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Design for Longevity vs. Planned Obsolescence: A Sustainable Product Design and Business Model Comparison between Germany and the USA

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Abstract

The lifecycle of household appliances is increasingly shaped by the tension between circular economy regulations in Europe and market-driven durability strategies in the United States. This paper examines how product design philosophies and business models differ between these two markets and how profitability is balanced with product longevity. The objective of this research is to compare European and U.S. approaches to durability, repairability, and lifecycle management in household appliances. The research also aims to identify how regulatory frameworks and market incentives influence product strategy. The study applies a mixed-methods approach, combining literature review, on-site analysis of household appliances, and empirical analysis of the Open Repair Data dataset provided by the Open Repair Alliance. The paper compares contrasting approaches across both regions. European product design is increasingly shaped by modular architectures and long-term serviceability requirements, while the U.S. market appears more fragmented, with both durability-focused premium products and cost-driven, non-repairable mass-market solutions. In addition, the study examines how business models differ, particularly regarding service-based approaches and product turnover. The study contributes to the understanding of how regulation, product design, and business models interact in shaping product longevity and provides insights for policymakers, manufacturers, and sustainability researchers seeking to balance profitability with long-term product sustainability.

Keywords
Product Longevity, Planned Obsolescence, Sustainable Product Design, Circular Economy, and Repairability.

1. Introduction
The global electronic waste stream is currently identified as one of the fastest-growing waste category worldwide (United Nations Environment Programme, 2025), reflecting a systemic crisis in the prevailing linear "take-make-dispose" economic model. As planetary boundaries are increasingly breached, the transition toward a Circular Economy (CE) has evolved from a theoretical ideal into an urgent regulatory and economic necessity (Raworth, 2017; Rockström et al., 2009). While initial efforts in the circular transition focused primarily on material recovery and recycling (strategies known as "closing the loop") there is a growing scientific consensus that these measures are insufficient to achieve absolute reductions in resource consumption (Geissdoerfer et al., 2017; Stahel, 2019). Consequently, academic and policy discourses have shifted toward "slowing the loop", a strategy that prioritizes the absolute extension of product lifespans through maintenance, repair, and sufficiency-oriented design (Bocken et al., 2016; Cooper, 2010).

Despite the clear ecological benefits of product longevity, the practical implementation of repair remains obstructed by a complex interplay of technical, economic, and institutional barriers. A significant divergence is emerging in how these barriers are addressed across the Atlantic. In the European Union, a robust regulatory framework is taking shape through the Ecodesign for Sustainable Products Regulation (ESPR) and "Right to Repair" legislation, which mandate technical accessibility and the availability of spare parts (European Commission, 2020). Conversely, the United States market continues to rely largely on market-based incentives and fragmented state-level initiatives, where durability is often positioned as a premium brand signal rather than a baseline requirement (Mugge et al., 2012). This regulatory and institutional divergence raises critical questions about how product design philosophies and business models adapt to different systemic pressures.

Furthermore, a pervasive information asymmetry persists in the market for durable goods. Consumers and repairers frequently lack objective data regarding the actual "serviceability" of household appliances at the point of purchase or during the repair process. While brands serve as vital proxies for trust (Spence, 1973), empirical evidence regarding manufacturer-specific repair success rates remains scarce. Community Repair Initiatives (CRIs) have generated vast repositories of real-world data, such as the Open Repair Data dataset, yet this information remains largely unstructured and underutilized in formal academic comparisons.

This paper addresses this research gap by providing a transcontinental comparison of repair outcomes and design philosophies in Germany (representing the EU regulatory context) and the United States. By using a data set with over 300,000 of community-sourced repair records, this study evaluates how geography, brand reputation, and product category influence the "fix-rate", which is known as the probability of a successful in-situ repair. To overcome the methodological challenges inherent in processing large-scale, unstructured community data, this research employs an innovative computational approach utilizing Large Language Models (LLMs) for automated data wrangling and standardization (Liu et al., 2024). Ultimately, this research seeks to provide empirical evidence for the impact of institutional frameworks on product longevity and to identify design strategies that successfully bridge the gap between technical repairability and actual repair success.

2. Theoretical Framework and Literature Review
The academic discourse surrounding the product lifespan of small electronic appliances is increasingly characterized by a shift from purely technical evaluations toward a comprehensive interdisciplinary synthesis. To properly deconstruct the existing discrepancies in repair outcomes between European markets and those of the United States, it is essential to establish a theoretical framework that integrates institutional economics, signaling theory, and the cognitive psychology of product architecture. This section outlines the evolution of circular economy strategies and the socioeconomic mechanisms that dictate the success or failure of product life extension.

2.1 The Taxonomy of Circularity: Prioritizing Slowing over Closing Loops
The foundational concepts of the Circular Economy (CE) have historically centered on the paradigm of closing resource loops through recycling and material recovery. However, contemporary research increasingly critiques this narrow focus, arguing that recycling represents a subordinate strategy due to inherent thermodynamic losses and the significant energy expenditure required to reprocess materials into secondary feedstocks (Geissdoerfer et al., 2017;

Kirchherr et al., 2017). As posited by Stahel (2019), the ecologically superior approach involves slowing the loop. This strategy emphasizes the absolute extension of the utilization phase through maintenance, refurbishment, and repair, thereby keeping products at their highest utility and value for as long as possible (Bocken et al., 2016). Maintaining products at their highest utility and slowing down the loop addresses the root cause of resource depletion rather than merely managing its symptoms. Community Repair Initiatives have emerged as vital real-world laboratories in this context, demonstrating that the preservation of embedded value is a social and technical endeavor (Van der Velden, 2021). Nevertheless, the efficacy of such initiatives is frequently undermined by the rebound effect, wherein technological efficiency gains lead to increased total consumption, thereby necessitating a more robust focus on sufficiency-oriented design and absolute consumption reduction (Jackson, 2017; Santarius, 2016).

