

AI for Sustainability through UX Design Principles for Recycling, Waste Reduction, and Eco-Friendly Behaviors in U.S. Cities

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Abstract- Urban resilience actions in the U.S. They are continuing to deal with persistent problems related to reduced recycling participation, pollution of waste, and incoherence with environmentally friendly actions. While AI (artificial intelligence) has improved the efficiency of waste management, its own packed potential remnants are underutilized, lacking efficient mechanisms for prosecuting and influencing human habits. The study seeks to find out how artificial intelligence can contribute to recycling, waste reduction, and ecologically responsible actions in the United States when integrated with the principles of user experience (UX). The paper explores the role of UX design as a crucial mediator between data-driven arrangements and urban dwellers, drawing on interdisciplinary fictions in AI, circular economy, human-computer interaction, and persuasive innovation. The study demonstrates how AI-enabled personalization, intelligent interfaces, and the adaptive evaluation loop enhance user engagement and consistency, while persuasive and gamified UX plans contribute to long-term habit formation. In order to safeguard different and virtuous urban outcomes, the research stresses the importance of equity, prudence, and faith in the design of machine learning-enabled resilience stages. These findings suggest that AI-enabled green UX can provide multi-dimensional support for recycling efficiency, reducing landfill dependency, neighborhood contribution, and financial optimization of waste frameworks. The study shows that automated reasoning can function not only in academic writing as an operational tool but also as a catalyst for urban longevity. The study for the upcoming US longevity initiatives. In order to achieve a long ecological impact, cities must organize moral, diverse, and behavior aware AI-UX integration.

Keywords: *Artificial Intelligence for Sustainability; Sustainable UX Design; Urban Sustainability; Recycling and Waste Reduction; Smart Cities; Behavioral Change Design; Ethical and Inclusive AI*

I. INTRODUCTION

Rapid urbanization in the U.S. poses new challenges related to municipal solid waste coevals, recycling shortcomings, and environmentally unsustainable

consumption. Nevertheless, after a decade of environmental policy intervention, recycling rates across the US have increased. Cities are uncoordinated, contamination levels in recycling streams are high, and masses participate in renewable projects in a wide range of demographic and socioeconomic categories. These obstacles show that advanced infrastructure is completely inadequate; user interaction, opinion, and action motivation play decisive roles in terms of sustainability.

Machine learning systems (MLS) have emerged as a groundbreaking force for urban sustainability, particularly at a time when they are integrated into arrangements that interact directly with citizens. User Experience (UX) design has advanced beyond usability to take over behavioral power, persuasion, handiness, and faith. When combined, AI and UX design provide a powerful foundation for shaping green, accountable behaviors. Man-machine intelligence helps personalization, forecasting, and automation during UX design, determining the manner in which users interpret, accept, and use these competences.

This study explores the ways in which machine learning-based structures, guided by renewable UX design principles, can contribute to recycling, reducing waste, and promoting sustainable behavior in the United States. City of lights. We draw on interdisciplinary creative writing across AI, the circular economy, human-computer interaction, and persuasive tools to investigate how intelligent interfaces can transform sustainability from a task of managing into an intuitive, entertaining, and diverse urban practice.

II. URBAN SUSTAINABILITY CHALLENGES IN U.S. CITIES: RECYCLING GAPS, WASTE OVERFLOW, AND BEHAVIOR PATTERNS

Due to the density of inhabitants, consumption intensity, and complex furnishings, a city center in The States produces disproportionately large volumes of municipal durable waste. While many towns have adopted curbside recycling schemes and smart waste initiatives, architectural and operational obstacles still stand in the way of their success. The continuing standstill between waste Backbone assistance and actual citizen participation is a major problem. Studies show that improper sorting, reduced participation, and misinterpretation of recycling guidelines contribute significantly to landfill overflows and contamination of recycling material (Kumar et al., 2023).

Demeanor incompatibility is a major factor in this road block. Usually, era power, limited input, and undefined incentives create recycling judgments. Without immediate or significant feedback, a person is unable to maintain a sustainable liable habit. The study on persuasive waste management functions suggests that users frequently disengage from durability media which do not fit in with their daily routines and other cognitive expectations (Daz et al., 2021). This points out the importance of interaction design in shaping green performance.

Moreover, socioeconomic and space inequalities exacerbate urban durability problems. Access to recycling resources, virtual tools, and resilience education varies in the area, eminently leading to unequal ecological results. Smart city waste innovations, which do not consider serviceability and ease of use, reinforce the aforementioned disparity rather than determining them (Kumar et al., 2023). As such, urban sustainability cannot be addressed solely through advanced technology deployment; it requires systems that are behavior-aware, inclusive, and context-sensitive.

