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RESEARCH ARTICLE

Repair Over Replacement: Consumer Behaviours and Repair Practices for Electronics in the Global South

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Abstract

Comprehensive data on consumer behaviour regarding the use and repair of electronic products in the Global South remains limited. This study's primary data collection method involves household surveys (n = 450), representing diverse socio-economic groups, to analyse 23 electronic products in Lahore (Pakistan). It examines: (i) key trends in product failures, repair costs, and spare part sourcing, (ii) householder attitudes towards repairs, and (iii) comparisons with repair practices in the Global North. Repair costs range from $5 - $100 for fridges, while air conditioners (ACs) require repairs most frequently. Major repairs occur within a year for ACs and seven years for flat display panel TVs, depending on usage, product quality and climate. Householders in the Global South prioritise repairs over replacements, primarily due to economic constraints and value recovery, contrasting with sustainability-driven repair advocacy in the Global North. The findings underscore how affordability, accessibility, and cultural attitudes shape repair behaviours.

Keywords Electronics · Repair · Product Value · Sustainable Consumption · Consumer Behaviour · Circular Economy

Abbreviations Electrical and Electronic Equipment (EEE), Waste Electrical and Electronic Equipment (WEEE), European Union (EU), Circular Economy (CE), European Commission (EC), Large Household Appliances (LHA), Small Household Appliances (SHA), Flat Display Panel (FDP), Air Conditioners (AC) Cathode Ray Tube (CRT), Television (TV), and Personal Computers (PCs)

Introduction

Electrical and electronic equipment (EEE) represents a significant share of global resource consumption and waste. In 2022, an estimated 62 million tonnes (Mt) of waste electrical and electronic equipment (WEEE, or e-waste) was produced globally, compared to 34 Mt in 2010 (Baldé et al., 2024). In the European Union (EU) alone, the premature disposal of functioning electronic products results in 35 Mt of waste annually, leading to 30 Mt of wasted resources and 261 Mt of greenhouse gas emissions. This costs €12 billion to consumers who choose replacement over repair (European Commission, 2023). Maximising product lifetimes, in particular, through repair, is prioritised to prolong the useful lifespan (Jaeger-Erben et al., 2021; Sabbaghi et al., 2016), as it aligns with the circular economy (CE) approach to promote the responsible and cyclical use of resources by retaining the value of materials and products as long as possible (Moraga et al., 2019).

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Repair refers to restoring the original functionality of a product after being broken, damaged or malfunctioning (Cordella et al., 2019; Potting et al., 2017). For EEE, this means replacing faulty (already failed) parts and components and repairing them to be functional again (Blomsma et al., 2019; Tecchio et al., 2016). It involves the diagnosis of a faulty component, disassembly for the accessibility or visibility of that component, followed by the repair of the defective component, and reassembly of that product (Pozo Arcos et al., 2021, 2020). While much research focuses on improved repairability, including TÜV SÜD repairability standard, disassembly map and HotSpot mapping tool (TÜV SÜD, 2023; De Fazio et al., 2021; Flipsen et al., 2020), product repair and its socio-economic structural conditions have been overlooked, specifically by individual product owners (Svensson-Hoglund et al., 2022; Llorente-González and Vence, 2020; McLaren et al., 2020).

Understanding the linkages between the compulsion to repair, the experience of repair, and the larger sociocultural environment remains a challenge (Korsunova et al., 2023). The choice of repair is essentially up to the consumer and is affected by technical, emotional and value aspects (Nazlı, 2021). The product's design determines the economic feasibility and complexity of product repair (Sabbaghi and Behdad, 2017) and gives the user the choice between repair and repurchase (European Commission, 2018). With technological advancement, the increasing design complexity in electronic appliances hinders product repairability for users and technicians alike (iFixit, 2019). Cost dynamics further complicate this trend. High labour costs pose a barrier to repairs, often making repairing items more expensive than buying new ones (Reimann, 2024). For example, the average price of a new free-standing fridge in the UK is £650 (or £787 for an integrated model), while the average repair cost ranges from £85 to £385 (Reynolds et al., 2024).

Another significant barrier is the legal restrictions imposed by manufacturers (Rosborough et al., 2023; Svensson-Hoglund et al., 2021). In the Global North, the repair landscape is shaped by manufacturers' (authorised) control over spare parts, diagnostic tools, and technical information, limiting consumers' ability to seek affordable alternatives. The formalisation of repair services through authorised channels by limiting competition, while intended to ensure quality and availability of spare parts, has the effect of inflating prices and reducing accessibility (Perzanowski, 2022). Consequently, even consumers inclined towards repair are frequently deterred by the inconvenience of long waiting times, the logistical challenges of accessing authorised centres, and the lack of transparency in pricing (Güsser-Fachbach et al., 2023; Korsunova et al., 2023; Russell et al., 2023; Svensson-Hoglund et al., 2021).

In contrast, the significance of product repair has remained dominant in many parts of the Global South. In many low- and middle-income countries, repair remains ingrained in societal norms rather than recycling or replacing household appliances. This reflects economic considerations and a cultural and environmental ethos that values resourcefulness and product longevity. Pakistan, in particular, faces a significant challenge, as no formal e-waste management infrastructure is in place (Baldé et al., 2024). Instead, the country relies heavily on a robust informal sector, characterised by self-employed or small independent businesses (Lepawsky et al., 2021). With a population of over 241.5 million, Pakistan is classified as a lower-middle-income country with a gross national income (GNI) per capita ranging from $1,136 to $4,465 (Pakistan Bureau of Statistics, 2023; The World Bank, 2023a), and a reported gross domestic product (GDP) per capita of $1,596 (The World Bank, 2023b). Notably, 54% of the country's population belongs to the middle-income group, defined as those earning $10 to $40 per day, and are assumed to drive future growth and consumer trends (Ali, 2022; Rehman et al., 2022). The lower-income group makes up 45.3% of the country's population, while the high-income group accounts for only 0.6% (The World Bank, 2023c). Pakistan presents a markedly different context for understanding repair practices in these economic conditions.

The studies assessed in this literature review are overwhelmingly from the Global North, focusing on design, repairability standards, and policies suited to formal economies with strong consumer protections and service infrastructures. There is a limited understanding of how repair operates in the Global South, where socio-economic conditions create distinct dynamics.

This study addresses this gap by examining consumer attitudes toward product repair and the broader repair practices within the cultural context of Pakistan (South Asia). It combines qualitative and quantitative analyses of 23 household products based on a structured questionnaire survey (n = 450) conducted among three socio-

economic groups in Lahore: lower-income (<$300), middle-income ($300–$1,200), and upper-income (>$1,200) households.

The research is guided by three key objectives:

1. To identify the frequent product failures per product category. This includes analysing possible causes, solutions, costs, spare parts availability, and product repair duration.
2. To examine how socio-economic differences influence repair behaviour. The study investigates consumer preferences for repairing specific products and explores how financial and cultural factors shape repair frequency and maintenance practices.
3. To determine the key barriers and enablers affecting household appliance repair. This includes identifying obstacles such as cost, accessibility of skilled technicians, and availability of spare parts, as well as factors that facilitate repair and maintenance.