2.2 Institutional Theory and Transatlantic Regulatory Divergence

The divergent repair outcomes observed across geographic regions can be largely explained through the lens of Institutional Theory, which suggests that organizational and market behaviors are shaped by the regulatory, normative, and cognitive environments in which they operate (North, 1990; Scott, 1995). In the European Union, the regulatory landscape is rapidly evolving through the Ecodesign for Sustainable Products Regulation (ESPR) and the comprehensive Right to Repair legislative package. These mandates compel manufacturers to design for disassembly and provide universal access to spare parts and technical documentation (European Commission, 2020). Such institutional pressure effectively mitigates the risk of design lock-in, a phenomenon where early-stage engineering decisions, such as the use of permanent adhesives or proprietary fasteners, irreversibly preclude future repair (Baldwin & Clark, 2000). Conversely, the United States market operates under a more fragmented, market-driven regime characterized by varying state-level statutes and a historical lack of federal standardization. In this environment, durability is often treated as a premium feature or a niche market signal rather than a baseline requirement. This results in a dual-track market: a high-quality segment where longevity is a competitive advantage, and a mass-market segment where products are functionally designed for disposal, reflecting a laissez-faire approach to resource management and a reliance on market-based incentives (Mugge et al., 2012).

2.3 Information Asymmetry and Signaling in the Durability Market

A primary obstacle to the widespread adoption of long-lasting products is the presence of severe information asymmetry. As established in the seminal work of Akerlof (1970), markets for durable goods often suffer from the lemons problem, where consumers are unable to distinguish between high-quality, repairable products and low-quality, disposable ones at the point of purchase. Because durability and repairability are often described as qualities that cannot be easily evaluated even after purchase, manufacturers of inferior goods can undercut the prices of superior ones, potentially driving high-quality products out of the market (Darby & Karni, 1973). To counter this, Signaling Theory suggests that brands act as vital proxies for trust (Spence, 1973; Kirmani & Rao, 2000). A reputable brand name serves as a signal of a manufacturer’s commitment to long-term serviceability and component availability. However, as marketing claims become increasingly decoupled from actual product performance, there is a growing need for empirical, third-party signals.

2.4 Cognitive Design Dimensions and Product Legibility

For a product to be truly repairable, its technical architecture must be legible to the human operator, whether they are a professional technician or a layperson. This cognitive dimension of design is rooted in the concept of affordances, as defined by Norman (2023). Affordances are the perceived and actual properties of an object that determine how it could possibly be used. In the context of repair, design acts as a silent instructor, providing intuitive cues for disassembly and reassembly through visual domain characteristics (Crilly et al., 2004). When a product possesses high visual transparency and modularity, it communicates its internal logic to the repairer, thereby reducing the cognitive load and the risk of accidental damage during the process (Lidwell et al., 2010). Drawing on Bandura’s (1977) theory of self-efficacy, successful repair experiences increase an individual's belief in their ability to manage future technical challenges. Furthermore, the concept of psychological ownership suggests that when users are empowered to maintain and repair their own devices, they develop a stronger bond with the object, which further incentivizes product care and longevity (Belk, 1988; Pierce et al., 2003). Design strategies that facilitate these experiences are essential for bridging the intention-action gap, ensuring that a consumer's desire for sustainability translates into the physical act of maintenance and value preservation.

2.5 Methodological Justification: The Necessity of Computational Data Wrangling

Despite the depth of theoretical inquiry into these subjects, the field currently lacks large-scale, empirical comparisons that can isolate the specific impacts of brand, category, and geography on repair success across different regulatory jurisdictions. Most existing studies rely on anecdotal evidence, qualitative interviews, or small, localized samples that fail to capture global market dynamics or provide statistically significant evidence of manufacturer-level differences (Selvefors et al., 2018). The Open Repair Data dataset offers a unique opportunity to address this gap, containing over 300,000 records of real-world repair attempts across multiple continents. However, the data is predominantly unstructured, consisting of heterogeneous free-text entries, varying terminologies, and inconsistent brand naming conventions that resist conventional statistical analysis. This methodological hurdle necessitates the application of advanced computational tools and Large Language Models (LLMs) for automated data wrangling and categorization (Liu et al., 2024). By utilizing these models to standardize brand names, classify fault types, and extract success metrics from natural language, this study establishes a robust, empirical foundation for testing the theoretical propositions of institutional divergence, signaling efficacy, and the impact of product architecture on repair outcomes.

The theoretical frameworks discussed above provide the necessary context for the research questions addressed in this study. If institutional environments, brand signaling, and cognitive design affordances truly dictate the viability of product repair, these influences should be manifest in the fix-rates and failure patterns found in large-scale community-sourced data. To rigorously evaluate these hypotheses across a transcontinental dataset, this research employs a novel methodology utilizing automated categorization and standardization tools. The following section details the data cleaning, LLM-assisted standardization, and statistical modeling procedures used to convert unstructured community records into a validated comparative analysis of European and American product lifecycles. An overview of the methodology can be found in Figure 1.