The literature can be fictitious or non-fictitious, on top of the circular economic points that waste reduction is never beyond disposal but still close to the top of user choice. AI-enabled frameworks capable of influencing such decisions through advice, forecasting, and feedback represent a shift from reactive waste

governance to prudent resilience design (Corridor, 2024). However, UX values that take account of motivation, reliance, and comprehension are still underutilized, similar to structures.

III. ARTIFICIAL INTELLIGENCE AS AN ENABLER OF SUSTAINABLE URBAN LIVING

Machine learning systems play a key role in the development of eco-friendly cities, enabling data-driven decision making, automation, and adaptive commentary mechanisms in waste and recycling management. Automated reasoning is increasingly used in smart cities to optimize waste collection paths, predict waste coevals form, and improve recycling performance using computer imagination and machine learning models (Kumar et al., 2023).

Besides optimizing the backbone, machine intelligence makes it easier to personalize at human and society levels. Machine learning methods can analyze user behaviour, consumption forms, and olden recycling facts to provide customary recommendations and incentives for sustainable development. That personalization capability is of particular importance since longevity behaviors are not uniform; they change according to family type, traditional guidelines, and ecological understanding (Khan et al., 2022). Machine intelligence enables resilience structures to change dynamically rather than rely on trust in a one-size-fits-all message.

Automated reasoning also helps move towards a circular economy model by facilitating material traceability, waste classification, and predictive resource management. The research shows that machine learning-based waste screen structures significantly improve recycling accuracy and reduce contamination, directly contributing to landfill diversion and supply recovery (Zhao et al., 2025). These capabilities can increase the community's reliance on recycling effects by making the framework efficiency visible and transparent at the same time.

Nevertheless, the success of automated reasoning in green urban life is closely related to the way its own final product is presented to the user. Research shows that opaque, otherwise excessively technical, automated reasoning frameworks may hinder buyer

confidence and involvement, thereby destroying longevity objectives (Rahman & Al-Sayed, 2024). The present stresses the need for UX design as an intercede layer between artificial intelligence, intelligence, and human behavior. Analytic influence is provided by AI, but UX design translates that control into purposeful, actionable experiences. In this context, AI should be observed not only in its use as an optimization tool in academic writing, but also as a catalyst. At the same time, implanting an indoor well-designed interface, AI can transform sustainability from an abstract policy goal to a personalized, synergistic, and socially reinforced aspect of urban life (Li & Chen, 2023).

IV. UX DESIGN PRINCIPLES THAT INFLUENCE RECYCLING AND WASTE-REDUCTION DECISIONS

User Experience (UX) design plays a decisive role to shape the way people perceive, interpret, and behave in relation to sustainability-related facts. UX design goes beyond interface aesthetics to embrace cognitive load leadership, manner guidance, clear direction, and passionate involvement in the context of recycling and waste reduction. The study on eco-friendly UX design stresses that sustainably trustworthy deportment is excessively anticipated to happen when eco-friendly activities are intuitive, low-friction, and seamlessly integrated into everyday routines (Li & Chen, 2023).

One of the most influential UX principles in recycling arrangements is simplicity. Users are further anticipated to comply with recycling recommendations at a time when interface complexity and choice fatigue are reduced. Common mistakes in disposal are confusion with the bin label, dense text, or other unstructured movable intention. The importance of clear ocular hierarchy, iconography, and contextual cues that guide users to correct waste sorting decisions without the need for extensive anterior awareness is highlighted in eco-friendly UX literature (Rahman & Al-Sayed, 2024).

Another important doctrine is commentary visibility. An immediate and valuable evaluation reinforces actions by helping users to assess the impact of their actions. Investigations on persuasive waste management applications show that users who accept ocular alternatively numeric confirmation, such as waste deviating from landfill otherwise carbon

emission reduced, are significantly more likely to sustain recycling habit (Daz et al., 2021). A UX plan with visible environmental impacts reverts from a passive undertaking to a rewarding interaction.

A key element in UX is also consistency and confidence. The user must trust the recommendations and instructions to be precise and fair in AI-powered resilience systems. A clear explanation of the framework logic, the absence of technical jargon, and modern automated reasoning support as a means of understanding rather than as a directive Fostering higher levels of interaction. A study based on eco-friendly UI/UX design proposes that openness in system behavior enhances user conviction and reduces resistance to deportment adaptation efforts (Rahman & Al-Sayed, 2024).

Collectively, these UX standards lay the foundations for the efficient functioning of machine learning-based longevity structures. Even the mainly advanced machine intelligence answers vulnerabilities removal, misuse, or even direct rejection by the user without any intentional UX design.