This study further compares local repair practices in Pakistan with those in the Global North, highlighting differences in repair culture, accessibility, and sustainability implications. The findings from this study suggest that repair practices are widely used as a responsible and cost-effective way of extending the lifespan of products, and it is important to encourage the adoption of sustainable consumption patterns.

Methodology

Research Area

The research was conducted in Lahore city, northeast of Punjab, near the Indian border (see SI Figure A1). Lahore is the capital of Punjab province and the second largest megacity in Pakistan, covering a total area of 1,772 km² with a population of 13.9 million (Government of Punjab, 2023). Considering the similarities in major cities of Pakistan, such as geographical location, local infrastructure, socio-cultural, and economic status (Azam et al., 2020). The study conducted in Lahore can be considered one of the leading examples at the national level.

Like in other developing countries, it is a societal norm to go for product repairs, as shown in Figure 1. A shared belief behind product repair is value for money and responsibility in spending. Either the consumer (observes and then conveys) or self-employed technicians identify the fault. This entails detecting the underlying issue, replacing or mending faulty components, and testing to verify that everything is working as intended. If maintenance, deep cleaning, or parts replacement are needed, all will be handled through them. Products go through multiple repairs before being hibernated/ disposed of.

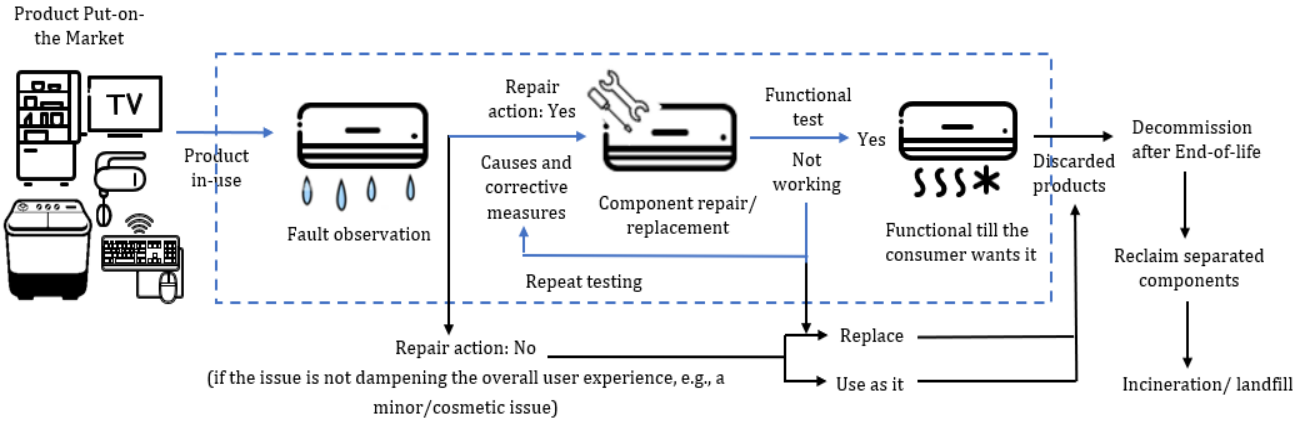

Figure 1 The Linear Economy Model (take-make-dispose). The blue arrows/ dotted boundary highlights the circularity within the system (product repairs in the use phase) and the research focus of this study.

For better insights, surveys cover households as they have their own metabolism, requiring material throughput to support inhabitants and activities (Baccini and Brunner, 2012). Surveys were conducted in three residential neighbourhoods (lower-income, middle-income, and upper-income urban households) to understand the insights of household product repair based on their socio-economic status. The selected areas are based on the property value among home buyers and investors in Lahore (Federal Board of Revenue, 2022).

Selection of Products and Identified Components

Following the European Commission's WEEE Directive (2012/19/EU) categories: I. temperature exchange equipment, II. screens, IV. large household appliances (LHA), V. small household appliances (SHA), and VI. small IT and telecommunication equipment (European Commission, 2012), we investigated a representative selection of a wide range of household products based on their profusion in society. Category III. lamps have been excluded from this study due to their non-repairable design structure. Each category includes products based on similar applications, comparable average weights, material compositions, end-of-life (EoL) characteristics, and lifespan distributions (Baldé et al., 2015). Table 1 provides the inventory of selected products studied in this repair study. In total, 23 different products were selected from the categories mentioned above.

Table 1 List of products per category studied in the product-repair study and type of repair (part replacement or product maintenance) suggested per product (products regrouped together based on similar functionality)

WEEE Directive category		Product Description	Recurring repaired parts
Category I. Temperature exchange equipment		Fridges (incl. combi-fridges) and Freezers	Compressor, capacitor, circuit breaker, motor, ball valve, defrost timer, fan, thermistor, rubber, coolant refill.
		Air Conditioners (household installed and portable)	Compressor, capacitor, circuit breaker, fan motor, thermostat, sensor, coolant refill.
Category II. Screens		IT Laptops (incl. tablets)	Power connector, screen, motherboard, hard disk drive (HDD), battery, processor, random access memory (RAM), read only memory (ROM).
		CRT Monitors and CRT TVs	Display system, motherboard, power connection, speakers, remote control, batteries.
		Flat Display Panel Monitors (LCD, LED) and Flat Display Panel TVs (LCD, LED, Plasma)	Display system, circuit board/motherboard, software maintenance.
Category IV. Large household equipment (LHA)		Washing Machines (incl. combined dryers) and Dryers (wash dryers, centrifuges)	Motor, belts, seals, tub, pumps, sensors, control panel, washing drum, ball bearings, door.
		Household electric fan	Motor, power connection, fuse, capacitor.
		Leisure (large exercise, sports equipment)	Belts, supports, chain system, circuit board, system reset.
Category V. Small household equipment (SHA)		Microwaves	Heater filament, motor, door seals, circuit boards, keyboard/touch sensors.
		Other Small Household (irons and sewing machine)	Power cord, heater, fuse, motor.
		Food (toaster, grills, food processing)	Heating filament, seals, motor, blades.
		Vacuum Cleaners	Brushes, power cord, battery, electric circuit.
		Personal Care (toothbrushes, hair dryers, razors)	Head, battery, power cord, power circuit.
		Household Tools (Water pumps)	Impellers, seals, rolling bearings, shafts, electric rotor, rubber, motor winding
		Household Medical (thermometers, blood pressure meters, blood sugar meters)	Batteries, sensor, processor.
Category VI. Small IT and telecommunication equipment		Desktop PCs (excl. monitors, accessories)	Motherboard, HDD, graphic card/screen panel, processor, RAM, ROM.
		Printers (scanners, multifunctional, faxes)	Toner, driver reinstallation, debugging.
		Telecom (cordless) phones, answering machines)	Wire/cable connection, batteries, screen, and dial pad.
		Mobile Phones (incl. smartphones, pagers)	Screen, batteries, charger.

A product is composed of numerous parts. To simplify the assessment, this study focuses only on functional parts (both hardware and software) that serve a product's primary or secondary function. The primary function is necessary to accomplish a product's intended use, while a secondary function supports, complements, or improves the primary function (Cordella et al., 2019). Table 1 shows an overview of the suggested common faults/ functional repairs by household consumers and technicians (parts and/ or maintenance) per product.