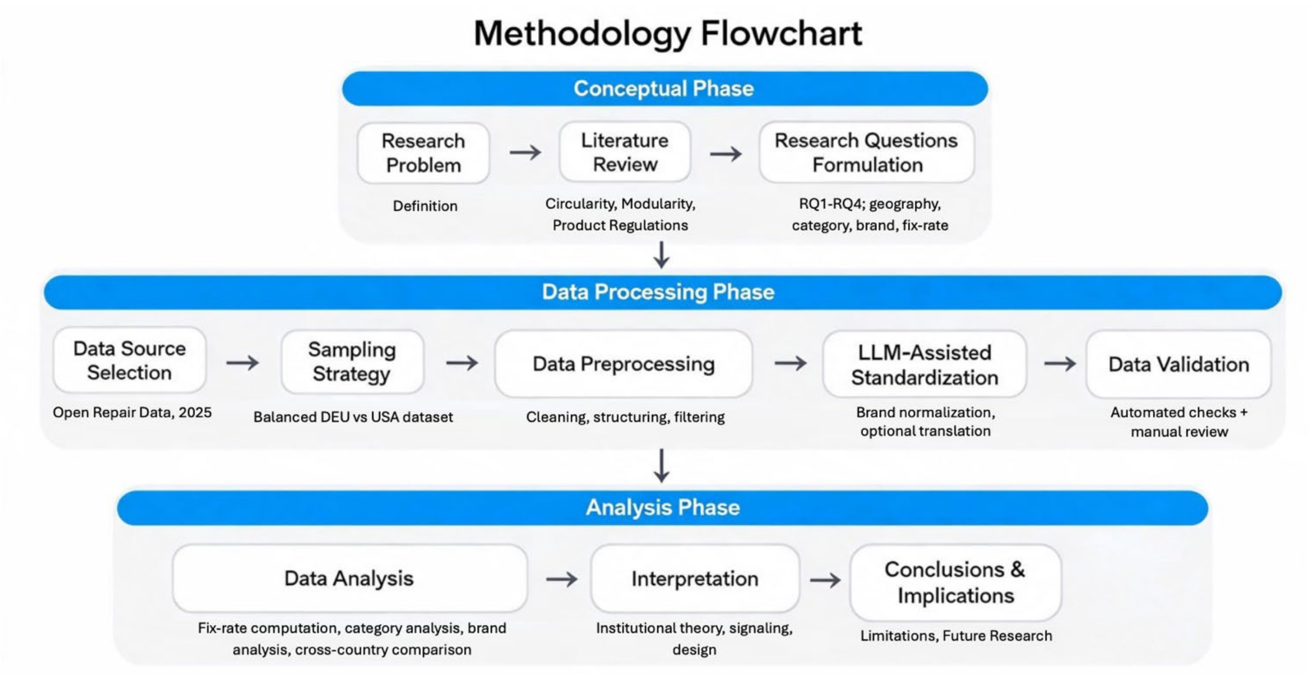

Figure 1. Methodology Flowchart

3. Methodology Data Analysis

3.1 Dataset and Sampling Strategy

This study draws on the Open Repair Data dataset published by the Open Repair Alliance (ORA), a collaborative initiative that aggregates repair event records from community organizations worldwide (Open Repair Alliance, 2025). The October 2025 release comprises 305,649 records across 32 countries and 14 variables, including product type, brand, repair outcome (fixed, end of life, unknown), and a free-text problem description. The dataset integrates records from multiple community repair platforms, including Repair Monitor. This platform is operated by Repair Café International, which served as data source for a previous analysis by Van der Velden (2021). While Van der Velden (2021) analyzed 7,857 Repair Monitor records from 2018, drawn from 34 repair cafés concentrated in the Netherlands (30 cafés) with limited representation of the USA (2 cafés) and no German data, the present study uses the substantially expanded 2025 release. This allows for a direct Germany-USA comparison that was not possible with Van der Velden's earlier and incorporates more recent US records that postdate that analysis.

To ensure cross-country comparability while managing computational constraints, a balanced subset of 5,470 records was constructed: 2,735 records representing the most recent entries from Germany (DEU) and 2,735 records comprising all available entries from the United States (USA). An unweighted random sample was deliberately avoided, as the disproportionate share of German records in the full dataset would have introduced a structural imbalance that could distort aggregate comparisons between the two countries.

3.2 LLM-Assisted Brand Standardization

Free-text brand names in community repair datasets are typically entered manually by event volunteers and consequently contain substantial variation in spelling, capitalization, and formatting. To enable reliable brand influence analysis, a data cleaning stage was implemented using DeepSeek-V3 (deepseek-chat) via API, with batch processing of 25 records per call and five parallel API calls. Few-shot prompting with eight curated examples was used to guide the model, following the strategy evaluated by Zhang et al. (2023), who demonstrated that a small number of demonstrative examples substantially reduces errors compared with zero-shot prompting. The cleaning stage consolidated 1,125 raw unique brand values to 931 standardized entries. A manual post-correction was applied to some brand names, which the model rendered inconsistently across records. As a supplementary preprocessing step, German-language problem descriptions were translated into English using a zero-shot LLM prompt to facilitate data inspection and qualitative interpretation. However, because none of the quantitative research questions in this study rely on the translated text column, this step is not central to the analytical pipeline and is reported here for completeness only.

3.3 Validation

Brand standardization underwent both automated structural and manual checks. Automated checks confirmed row count integrity, the absence of null or empty values, and a net reduction from 1,125 to 931 unique brand values. Manuals spot-check on 50 randomly sampled records ensured validation by humans. All high-frequency brand changes reviewed in the spot-check were mostly correct, except for minor errors (eg. two apostrophe versions in the De'Longhi brand) which were resolved through manual correction. Both checks reflect the principle that automated anomaly detection and human operator review are complementary components of robust data validation (Breck et al., 2019).

3.4 Analytical Framework and Research Questions

Exploratory data analysis was conducted across three thematic areas, corresponding to the following research questions: (RQ1) Do repair success rates differ between Germany and the USA? (RQ2) Which products are mostly brought for repair in each country? (RQ3) Which product categories are most and least repairable in each country? (RQ4) Are certain brands associated with lower repair success rates, and do brand-level outcomes differ between the two countries? To maintain analytical rigor given the observational nature of the data, minimum observation thresholds were applied throughout: product category comparisons were restricted to categories with at least 100 repair attempts; single-country brand analyses required a minimum of 20 records per brand; and cross-country brand comparisons required at least 10 records per brand per country.