V. AI-DRIVEN PERSONALIZATION AND FEEDBACK LOOPS FOR ECO-FRIENDLY BEHAVIORS

AI-powered personalization is one of the most powerful mechanisms for influencing green behaviors in the urban environment. Unlike an inactive resilience political campaign, machine intelligence systems can change to be users based on performance data, interaction history, and contextual variables. The current situation allows longevity platforms to provide tailored recommendations that are consistent with user habits, tastes, and limitations (Khan et al., 2022).

Personalization should be particularly proficient in recycling and waste reduction since eco-friendly behavior is changing broadly in families and inhabitants. A machine learning model may determine a shape such as frequent recycling mistakes, incoherence, or peak waste coevals, allowing frameworks to intervene in a timely, connected manner. For instance, when contamination hazards are detected or personalized screen guidance based on past mistakes, a machine learning-enabled aim may advise the user.

Feedback loop is essential for a long-term transformation in performance. AI systems continuously learn from interactions with consumers, improve recommendations, and adjust interface aspects to optimize. Engagement. Analyses on persuasive longevity purposes show that adaptive feedback, such as progress tracking, comparative benchmarking, or otherwise goal reinforcement, significantly enhances customer motivation and retention (Daz et al., 2021). Long-term behavior becomes self-reinforcing rather than externally reinforcing when the user observes a change in growth overdue.

Furthermore, context-aware feedback which adjusts the resilience direction based on location, duration, and situational elements can be provided by machine intelligence. The United States. Data-driven systems, which can dynamically update a locational manual, thereby reducing the amount of confusion and errors, in a city where recycling rules may change by locality or neighborhood. This capability contributes to inclusiveness by adapting to different urban contexts rather than assuming uniform infrastructure or intelligence qualifications analysis Corridor.

Importantly, the productivity of personalization depends on ethical and clear statistical use. Eco-friendly UX analysis stresses that users need to know how their statistics are used and detect self-confidence that personalization serves sustainable targets rather than surveillance or coercion (Li & Chen, 2023). When trust is established, the AI-powered feedback loop becomes a powerful catalyst for the introduction of environmentally friendly actions in everyday urban life.

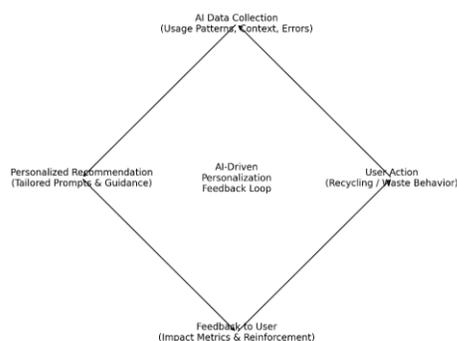


Figure 1: AI-Driven Personalization and Behavioral Feedback Loop in Urban Sustainability Systems

VI. INTELLIGENT INTERFACES FOR RECYCLING SYSTEMS AND SMART WASTE INFRASTRUCTURE

As the main interface layer between urban dwellers and intelligent technology-driven waste management systems, intelligent interfaces translate complex backend processes, such as computer vision-based waste classification, forecasting systematic analysis, and automated sorting, into available, user-oriented experiences in the smart city environment. The study on machine learning-driven waste governance underlines that the framework's success will be significantly improved when the user interacts with and perceives the intelligent Foundation rather than the passive contestants (Kumar et al., 2023).

Recycling arrangements increasingly rely on intelligent interface installations in smart containers, portable applications, and citizen booths for recycling. Computer perception technologies recognize the type of waste in real time, while interfaces respond immediately to the user in case of correct or otherwise incorrect disposal operations. The research on deep learning-based waste screen shows that identical systems are not only used in academic writing only to enhance screen correctness but also to guide users through recurrent interaction, eventually designing correct disposal habits (Zhao et al., 2025).

From a UX point of view, intelligent interfaces need to be aligned with the customer agency. In all aspects, automated structures risk detachment assuming users perceive detachment from consequences during excessively manual interventions increase cognitive burden. A long-term UX study suggests that interfaces should adopt a "directed autonomy" method wherein AI help verdict is given while user restraint and comprehension is maintained (Rahman & Al-Sayed, 2024). For instance, visual cues, voice prompts, or alternatively simple confirmations may assist users without overwhelming them.

Smart waste infrastructure also benefits from AI-enabled data visualization. Dashboards that present neighborhood-level recycling rates, contamination reductions, or environmental impact metrics foster collective accountability and community engagement. This interface, rather than an invisible municipal procedure, alters waste management within a shared

urban responsibility. Circular economy research highlights that visibility of material flows strengthens public trust and participation in sustainability initiatives (Research Corridor, 2024).