Sample Size

Based on the 2023 Pakistan Bureau of Statistics Censuses results, the estimated population of Lahore is 13.9 million (Pakistan Bureau of Statistics, 2023). A confidence level of 95% was considered, with a confidence interval of 5 ($e \neq 0.05$). We used Slovin's formula to determine that a minimum of 400 samples/respondents is required for conducting the research. To ensure accurate and reliable data, a decision was made to increase the number of surveys by at least 50 in case of any failed interviews. Additionally, to achieve comparable results, the sample size is relative to the size of the income groups. This approach ensured that the data collected was comprehensive and representative of the population surveyed.

450 semi-structured, face-to-face interviews were conducted anonymously in early 2023 through a door-to-door recruitment approach. While the study initially aimed to employ a random sampling strategy using online survey software, logistical constraints necessitated a convenience-based approach, with participation dependent on respondents' availability and willingness to engage. Each interview lasted approximately one hour, with no enumeration or compensation provided to participants. The questionnaires were administered in paper format and personally conducted to encourage open and honest responses, and ensure higher credibility. The interviews were conducted primarily by the author, with occasional assistance from family members to facilitate the process. Prior to the interviews, participants were thoroughly briefed on each product category to ensure informed engagement. Respondents were cooperative and engaged throughout the interviews, with no instances of refusal.

The survey areas selected for upper-income households (n = 3) are the Model town, Garden town, and Gulburg. For middle-income households (n = 243), the survey areas selected are Gulshan e Ravi, Samanabad, Allama Iqbal town, Sabzazar, Johar town, and Baghbanpura. Survey areas selected for lower-income households (n = 204) are Harbanspura, Gawalmandi, Sanda, Wagha, Gajju Matta, Shahdara, and Bhati. This affirms that the survey represents a good cross-section of the Lahore population (socio-economic groups and walks of life) by the random approach of collecting the interviews.

Household Questionnaire

This study's primary data collection method involved semi-structured interviews (see SI Table A1), designed to explore the relationship between consumption attitudes and product repairs in different socio-economic backgrounds. The interviews followed a general thematic guide, ensuring consistency while allowing for in-depth insights.

To provide a comprehensive understanding, the survey is based on two sections. Section one consists of the socio-economic composition of survey participants, including key demographic variables such as location, age group, gender, education level, employment, and monthly income. Section two comprised product-specific questions addressing aspects such as products put on the market, in-use and hibernated stocks, usage patterns (e.g., faults, frequency of repairs, product lifetimes), and end-of-life (EOL) disposal behaviours. The findings from this survey necessitated the development of two parallel research papers, with this particular study centring on consumer attitudes toward product repair. The interviews followed a standardised set of questions, repeated for each of the 23 selected products. A sample of these questions for air conditioners (ACs) is provided below:

- Does your currently operational AC effectively cool the room?
- Have you had any repairs conducted on your AC over the past two years? If yes, what specific issue or fault necessitated your AC repair?
- Please specify the amount you paid and the time for the repair services rendered on your AC.
- How often has it been serviced or repaired over time, and when did it need its first major repair?

- What motivated you to seek repairs for your AC? What was your primary motive for repairing the product?
- What challenges did you encounter when repairing your AC? What was your primary barrier to fixing the product?

Based on early review feedback, section 3 was subsequently added to incorporate additional insights, particularly addressing the perspective of repair technicians. To enhance the study's analytical depth, approximately nine repair technicians were interviewed, providing valuable insights into fault diagnosis, repair solutions, and spare part sourcing. This structured yet flexible approach allowed for the collection of detailed, comparable data across a diverse range of products, facilitating a deeper understanding of consumer decision-making regarding product repairs.

Statistical Analysis

Regression analysis and the Freeman-Halton exact test were applied to evaluate whether the categorisation of respondents into three socio-economic groups (lower, middle, and upper income) and repair frequency was analytically meaningful to respective product usage.

First, the coefficients between the repair frequency for each product-income group combination were calculated using the linear regression model (Equation 1) (Wooldridge, 2019).

$$Repair\ Frequency_{ij} = \beta_0 + \beta_1 D_{Lower_j} + \beta_2 D_{Upper_j} + \beta_3 (Family\ Size_j)$$

$$+\beta_4 (Education_j) + u_i + \varepsilon_{ij} \qquad Equation\ 1$$

Where:

j index's income group (lower, middle, upper)
i index's product
D_{Lower} and D_{Upper} are dummy variables (with middle income as the reference category)
Family Size$_j$ and Education$_j$ capture household-level demographics
u_i is a random effect to account for product-level clustering
ε_{ij} is the error term

After estimating the model coefficients, p-values were calculated to assess the statistical significance of each explanatory variable. The test evaluates the null hypothesis using Equation 2, that each coefficient β_k equals zero. Each coefficient $\widehat{\beta_k}$ is estimated along with its standard error SE($\widehat{\beta_k}$).

$$t = \frac{\widehat{\beta_k}}{SE(\widehat{\beta_k})} \qquad Equation\ 2$$

The resulting p-value, derived from the t-distribution, provides the statistical significance of each explanatory variable. This enables a rigorous evaluation of household-level factors, whether they are systematically associated with higher or lower repair frequencies, offering insights into product reliability across demographic groups.

The Freeman-Halton exact test (an extension of Fisher's exact test) was applied to complement the regression analysis. This non-parametric test is particularly appropriate for categorical data with small or uneven subgroup sizes, as was the case with the upper-income group and specific product categories having zero repair reports (e.g., CRT monitors and televisions) (Freeman and Halton, 1951). It calculates the exact probability of observing a specific r×c contingency table under the assumption of independence, using the following equation:

$$P = \frac{(\prod row\ totals!)\cdot(\prod column\ totals!)}{grand\ total!\cdot\prod cell\ counts!} \qquad Equation\ 3$$

This forms the basis for computing the p-value by summing the probabilities of all equally or more extreme tables under the null hypothesis. All statistical analyses, including the regression models and Freeman-Halton exact tests, were conducted using Python with relevant libraries such as statsmodels and scipy.

Limitations of This Study

In acknowledging the limitations associated with the door-to-door sampling method, we recognise that, although it provided detailed insights, it posed challenges concerning accessibility and voluntary participation, which may have compromised the representativeness of the sample. Future research could benefit from employing alternative recruitment strategies, such as stratified sampling or predefined participant quotas, to enhance representativeness. Providing these methodological details supports transparency and facilitates potential replication in similar research contexts, particularly in the Global South, where such studies contribute valuable insights to the circular economy debate.

Further, this study is limited to socio-economic metabolism at the household level from behavioural aspects. To improve product and repair knowledge, a comprehensive approach including electronic vendors, repair specialists, sustainability/ circular economy experts, consumer behaviour experts, and advocacy associations is recommended (Roskladka et al., 2023). Successful repair rates from professional versus private technicians should be explored further. Also, expanding the scope of research, including the effect of product lifetime extension coupled with repairs (Jaeger-Erben et al., 2021; Woidasky and Cetinkaya, 2021) will provide a clearer picture of the local socio-economic metabolism.