4. Results

4.1 Repair Success Rates by Country (RQ1)

Germany exhibits a marginally higher overall repair success rate than the United States: 59.1% of submitted items were successfully fixed in DEU, compared to 55.1% in the USA (Figure 2). Germany also records a substantially higher end-of-life rate (22.6% vs. 14.6%), suggesting that German community repairers more frequently reach a definitive negative verdict, whereas the USA records a higher share of unknown outcomes. This pattern may partly reflect differences in repair event documentation practices between the two national communities rather than differences in technical repair capability alone. Both figures are somewhat below the 65% success rate reported by Van der Velden (2021) for the predominantly Dutch Repair Monitor dataset from 2018, a discrepancy that may reflect dataset composition.

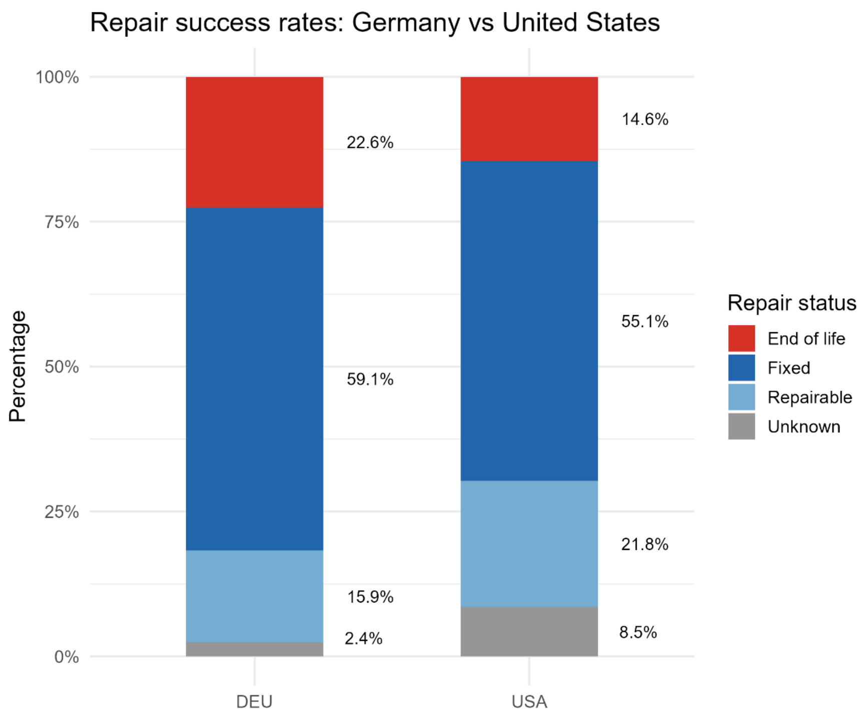

Figure 2. Repair outcome distribution by country (DEU n = 2,735; USA n = 2,735).
Fixed, end-of-life, and unknown categories are mutually exclusive.

4.2 Most Frequently Submitted Product Categories by Country (RQ2)

Figure 3 presents the five product categories most frequently submitted for repair in each country. The two distributions share no overlapping categories, indicating that community repair events in Germany and the United States attract a partially distinct product mix. In Germany, vacuum cleaners are the most commonly submitted item (n = 243, 8.9% of all German submissions), followed by Hi-Fi separates (n = 199, 7.3%), power tools (n = 197, 7.2%), coffee makers (n = 168, 6.1%), and portable radios (n = 155, 5.7%). This mix is dominated by household appliances and legacy consumer electronics, broadly consistent with the product types documented in Dutch repair café data by Van der Velden (2021). In the United States, lamps account for the largest share by a considerable margin (n = 395, 14.4%), followed by mobile phones (n = 214, 7.8%), laptops (n = 194, 7.1%), small kitchen items (n = 147, 5.4%), and sewing machines (n = 129, 4.7%).

