclability, and compliance with standard interfaces. Table 6 presents the concept screening table, which is used to compare multiple product design alternatives based on key evaluation criteria. Each concept is assessed using a qualitative scoring system where the symbols (+), (0), and (–) indicate performance relative to a baseline. A (+) means the concept performs better on that criterion, a (0) indicates similar or equal performance, and a (–) shows the concept performs worse. This method helps identify which design alternative best meets the product requirements and should proceed to the next stage of development.

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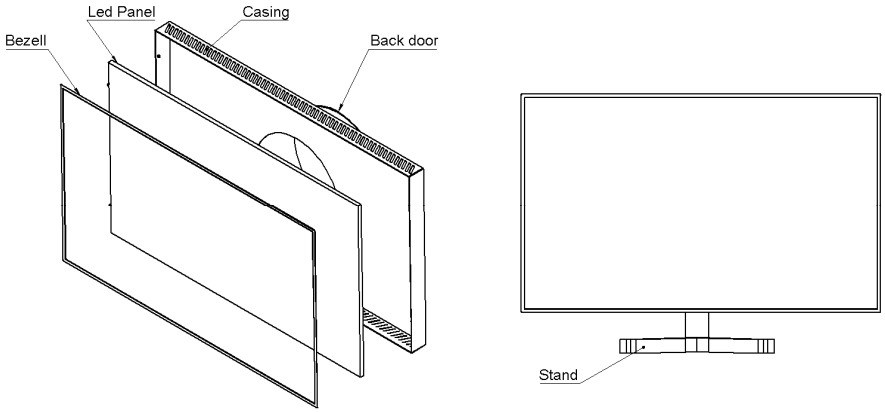


Figure 4. Concept C.

Table 6. Concept screening table.

Criteria	Concept A	Concept B	Concept C
Product weight	0	−	+
Number of casing components	+	−	+
Number of screws on casing	0	+	+
Repair access to main components	+	0	−
Component modularity (panel, PSU, I/O)	+	+	+
Recyclability of all material components	+	+	+
VESA mount compatibility	0	−	−
Surface marking for recycling (resin codes)	+	+	+
Overall score	5	1	4
Continue?	Yes	No	No

Based on the product concept screening results, Concept A emerged as the most suitable design candidate. It demonstrated strong alignment with the 'reduce' principle through its minimal component count and lightweight structure while also satisfying key functional targets such as VESA mount compatibility and modular access to internal components. To enhance serviceability, the final design integrates the magnetic connector mechanism from Concept B for selected casing areas, particularly on the bezel, enabling easier access during maintenance without compromising structural integrity.

The final concept as illustrated in Figure 5 is concept A, which focuses on material efficiency and simplified construction, with an improvement in the form of a magnetic bezel attachment, inspired by concept B, to enhance serviceability.

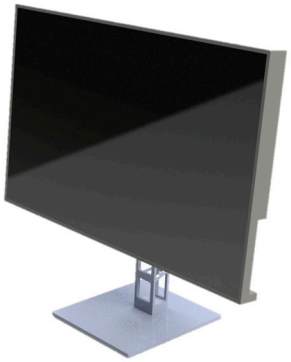


Figure 5. Final concept monitor.

The redesigned monitor weighs only 2.4 kg, including the stand, which is significantly lighter than most 24-inch monitors available on the market, contributing to reduced material

usage and lower transportation impact. Its flat, compact design also optimizes packaging space, minimizing environmental impact during distribution. The outer casing is made from 90% recycled plastic and deliberately avoids the use of paint, supporting recyclability and reducing environmental harm. This hybrid solution combines the material efficiency and simplified architecture of Concept A with the user-friendly disassembly features of Concept B. The result is a well-balanced and environmentally responsible monitor that is lightweight, maintainable, and designed with sustainability in mind throughout its lifecycle.

3.3. Design Evaluation and Testing

Table 7 presents a comparison between the average specifications of five existing commercially available 24-inch monitors and the redesigned monitor concept. The comparison highlights key physical, material, and functional attributes relevant to sustainability, maintainability, and user convenience. This side-by-side assessment provides a clear view of how the redesigned concept addresses the objectives of reduced material usage, improved recyclability, and enhanced serviceability without compromising essential monitor functions.

Table 7. Case studies vs. redesign monitor.

Criteria	Average of 5 Case Study Monitors	Redesign Monitor
Total Weight	3.2 Kg	2.4 Kg
Casing components	12 Parts	6 Parts
Fastener Type	Plastic clips	Screw + magnet
Material composition	100% virgin PC/ABS blend	90% recycled ABS, bo paint
Modular access	Low (integrated assemblies)	High (separable PSU, ports, panel)
Recyclability	40–50%	≥90%
Recycle labeling	Absent	Present on all plastic parts
VESA compatibility	Some models only	Fully compliant

The reduction in total weight from an average of 3.2 kg to 2.4 kg not only decreases material usage but also facilitates easier handling during assembly, transport, and repair. By reducing the casing components from 12 to 6 parts and replacing plastic clip fasteners with a combination of screws and magnets, the design enhances modular access, making it easier to replace or upgrade individual components. The shift from a 100% virgin PC/ABS blend to 90% recycled ABS with no paint improves recyclability to over 90%—a substantial increase from the 40–50% range of current models—while also aligning with sustainable material sourcing goals. The addition of clear recycling labels on all plastic parts further supports proper end-of-life processing. Lastly, ensuring full VESA compatibility enhances adaptability, allowing the monitor to be mounted or repositioned according to user needs. Collectively, these improvements show that the redesign integrates sustainability features while retaining and, in some cases, improving upon established functional standards.

The results of the concept testing indicate that the final design, which is a combination of Concept A with a magnetic bezel inspired by Concept B, is well received by users across different segments. The product's minimalist visual appeal, lightweight impression, and environmentally conscious design choices were particularly appreciated by the respondents. The survey played an important role in confirming that the redesigned monitor, while integrating sustainability features such as recycled materials, modular construction, and improved recyclability, remains aligned with user expectations for a well-established product category. Monitors have long been standardized in terms of functionality and ergonomics, so it was crucial to ensure that the redesign did not introduce radical changes that could disrupt usability or performance.

4. Conclusions

This study redesigned a monitor to improve its environmental sustainability. By evaluating five 24-inch monitor models on the market using the 3R framework and interviewing experienced field technicians, several key limitations in current designs were identified. These included excessive material use, low modularity, limited repairability, and poor end-of-life recyclability. However, the case studies were limited to five 24-inch models, which, although common, may not represent the full range of monitor designs and technologies available worldwide. In addition, the redesigned prototype is still conceptual and has not been tested in real production settings. Future research could focus on examining the monitor's electrical system in more detail, including circuit design, power supply improvements, and modular electronic components. Building a functional prototype based on the redesigned concept would also allow testing its feasibility, performance, and actual environmental impact in real-world conditions.

Author Contributions: Conceptualization, I.N. and R.A.; methodology, I.N.; software, R.A.; validation, I.N., R.A., R.F. and D.R.; formal analysis, R.A.; investigation, I.N.; resources, I.N.; data curation, R.A.; writing—original draft preparation, I.N. and R.A.; writing—review and editing, R.F. and D.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Universitas Muhammadiyah Surakarta grant number PID-4484 and the APC was funded by Universitas Muhammadiyah Surakarta.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of Universitas Muhammadiyah Surakarta.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to the presence of personal information.

Conflicts of Interest: The authors declare no conflicts of interest.

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