Results and Discussion

Respondent's Socio-Economic Characteristics

The survey results according to socio-economic composition are shown in Table 2. Based on the sociodemographic results, 58% were males, and the highest percentage of responses came from respondents in the age group 25 – 44 years old with 43%. We noticed a lower percentage of participants (5%) in the 65+ age range. Educational data shows that about 47% of participants had passed upper secondary school, and 9% had a master's degree. We also collected employment data and created location-specific categories. Skilled workers, who were employed in non-salaried jobs, comprised the biggest group of respondents (40%). Managers, directors, and senior officials, who were classified as senior professionals, comprised only 5% of the total. Overall, the socio-demographic traits of the randomly chosen sample were comparable to those of Pakistan's urban income groups as a whole.

Table 2 Socio-economic composition of the respondents per income group who participated in the survey (n = 450)

		Category			**No. of respondents**	**Proportion of respondents (%)**
		lower–income (<300$)	middle–income (300 – 1200$)	upper–income (>1200$)		
No. of respondents		204	243	3		
Proportion of respondents		45.3%	54%	0.6%		
Gender[2]	Female	80	110	1	191	42
	Male	124	133	2	259	58
Age Group[3]	18–24	49	54	-	103	23
	25–44	70	123	2	195	43
	45–64	66	61	1	128	28
	65+	19	5	-	24	5
Respondent's education level	Elementary school	19	-	-	19	4
	Upper secondary school	127	86	-	213	47
	Graduation	51	127	-	178	40
	Master's (or above)	7	30	3	40	9

[2] Lahore population as per the 2023 census attributes to 13.9 million inhabitants, comprising of 7.27 million (52%) males, and 6.71 million (48%) females (Government of Punjab, 2023).
[3] Pakistan Bureau of Statistics data shows 33.9% aged 0-14 years, 65.2% aged 15-64 years, and 1% aged 65+ years.

Table 2 (cont.) Socio-economic composition of the respondents per income group who participated in the survey (n = 450)

		Category			No. of respondents	Proportion of respondents (%)
		lower–income (<300$)	middle–income (300 – 1200$)	upper–income (>1200$)		
Occupation	Student	-	18	-	18	4
	Skilled working class (non–salaried jobs)	143	35	-	178	40
	Administrative and secretarial occupations	48	98	-	146	32
	Mid–level (seniority) professionals	13	71	1	85	19
	Senior professionals	-	21	2	23	5
	Others	-	-	-	0	0
Family size		6.5	5.3	4	5.2	
Size of the property (sq. ft)		98	222	663	328	

Frequent Product Failures per Product Category

Survey results indicate inadequate cooling performance is a major consumer concern, particularly during Pakistan's extreme summers, where ambient temperatures exceed 40°C (104°F). High temperatures place significant strain on fridges and air conditioners, leading to increased compressor wear, reduced efficiency, and frequent complaints about insufficient cooling. Table 3a - 3b presents survey findings on the most common consumer complaints related to cooling appliances, along with reported repair costs and estimated repair durations. These tables further expand on these findings with insights from repair technicians, identifying the underlying causes of these issues and outlining recommended solutions. According to technicians, common faults include refrigerant leaks, blocked airflow, and component malfunctions. Technicians frequently attribute cooling failures to dirty condenser coils, faulty thermostats, and malfunctioning compressors, which often necessitate part replacements and sourcing specific components from suppliers (Guo and Rasmussen, 2023). Addressing these issues typically requires multiple repair interventions, such as replacing thermostats, repairing compressors, and recharging refrigerants, to restore optimal performance. By linking consumer-reported complaints with technician diagnoses, Table 3a - 3b helps to contextualise specific mechanical failures and repair processes.

Survey findings indicate that users frequently report laptop issues, including difficulty powering on, battery not holding charge, overheating, and a noisy fan. Recent studies have confirmed that the most repaired parts (including replacement) are batteries, power supplies, laptop housing, fans and cooling fins, keyboards and keys, and connectors (USB, network). Additionally, hard disk drives and laptop displays are frequently serviced (Lynch and Serrenho, 2023; Woidasky and Cetinkaya, 2021; Cordella et al., 2019). Repair technicians highlight circuit board/motherboard failures and software-related issues as recurring problems, requiring either component-level repairs or system reconfiguration.

Regarding televisions, the phase-out of CRT monitors and TVs has led to a decline in repairs for these products. In contrast, flat display panel TVs remain widely used, but their display panels are among the most expensive components to repair, often costing around 70% of the full unit price. Panel defects are common, yet most manufacturers do not recommend panel replacements due to high costs. Instead, consumers are advised to purchase a new product if the defect occurs outside of the warranty period (Sampath, 2019).

Results suggest that top-load and semi-automatic washing machines often have weak motors, pump failures, and durability problems with mechanical components. Semi-automatic machines often face spin tub malfunctions, rust, and water leaks. Fully automatic machines, increasingly popular, commonly experience water leakage due to blocked or damaged drain pumps (Bracquené et al., 2021) along with motor, belts and sensor issues.

Electric fans frequently develop motor failures, worn-out bearings, damaged fan blades, capacitor malfunctions, and power connection issues. Similarly, large exercise equipment, such as treadmills, commonly encounters problems with treadmill belts, chain systems, control boards, speed sensors, and motors.

Table 3a Category I. Temperature exchange equipment: Frequent consumer complaints – availability of spare parts, associated cost, and repair time for Fridges (incl. combi-fridges) & Freezers

Frequent consumer complaints	Possible cause	Solution	Parts for replacement	Estimated cost (USD[4])	Estimated time to repair	Suggested source for replacement parts[5]
The fridge/ freezer is not cooling	Dirty condenser coils, faulty thermostat, malfunctioning compressor, insufficient refrigerant.	Clean the condenser coils, replace the thermostat, fix compressor issues, and inspect and recharge refrigerant if needed.	Thermostat, compressor, refrigerant (if there's a leak).	40 – 100	5 – 7 hours	1, 2
Excessive frost or ice buildup	Defective defrost timer, malfunctioning defrost heater or thermostat, poor gasket.	Replace the defrost timer, test and replace the faulty defrost heater or thermostat, and check and replace the gasket if damaged.	Defrost timer, defrost heater, defrost thermostat, gasket	30 – 45	2 – 3 hours	2
Water leakage inside the fridge	Blocked defrost drain, damaged or clogged drain pan, faulty water inlet valve.	Clear the defrost drain, inspect and clean the drain pan, and replace a malfunctioning water inlet valve.	Water inlet valve.	5 – 10	1 – 2 hours	1, 2
Unusual noises	Faulty condenser fan motor, worn-out evaporator fan motor, and noisy compressor.	Replace the condenser fan motor, replace the evaporator fan motor, and inspect the compressor for issues.	Condenser fan motor, evaporator fan motor.	10 – 20	1 – 2 hours	1, 2
The fridge/ freezer is too warm	Faulty temperature control, and damaged door gaskets.	Replace the temperature control, and check and replace damaged door gaskets.	Temperature control, door gaskets.	20 – 30	30 – 60 minutes	1, 2
The fridge/ freezer not running	Power supply issues, malfunctioning start relay.	Check the power supply and outlet, and replace the start relay if it is faulty.	Start relay.	5 – 10	30 – 45 minutes	2, 3
Inconsistent temperature	Faulty temperature sensors and a malfunctioning control board.	Replace faulty temperature sensors, and inspect and replace the control board.	Temperature Sensor, Control Board	20 – 45	2 – 4 hours	1, 2, 3
Excessive cycling on and off	Dirty condenser coils, a malfunctioning thermostat, or issues with the start relay.	Clean the condenser coils, replace a faulty thermostat, or inspect and replace the start relay.	Thermostat, Start Relay	20 – 25	1 – 2 hours	1, 2, 3
Door seal issues	Damaged or worn-out door gaskets.	Check and replace damaged or worn-out door gaskets to ensure a proper seal.	Gasket	15 – 20	30 – 60 minutes	2