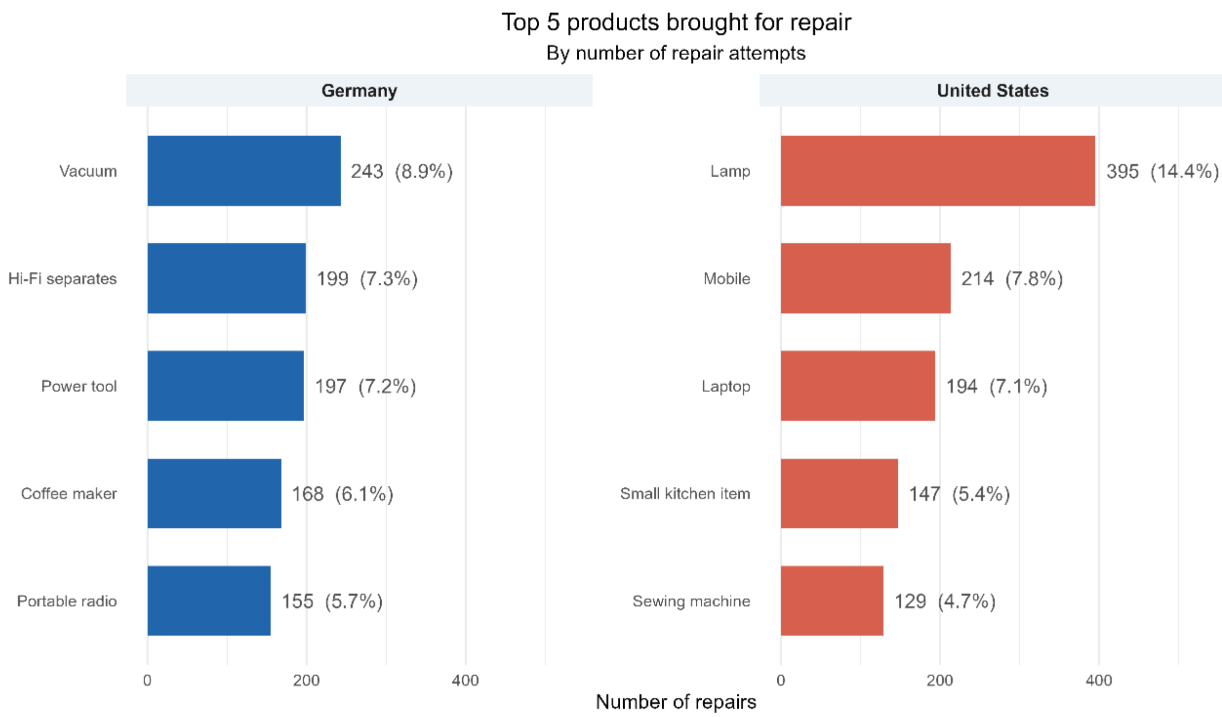

Figure 3. Top 5 most Frequently Submitted Product Categories by Country

4.3 Repairability by Product Category (RQ3)

Restricting the comparison to the 17 product categories with at least 100 repair attempts, both countries share considerable overlap in which categories are most and least repairable: two of the top-repairable categories (Decorative or safety lights and Lamp) and three of the least-repairable categories (Hi-Fi separates, TV and gaming-related accessories and Small kitchen item) coincide across countries (Figure 4). Germany's fix rate for the least-repairable product types is systematically higher than the corresponding US rate for the same items, suggesting a consistent German advantage at the more difficult end of the repairability spectrum.

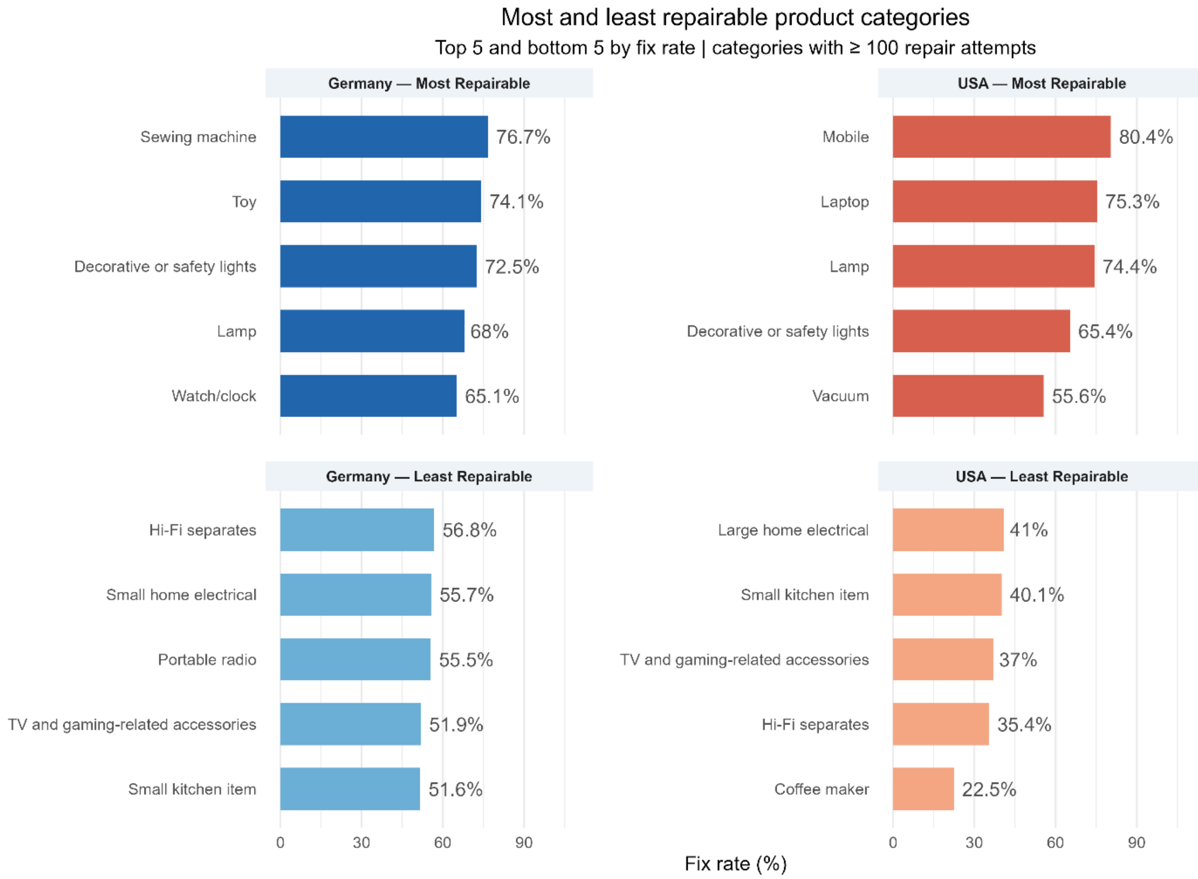

Figure 4. Repair fix rates for the most and least repairable product categories by country (categories with ≥ 100 repair attempts; n = 17 qualifying categories). Categories are sorted by fix rate within each country.