[4] As of January 2nd, 2023, the exchange rate for the Pakistani Rupee (PKR) to the United States Dollar (USD) was 226.6.
[5] Spare parts can be classified into three categories: 1. new original equipment manufacturer (OEM) parts, 2. third-party newly manufactured aftermarket parts, and 3. parts that are harvested from products and either directly reused or refurbished (Richter et al., 2023).

Table 3b Category I. Temperature exchange equipment: Frequent consumer complaints – availability of spare parts, associated cost, and repair time for Air Conditioners (household installed and portable)

Frequent consumer complaints	Possible cause	Solution	Parts for replacement	Estimated cost (USD)	Estimated time to repair	Suggested source for replacement parts
AC is not turning on	A faulty thermostat, electrical issues, or a malfunctioning capacitor.	Replace the thermostat, check electrical connections, or replace the capacitor if needed.	Thermostat, capacitor.	10 – 15	30 – 60 minutes	1, 2
Insufficient cooling	Dirty or blocked air filters, refrigerant leakage, or a malfunctioning compressor.	Clean or replace air filters, inspect for refrigerant leaks, and repair or replace the compressor as necessary.	air filters, compressor, and refrigerant (if there's a leak).	50 – 130	4 – 6 hours	1, 3
Strange noises	Loose or damaged fan blades, malfunctioning motor, or debris in fan.	Tighten or replace fan blades, inspect and replace the motor, or remove debris from fan.	Fan blades, motor.	10 – 20	1 – 2 hours	2, 3
Water leakage inside the room	Clogged or disconnected condensate drain line, or a damaged condensate pump.	Clear the condensate drain line, reconnect if necessary, or replace a malfunctioning condensate pump.	Cleaning and Condensate pump.	5 – 25	1 – 2 hours	1, 2
Foul odors	Mould or mildew growth on coils or filters.	Clean and disinfect the coils and filters to eliminate the source of the odour.	-	5 – 10	Varies (depends on severity)	-
AC is freezing up	Insufficient airflow, low refrigerant levels, or a faulty thermostat.	Check and improve airflow, recharge refrigerant if low, or replace a malfunctioning thermostat.	Thermostat.	5 – 10	30 – 60 minutes	1, 2
The remote control/ or display is not working	Dead batteries, faulty remote control sensors, or a malfunctioning display board.	Replace remote control batteries, check and replace the remote control sensor, or replace a malfunctioning display board.	Remote control sensor, display board.	15 – 20	1 – 2 hours	1, 3
Continuous cycling on and off	Dirty or blocked condenser coils, issues with the thermostat, or low refrigerant levels.	Clean condenser coils, replace a faulty thermostat and recharge refrigerant if needed.	Thermostat.	5 – 10	30 – 60 minutes	1, 2
AC unit not blowing air	Faulty blower motor, issues with the capacitor	Replace the blower motor and capacitor	Blower motor, and capacitor	15 – 30	1 – 2 hours	2, 3

Survey results indicate that while traditional cleaning methods, such as straw brooms and wet mopping, remain prevalent in Pakistan, vacuum cleaners are gaining popularity among urban middle- and upper-income families due to their convenience and affordability. Common issues with vacuum cleaners include suction problems, blocked filters, and damaged hoses or cables (Cordella et al., 2019).

For small household appliances related to food, personal care and health, survey respondents reported that these items are often discarded or left unused rather than repaired, except for minor fixes like cable

replacements. Repair technicians highlighted the difficulty of accessing affordable spare parts as the primary barrier to repairs (Bovea et al., 2017).

The survey findings reveal that the central processing units (CPUs) frequently experience failures with the motherboard, hard drive, graphics card, processor, RAM, and ROM. Printers frequently require toner replacements, driver reinstallation, and general troubleshooting. Mobile phones are most often repaired for display damage, battery degradation, and charger issues, along with back cover, operating system, and electronics failures, such as short circuits or disconnected components (Cordella et al., 2021). Landline phones primarily require minor repairs, including wire or cable connections, battery replacements, screen fixes, and dial pad adjustments. Back-end issues such as line disconnection, distortion, and echo are more common with landline phones. For a detailed breakdown of product-specific repair challenges, refer to SI Table A2 – A30.

Repair Associated Cost In the informal and highly localised repair markets of Pakistan, prices are not predetermined; rather, they are generally subject to negotiation. Consumers routinely partake in bargaining according to their willingness and ability to pay, particularly within lower- and middle-income households, where financial constraints significantly impact repair decisions. When deciding whether to repair a product, consumers determine the repair cost to the product's perceived value, timing and their past experiences (Güsser-Fachbach et al., 2023; Korsunova et al., 2023; Russell et al., 2023).

Table 4 presents the distribution of average repair costs across different products and compares them with the market price of new products. Findings conclude that cost savings through repair are often substantial, particularly for temperature exchange equipment. For screen-based products such as flat display panel TVs, panel replacement can cost up to 70% of the total product price, making it a difficult and often economically unjustifiable choice for consumers to pursue repair. Nevertheless, a consumer may opt to replace the product if the damage is more extensive and the cost of repair equals or exceeds its value and useful life (Tecchio et al., 2019), also known as economic obsolescence (Déméné and Marchand, 2016).

Table 4 Repair cost compared to local product rice (cost varies depending on product specifications/ component repair(s)). See Table 2 and SI Table A2 – A30 for a specific repair price

Product Description	Product price ($)	Repair price ($)	Repair price compared to product cost (%)
Fridges (incl. combi-fridges) & Freezers	295 – 1000*	5 – 100	1.7 – 10
Air Conditioners (household installed and portable)	650 – 1000*	5 – 130	0.8 – 13
IT Laptops (incl. tablets)	380 – 1200*	10 – 250	2.6 – 20.8
CRT Monitors & 0407 CRT TVs	50 – 80**	5 – 40	10 – 50
Flat Display Panel Monitors (LCD, LED) and Flat Display Panel TVs (LCD, LED, Plasma)	135 – 600*	10 – 400	7.4 – 66.7
Washing Machines (incl. combined dryers) and Dryers (wash dryers, centrifuges)	100 – 700*	5 – 150	5 – 21.4
Household electric fan	30 – 70	10 – 50	33.3 – 71.4
Leisure (large exercise, sports equipment)	270 – 930*	10 – 200	3.7 – 21.5
Microwaves	80 – 490	10 – 60	12.2 – 12.5
Other Small Household (irons and sewing machine)	40-150	2 – 25	5 – 16.7
Food (toaster, grills, food processing)	20 – 330	5 – 40	12.1 – 25
Vacuum Cleaners	85 – 415	5 – 75	5.9 – 18.1
Personal Care (toothbrushes, hair dryers, razors)	8 – 140	2 – 35	25
Household Tools (Water pumps)	55 – 300	5 – 40	9.1 – 13.3
Household Medical (thermometers, blood pressure meters, blood sugar meters)	7 – 25	1 – 15	14.3 – 60

Table 4 (cont.) Repair cost compared to local product rice (cost varies depending on product specifications/ component repair(s)). See Table 2 and SI Table A2 – A30 for a specific repair price

Product Description	Product price ($)	Repair price ($)	Repair price compared to product cost (%)
Desktop PCs (excl. monitors, accessories)	110 – 395*	5 – 200	4.5 – 50.6
Printers (scanners, multifunctional, faxes)	80 – 440*	5 – 80	6.3 – 18.2
Telecom (cordless) phones, answering machines)	14 – 160	3 – 20	12.5 – 21.4
Mobile phone (incl. smartphones, pagers)	50 – 1120*	3 – 300	6 – 26.8

* This price range refers to domestically assembled mid-range products that are widely available and affordable (excluding basic/cheap and imported branded products).
** These products are no longer available, so we are discussing used ones that are in excellent condition.

Repair Time Inconvenience (i.e., urgency of repair) is often attributed to the time required for repairs (Russell et al., 2023). As illustrated in Tables 2a – 2b and SI Table A2 – A30, simpler devices such as electric irons may take less repair time compared to repairing a complex device like a laptop or an AC. Repair times varied widely, ranging from a few minutes for minor fixes to several hours or days if parts have to be ordered post-inspection. In cases where specific spare parts were not readily available, it was reported that smaller or more portable items were sometimes taken back to the repair shop by technicians for off-site servicing. During this period, the product remained with the repair technician, and no temporary replacement was offered to the customer, further contributing to the perceived inconvenience. The duration of electronic repairs is influenced by multiple factors, including product complexity, issue severity, spare part availability, and technician skill (Korsunova et al., 2023; Russell et al., 2023; Svensson-Hoglund et al., 2021) and repair shop backlog (Güsser-Fachbach et al., 2023).

Sourcing of Spare Parts Informal interviews with repair technicians indicated that the spare parts required for electronic repairs vary depending on the device type and the specific malfunction. Circuit boards, semiconductors, capacitors, resistors, connections and cables, motors, batteries, fans and cooling systems, mechanical parts, housing, and miscellaneous components (knobs, switches, etc.) are examples of common spare parts. Technicians in Pakistan's household consumer electronics sector have observed that, while some products are assembled locally, the majority still rely significantly on imported components (e.g. compressors, electronic controls, etc.). This continued dependence on imported products poses challenges related to the timeliness and quality of repairs. Furthermore, repairability is often constrained when spare parts for old appliances are no longer available (Tecchio et al., 2019).

The local technician also referenced the classification proposed by Richter et al. (2023), which groups spare parts into three categories: i. new original equipment manufacturer (OEM) parts, ii. third-party newly manufactured aftermarket parts, and iii. parts harvested from (used and waste) products and either directly reused or refurbished. Based on this classification, local technicians described their sourcing as context-dependent, which includes all three categories according to availability, pricing and specific repair scenario (see Table 3a, 3b and SI Table A2 – A30).

Who Repairs What, and When?

In Pakistan, electronic products often require significant repairs much sooner than in the Global North, primarily due to the frequent power fluctuations resulting from outdated and weak infrastructure, high reactive power demand, and overloads in single-phase supply systems. This is further coupled with lower-quality goods, high seasonal usage, and harsh environmental conditions (e.g., heat, dust, etc.). For instance, ACs typically require servicing every 1-2 years, while LCDs often need attention after about seven years. Similarly, laptops and smartphones typically experience major repairs, such as hard drive or battery replacements, within 2-3 years. Limited regular maintenance and reliance on temporary repairs can further shorten product lifespans.

Survey results indicate that the daily used household items like fridges, freezers, and washing machines have a high repair frequency (see Figure 2). In this context, repair frequency is used to define how frequently repairs are needed to keep the equipment operational and functioning properly over the working lifetime of the product (including the time they have owned it). In contrast, expensive leisure equipment like exercise machines is rarely repaired due to the lack of professional technicians. SHA experiences low repair rates because new items and spare parts are inexpensive. Screens and small IT devices also have low repair frequencies due to early obsolescence. Repair statistics from existing literature reveal that mobile phones are more prone to repairs, accounting for 28% (Laitala et al., 2021). In contrast, SHA have much lower repair rates, with only 9.6% of consumers opting for repairs, as repair costs often match or even exceed the price of purchasing new items (Bovea et al., 2017).

Results suggest that individuals with lower incomes are more likely to opt for multiple repairs rather than replacements. This is likely due to the high cost of new devices and irregular maintenance, leading to more frequent breakdowns. Delaying repairs can result in more extensive damage, resulting in lower- and middle-income individuals requiring repairs more often than expected. In contrast, upper-income individuals can afford regular maintenance and experience fewer breakdowns, as their products are well-maintained and less prone to malfunction.

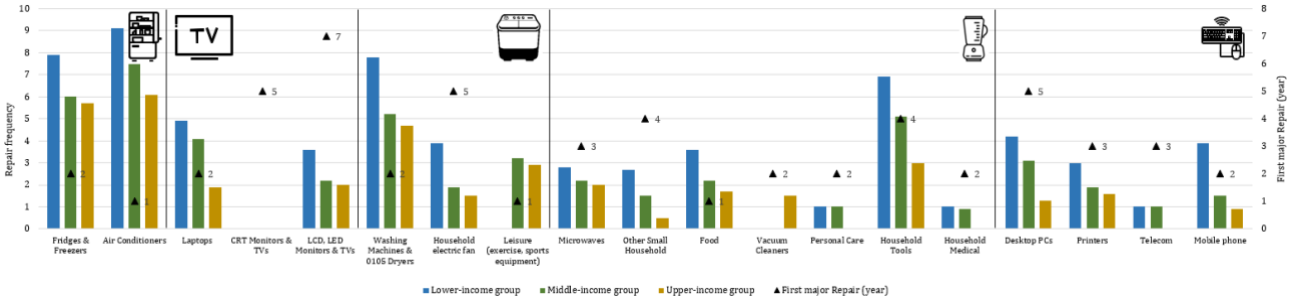

Figure 2 The average repair frequency of broken electrical applicances during their used life and the timing for the first significant repair reflect local usage patterns and maintenance practices

Statistical Validation of Socio-Economic Grouping Through Repair Frequency Analysis

Based on the survey results, regression analysis was performed using the dependent variable (product-level repair aggregates) and independent variables (income groups, family size and education level). Regression analysis values are reported in Table 5. Respondents from lower-income groups reported significantly higher repair frequencies than those in the middle-income group, with an average increase of approximately 0.95 repairs per product ($p = 0.001$). In contrast, individuals in the upper income group tended to report fewer repairs, averaging 0.57 fewer repairs per product than the middle-income group; however, this effect was only marginally significant ($p = 0.062$). The analysis showed that larger family sizes were linked to higher repair frequency. In contrast, higher levels of education corresponded with a decrease in reported repairs. These results indicate that economically constrained households experience a higher incidence of appliance repairs.