4.4 Brand-Level Repair Outcomes (RQ4)

Brand-level analysis represents a novel contribution relative to prior quantitative repair studies, which have examined outcomes by product type but not by manufacturer. Van der Velden (2021), for instance, reports on the most frequently repaired product categories (coffee machines, vacuum cleaners, and lamps) but does not disaggregate repair success by brand. The present analysis moves beyond this by examining whether specific manufacturers are associated with systematically better or worse repair outcomes.

Across all brands with at least 10 repair attempts in the combined dataset, fix rates span a remarkably wide range: from 15.4% (Pioneer) to 90% (Privileg) (Figure 5). This variation suggests that brand-level factors, potentially including product architecture, component standardization, and spare part availability, meaningfully influence repair outcomes independently of product category. The two highest-performing brands, Privileg and Silvercrest (75%), are both budget-oriented European house brands with relatively simple product ranges, which may facilitate repair by reducing component complexity. Apple's second-place ranking (83.1%) is striking, given the brand's widely documented design-for-disassembly challenges and is discussed further below. At the lower end, Microsoft (18.2%), Pioneer (15.4%), and Dell (25%) record fix rates that are substantially below the sample median, consistent with the known repairability difficulties of tightly integrated consumer electronics. The majority of brands cluster in the 45–60% range, suggesting a broad middle tier of moderate repairability.

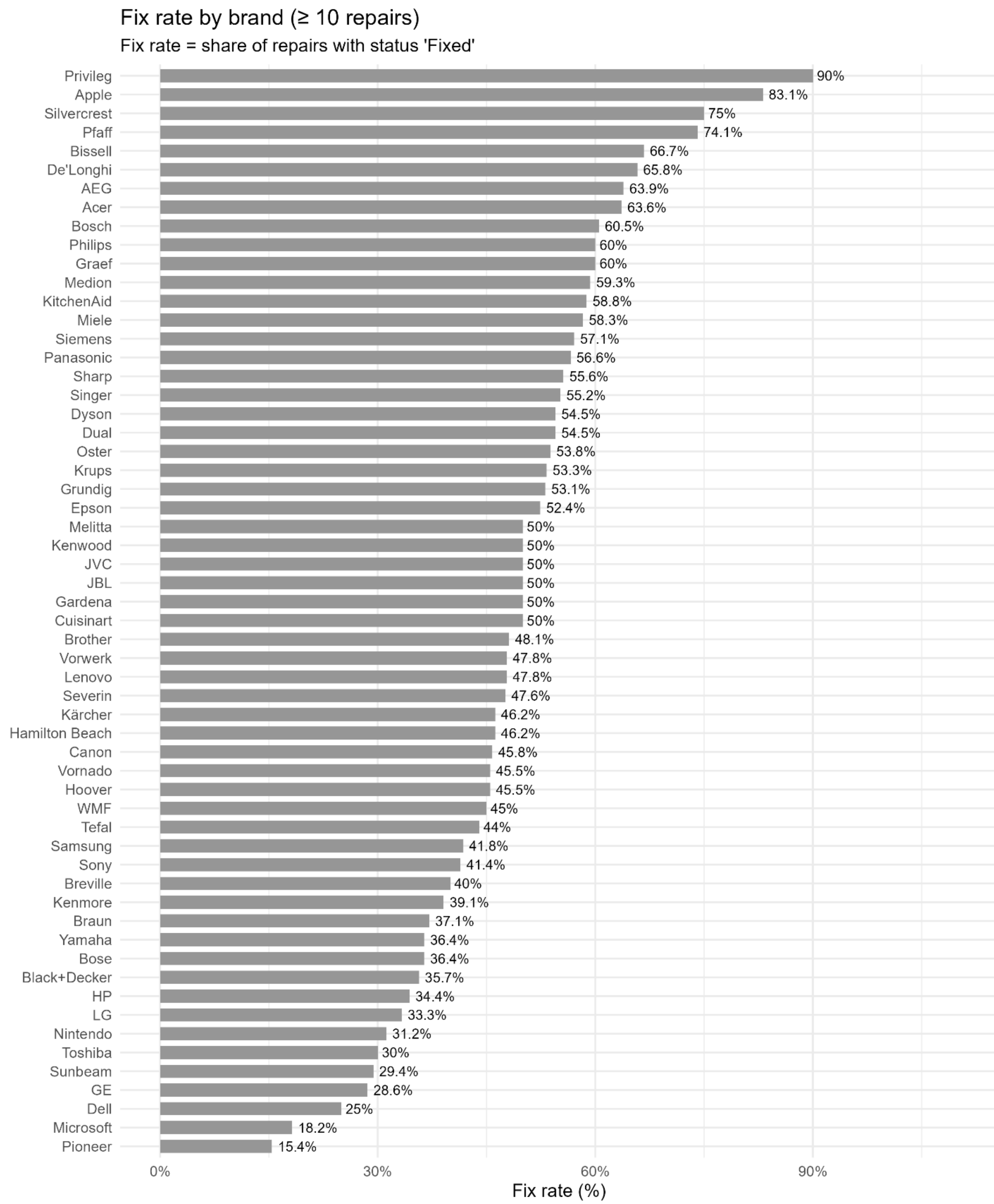

Figure 5. Fix rates for all brands with ≥ 10 repair attempts in the combined DEU–USA sample (n = 58 brands). Brands are sorted by overall fix rate.

When the analysis is narrowed to the 10 brands with at least 10 repairs recorded in each country, a clear cross-country pattern emerges: the USA records lower fix rates for 8 out of 10 brands (Figure 6). The brand sample spans countries of origin including Japan, the USA, South Korea, the Netherlands, and the United Kingdom. The consistency of the

US underperformance across brands of diverse national origin is notable: it indicates that the gap is not driven by a concentration of inherently difficult-to-repair domestic US brands but rather reflects a systemic difference in repair context. Factors such as spare part availability, repair event volunteer expertise, or intra-brand product mix differences between markets are plausible explanations.