Table 5 Regression analysis presenting household repair frequency by income group

Predictor	Coefficient	Std. Error	t-value	p-value	Interpretation
Middle-income (as reference)	2.68	0.20	13.40	<0.001	The baseline repair frequency for middle-income groups is 2.68 repairs per product.
Lower-income	3.63	0.25	3.80	0.001	Lower-income products have, on average, 0.95 more repairs per product than middle-income.
Upper-income	2.11	0.30	–1.90	0.062	Upper-income products tend to have about 0.57 fewer repairs per product, borderline significance.
Family Size	+0.10	0.05	2.00	0.050	Each extra household member is associated with an increase of 0.10 repairs per product.
Education Level	–0.15	0.06	–2.50	0.020	Each additional education unit is associated with 0.15 fewer repairs per product.

Further, the results of the Freeman-Halton exact test are reported in Table 6. In particular, several household appliances (e.g., washing machines, ACs, leisure equipment, fridges, and vacuum cleaners) yield significant p-values ($p < 0.05$), indicating that repair frequencies for those products differ by income group. Several other products yielded borderline p-values from 0.05 to 0.06, indicating marginal levels of significance that warrant cautious interpretation. In contrast, no statistically significant differences were observed for personal care devices, household medical equipment, and telecommunications products. These results indicate a clear pattern in which the distribution of repair frequency across various durable goods appears to be influenced by socio-economic status.

Table 6 Freeman-halton exact test p-values for the association between repair frequency and income groups

Product Description	p-value	Interpretation
Fridges & Freezers	0.03	Significant
Air Conditioners	0.02	Significant
Laptops	0.04	Significant
CRT Monitors & TVs	1.00	No variability observed (all zeros).
Flat display panel Monitors and TVs	0.05	Borderline, modest association with income
Washing Machines & Dryers	0.01	Significant
Household electric fan	0.05	Borderline, modest association with income
Leisure (exercise, sports equipment)	0.02	Significant
Microwaves	0.10	No significant differences
Other Small Household	0.08	No significant differences
Food	0.05	Borderline, modest association with income
Vacuum Cleaners	0.03	Significant
Personal Care	0.80	No significant differences
Household Tools	0.04	Significant
Household Medical	0.80	No significant differences
Desktop PCs	0.06	Borderline, modest association with income
Printers	0.10	No significant differences
Telecom	0.80	No significant differences
Mobile phone	0.08	No significant differences

Drivers and Barriers Related to Electronic Products' Repairs

Different socioeconomic groups exhibit different repair behaviours, with lower-income groups being less concerned with ethical consumption and emotional attachment, and middle-income groups being more interested in optimal use and value recovery. The repair of electronic products is influenced by various factors, as listed in Figure 3a and 3b. Repairing electronic products is often motivated by cost-effectiveness (43%), value recovery (28%), ethical consumption (7%), local infrastructure (18%), emotional attachment (3%), and didn't think before (0%). Both internal motivation and external infrastructure influence repair practices (Parajuly et al., 2023). Haase et al. (2024) studied value preservation from a consumer perspective. They categorised it as economic (value for money), functional (physical performance and perceived utility), social or sign (enhance a social self-concept), emotional (feelings) and epistemic (evoke curiosity).

However, repairing electronic products also faces various barriers, including inferior repairs due to poor quality and durability (37%), unavailability or high cost of spare parts (32%), limited access to professional technicians (24%) due to location, scarcity in terms of specialisation, and affordability, reasonable cost of buying a newer product (1%), time constraints (4%), and didn't think before (2%). Lower-income groups face the challenge of accessing professional technicians, often resorting to private (unskilled) technicians who may use inferior spare parts, leading to substandard repairs. On the other hand, upper-income groups prefer to purchase newer products to upgrade functionality, especially if the price is reasonable. Barriers to repairing products include lack of access to spare parts, tools, repair information, and legal knowledge (trademarks, copyright,

contract law, designs, patents, legal ownership and products as a service, product safety and liability law) (Möslinger et al., 2022).