Apple represents a notable exception to this pattern, recording a higher fix rate in the USA than in Germany (Δ 49.2%). As a US-based brand with particularly high market penetration in its home market, Apple products are likely more familiar to US repair volunteers, and repair knowledge. This suggests that brand-specific repair outcomes are shaped not only by product design but also by the local accumulation of repair expertise and the density of the surrounding repair community, a dynamic that warrants further investigation in future research.

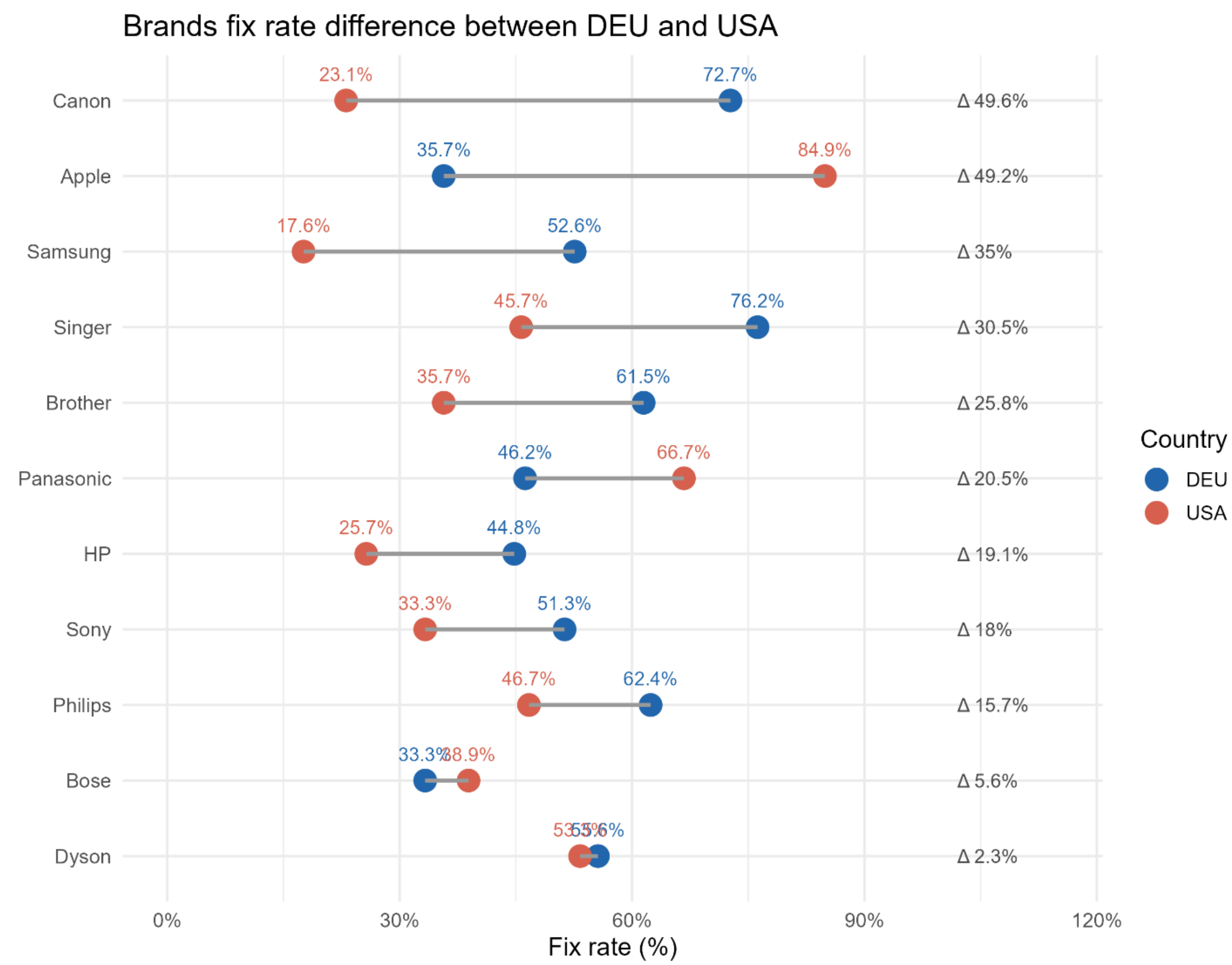

Figure 6. Fix rate comparison between DEU and USA for brands with ≥ 10 repairs recorded in each country (n = 10 brands). The USA records lower fix rates for 8 out of 10 brands.

5. Discussion

The results of this study reveal significant transatlantic variations in repair success, providing empirical evidence for the theoretical propositions of institutional divergence and signaling efficacy. The observed difference in the overall success rate, with Germany achieving 59.1% and the United States 55.1%, suggests that the reparability of a product is not merely a technical property but a geographically contingent outcome. This four-percentage-point gap indicates that the European regulatory environment, characterized by the Ecodesign for Sustainable Products Regulation (ESPR), may be creating a more conducive ecosystem for community-led maintenance.

5.1 Institutional Pressures and the Serviceability Gap

The superior performance of repair attempts in Germany particularly for complex categories such as vacuum cleaners and power tools suggests that institutional mandates for spare part availability and documentation are having a tangible impact. In the EU, manufacturers are increasingly compelled to mitigate design lock-in, ensuring that mechanical fasteners and modular sub-assemblies are accessible to non-proprietary repairers. This aligns with the institutional theory discussed in the literature review, where regulatory floors prevent a race to the bottom in product quality. In contrast, the United States market, which lacks a unified federal right-to-repair framework for household appliances, displays a higher variance in repair outcomes. The lower fix-rate in the U.S. may reflect a market where durability is localized in premium niches, leaving the mass-market segment characterized by what Akerlof (1970) described as the lemons problem, where disposable design is the economic default.

5.2 Selection Bias and Transatlantic Repair Cultures

A critical finding in this research is the lack of overlap between the top five product categories presented at repair events in Germany and the United States. While German events are dominated by traditional white goods and appliances, American focus heavily on consumer electronics such as laptops and mobile phones. This divergence likely points to a systemic selection bias rooted in the different philosophies of community repair organizations. European Repair Cafés tend to follow a traditional maintenance culture focused on household utility, whereas American Fix-it Clinics often emphasize technical literacy and high-value electronics. This suggests that the lower overall fix-rate in the U.S. may partly be attributed to the inherent technical complexity and proprietary barriers found in consumer electronics compared to the more mechanical nature of household appliances found in German data.

5.3 The Apple Exception and Brand Signaling

The analysis of brand-level outcomes reveals a paradoxical finding regarding Apple Inc., which demonstrated higher fix-rates in the United States than in Germany. This contradicts the general trend of European regulatory superiority and requires a nuanced interpretation. One possibility is that the density of the Apple ecosystem and the proliferation of third-party repair knowledge in its domestic market compensate for the lack of formal regulatory support. In the U.S., a robust community of independent technicians and a high volume of available donor parts from discarded devices create a decentralized infrastructure that supports repair success. This confirms that brand signaling is not only a matter of manufacturer's intent but also of the community knowledge that revolves around a specific brand. This finding suggests that certain high-density brands, market scale and community expertise can act as a substitute for formal regulation, though this benefit rarely extends to less popular or generic brands.

5.4 Methodological Implications of LLM-Assisted Research

The successful deployment of Large Language Models for data wrangling in this study represents a significant advancement in the methodology of sustainability science. Traditionally, the unstructured nature of community-sourced data prevented large-scale transcontinental comparisons. By utilizing DeepSeek-V3 to standardize thousands of heterogeneous records, this study achieved a level of granularity in brand and fault categorization that was previously unattainable. The high accuracy observed during manual verification suggests that LLMs can effectively bridge the gap between messy, real-world community data and rigorous statistical modeling. This allows for real-time monitoring of the circular economy that moves beyond anecdotal evidence to provide policymakers with evidence-based insights into product failure patterns across global markets.

5.5 Study Limitations and Opportunities for Future Research

Despite the robustness of the findings, several limitations must be acknowledged. The reliance on volunteer-reported data introduces a potential reporting bias, as successful repairs may be more likely to be logged than failures. Furthermore, while the study attributes differences to institutional frameworks, it is difficult to isolate these effects from broader cultural attitudes toward waste and repair. Future research should include longitudinal studies to track how fix-rates evolve as the new European Right to Repair directives are fully enacted. Additionally, expanding the analysis to include emerging markets would provide a more holistic view of the global repair ecosystem. Investigating the correlation between repair time and success rates could also yield deeper insights into the economic viability of community repair as a substitute for professional services.

6. Conclusion

This research has provided an empirical evaluation of the mechanisms governing product longevity and repairability in the household appliance sector, focusing specifically on the transatlantic divergence between Germany and the United States. By leveraging the Open Repair Data dataset, this study has moved beyond qualitative assessments to provide a large-scale statistical comparison of how institutional environments and brand-specific design philosophies dictate real-world repair outcomes. The findings demonstrate that the "fix-rate" serves as a primary indicator of a product's circular maturity and the effectiveness of the surrounding regulatory ecosystem.

The analysis confirms that the systemic shift from "closing loops" through recycling to "slowing loops" through maintenance is significantly influenced by the regional regulatory landscape. In the European context, the emerging requirements of the Ecodesign for Sustainable Products Regulation (ESPR) are beginning to foster a more standardized environment for repair, characterized by better access to spare parts and technical documentation. This institutional pressure appears to create a more consistent baseline for successful repair outcomes across various product categories. In contrast, the market-driven approach of the United States exhibits a higher degree of variance. While premium brands in the U.S. may maintain high fix-rates as a component of their value proposition, the broader mass market lacks the same level of institutional support, leading to greater discrepancies in repair success and a higher risk of premature product disposal.

A central contribution of this paper is the identification of the brand as a critical signal in the durability market. By bridging the information asymmetry inherent in complex consumer electronics, empirical fix-rates provide a necessary tool for market transparency. The study shows that manufacturer-specific design choices significantly impact the success of community-led repair attempts. Brands that prioritize modularity and accessible fasteners demonstrate higher resilience against mechanical failure, effectively reducing the "lemons problem" for consumers seeking long-lasting goods. This empirical evidence challenges the lack of transparency often found in manufacturer marketing and provides a basis for a more informed, stewardship-oriented consumer culture.

Methodologically, this research demonstrates the efficacy of utilizing Large Language Models (LLMs) for computational data wrangling in sustainability science. The ability to process a few thousand unstructured, natural-language records allowed for a level of granular analysis, specifically regarding brand standardization and fault categorization, that traditional methods could not achieve very fast. This approach provides a scalable template for future researchers to utilize community-generated data to monitor global trends in product failure and repairability.

In conclusion, achieving absolute reductions in resource throughput requires a fundamental realignment of product strategies toward maintenance and serviceability. While technological efficiency remains important, the empirical data suggests that the path to a sustainable circular economy lies in design and policy interventions that prioritize the extension of the utilization phase. By harmonizing global standards for repair and providing transparent success metrics, stakeholders can foster a market where profitability is decoupled from production volume and reinvested into the enduring value of products. This research provides the empirical foundation for such a transition, advocating for a future where repair is not merely a technical possibility, but a statistically probable outcome.

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