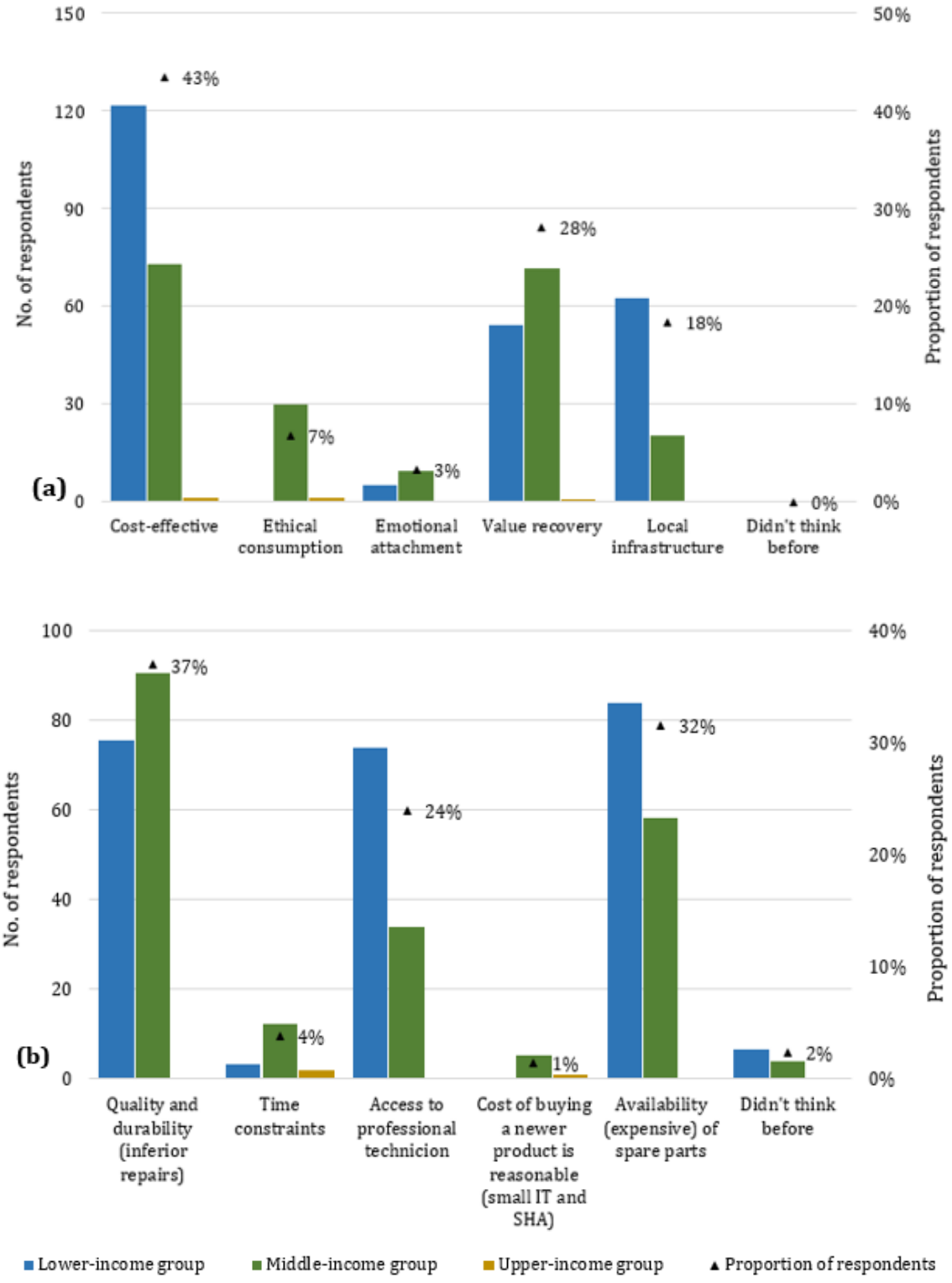

Figure 3 (a) Consumer motives to engage in product repairs, accounting for 43% of respondents as cost-effective; (b) Barriers to fixing a product, 37% proportion of respondents as quality and durability (inferior repairs)

Comparison of Local Repair Practices vs. the Global North

Repair activity is significantly higher in the Global South, reflecting practical needs and a focus on value for money. In places like Pakistan, weak consumer regulations and little attention to product warranties lead to

reliance on local repair professionals for necessary fixes, as replacements or refunds are rarely offered. The repair market is largely decentralised and driven by an informal sector lacking access to formal training and high-quality parts. Most repair services are provided by self-employed technicians who operate outside formal business structures. These technicians are typically accessible, affordable, skilled, offering flexible pricing models and direct negotiation with consumers. Spare parts are often sourced through informal channels, including salvage operations and cross-border imports, which help keep repair costs low and accessible for many individuals. Despite challenges, this industry is vital in extending the lifespan of electronic devices and reducing e-waste. Enhancing technical training, parts availability, and consumer rights could improve repair quality and reliability.

In contrast, the North's infrastructure is focused on recycling. Product repair practices in the Global North derive from sustainability, resource recycling, and fostering of a repair culture over disposal. According to Eurobarometer, 77% of Europeans would rather repair a device than purchase a new one (European Commission, 2023). Repair cafés, fix-it clinics, and tool libraries across various European countries, and most recently spawning to other parts of the globe, providing resources and workshops for repairing and upcycling products.

In the Global North, product repair operates within a complex policy landscape (Svensson-Hoglund et al., 2021). A single product may be covered by multiple intellectual property (IP) rights, such as patents, copyrights, trademarks, and end-user license agreements (EULAs), complicating the consumer repair process (Rosborough et al., 2023; Svensson-Hoglund et al., 2021). Further, the increase in independent repair work raises concerns about manufacturers' ability to maintain control over profitable aftermarkets for parts and services (van der Velden et al., 2023). They are also concerned about safety (fire and electrical) issues related to unauthorised (third-party improper) repairs bearing their brand.

In the EU, initiatives like the Eco-Design Directive and Right-to-Repair legislation, reflect this focus. The right-to-repair legislation is consumer-centric (Rosborough et al., 2023) by making it easier to repair defective goods, reducing waste and supporting the repair sector, including independent repairers (European Commission, 2023). It requires manufacturers to provide access to parts, tools, and information beyond the legal guarantee (European Commission, 2024). In the U.S., some states have introduced similar legislation to ensure that manufacturers offer repair resources for electronic products (National Conference of State Legislatures, 2023). However, compliance challenges persist, necessitating ongoing advocacy and legislative efforts to expand these initiatives across more states (iFixit, 2024).

Repair is experiencing a revival (Nazlı, 2021). Several countries have introduced measures to encourage repair activities, including tax incentives in Sweden (Sveriges Radio, 2017), a repair index in France (Ministère de la Transition écologique, 2021), and repair bonus in Austria (Digitales Amt, 2022), Reparatur-Initiativen in Germany (Netzwerk Reparatur-Initiative, 2014), restart project in the UK (restart, 2013), fairphone in the Netherlands (Fairphone, 2013), Miljødirektoratet in Norway (Miljødirektoratet, 2021), Reparaturführer in Switzerland (Amt für Umwelt, 2024), repair together in Belgium (Repair Together NPO, 2013), iFixit in the United States (iFixit, 2003), and sustainable business network in Australia and New Zealand (Sustainable Business Network, 2022) reflect a growing global movement towards encouraging product repair and sustainability.

Despite these initiatives, consumers have positive attitudes about repair, but don't engage with them often (Cerulli-Harms et al., 2018). Consumer spending on repairs and the number of repair businesses have declined in many European countries over the last 20–40 years (Korsunova et al., 2023). Factors like product obsolescence, costly authorised repairs, limited spare parts, and lower product prices have shifted consumer preference toward replacements (Godfrey et al., 2022). To improve attitudes toward repair, innovative solutions involving both producers and consumers are essential (Korsunova et al., 2023).

Conclusion

Repairing electronic products is nothing new. Repair reduces new product consumption by optimising product use. Understanding the socio-economic factors influencing repair culture is critical in promoting sustainable consumption patterns. Driven by the necessity of limited resources, repair is a cost-effective alternative. However, systematic quantitative assessments of consumer behaviour are limited. This paper has presented product repairs from a different socio-economic, geographic, and cultural context for the first time. It provides quantitative data about consumers' experiences, coupled with product failures and insights about product repairs.

In developing countries like Pakistan, the local informal waste electrical and electronic equipment sector is built around independent repairers. Electronic products have varying lifespans, typically lasting 5 to 20 years. It's important to note that the individual components of these products may have a limited lifecycle, making repair an integral part of the circular economy. Independent repairers have limited infrastructure and technical and economic support in the Global South. Policymakers in developing countries must ensure that repairing devices is easy, affordable, and accessible. This includes supporting local repair shops, encouraging manufacturers to make durable products, and protecting consumers through clear warranty laws and fair pricing for repairs. When something breaks, consumers shouldn't have to choose between spending a disproportionate cost of the actual product value or replacing it entirely. Governments may build a system that helps consumers, strengthens local economies, and supports a more sustainable future by imposing restrictions on low-quality imports. This could include supporting repair shops, incentivising durable product designs, and ensuring that repair is a viable option for everyone.

The strong repair culture in the Global South can be a powerful guide for policy development. By recognising how repair practices have flourished due to practical needs, policymakers can create laws that support and expand this culture. In the Global South, repair is a way of life, driven by practicality and cost-saving, while in the Global North, it's often hindered by high labour costs and limited accessibility. To change this, the North can take inspiration from the South by supporting local repair networks, encouraging repairable product designs, and making repairs more affordable. Rather than starting from scratch, the Global South's experience can help guide thoughtful, practical policies for a more sustainable and resilient future.

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Data availability See supplementary information.

Declarations

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