In U.S. cities characterized by regulatory variation and infrastructural diversity, intelligent interfaces provide a unifying layer that adapts to local rules while maintaining consistent user experiences. Cities can bridge the gap between progressive waste frameworks and common citizen performance by implanting intelligent reasoning skills into carefully designed interfaces.

VII. PERSUASIVE AND GAMIFIED UX STRATEGIES FOR LONG-TERM BEHAVIOR CHANGE

Increasing the longevity of the product does not depend solely on the initial acceptance but also on the continued involvement of the user. Using motivation, social domination, and habit formation mechanisms, persuasive and gamified UX approaches have been effective in reinforcing environmentally reliable actions. The study on persuasive durability functions has shown that users are more likely to take action to reduce waste and recycling efforts at a time when arrangements integrate motivational design factors rather than rely solely on information (Daz et al. 2021).

Gamification in Resilience Media aims at achieving goals, improving trailing, wages, and social similarity. Machine Intelligence enhances the abovementioned approaches by dynamically adapting obstacles and incentives based on user performance and interaction levels. For instance, machine learning techniques can detect when users lose motivation and introduce new purposes or feedback to re-engage them. Surveys have shown that adaptive gamification significantly enhances sustained sharing compared to inactive wage structures (Li & Chen, 2023).

Another important dimension is societal persuasion. ML-enabled media may include corporate achievements, neighborhood ranking, or peer comparison to encourage green behaviors. Circular economic prose underlines the robustness of longevity

at a time when longevity is a social practice rather than a duty (Khan et al., 2022). A UX plan highlighting the group's consequences, above all obedience, reinforces this framework.

However, persuasive design must be applied ethically. Customer resistance or detachment may be caused by excessively aggressive nudging or an opaque incentives mechanism. The green UX analysis highlights the importance of respecting user autonomy and supplying an opt-in mechanism for gamified features (Rahman & Al-Sayed, 2024). Openness in AI-powered persuasion ensures that users perceive longevity channels as a means of understanding rather than manipulative frameworks.

Urban sustainability platforms can move beyond short-term behavioral changes to last ethnic adaptation by combining machine intelligence versatility with powerful persuasive UX approaches. Therefore, gamification and persuasive interface play a key role in implanting environmentally friendly actions within the fabric of everyday urban life.

VIII. EQUITY, ACCESSIBILITY, AND TRUST IN AI-POWERED SUSTAINABILITY PLATFORMS

The essential determinants for the success of US longevity initiatives based on smart technology are equity and accessibility. Urban groups are socioeconomically, traditionally, and digitally diverse, and the stages of resilience that fail to account for this diversity's perils exclude the very groups most affected by ecological degeneration. The analysis of waste management in smart cities underlines the fact that digital advancement is not used in academic writing for equitable effects unless it is deliberately used in terms of overall design values (Kumar et al., 2023).

From a UX design perspective, accessibility encompasses language simplicity, multimodal interaction, and adaptability to different levels of digital literacy. Sustainable UX studies emphasize that interfaces designed for environmentally responsible behavior must be user-friendly, with changing cognitive capabilities, corporeal damage, and access to innovation (Li & Chen, 2023). Machine intelligence enables voice interfaces, adaptive text complexity, and

context-aware aid that adjusts to the customer's needs in real time.

In addition to data-driven resilience structures, trust should be another basic necessity for user involvement. The user must rely simultaneously on the accuracy of the automated reasoning recommendation and the objectives derived from statistical clustering and personalization. A study based on green UI/UX design shows that clarity in AI decision-making, such as explaining why a recommendation should be made another way in which information is used, significantly enhances buyer confidence and long-term involvement (Rahman & Al-Sayed, 2024). When a user understands the purpose and logic of automated reasoning systems, he is expected to show resilience instructions.

Equitable sustainability design also requires addressing systemic disparities in waste infrastructure. Some communities lack access to reliable recycling services or smart waste technologies, limiting the effectiveness of AI-enabled platforms. The circular economy analysis stresses the need to implement machine learning-driven longevity alongside policy support and infrastructure investments to avoid a deterioration of the current natural unfairness (analysis Corridor, 2024). UX design can help regulate these spaces by providing a substitute engagement nerve pathway, such as mobile training, where the corporeal infrastructure is limited.

Cities can ensure that environmentally friendly actions are not used in academic writing as a privilege of digitally advantaged groups but nevertheless a common urban norm by integrating equity, handiness, and confidence into smart technology-driven resilience channels.

IX. ENVIRONMENTAL, SOCIAL, AND ECONOMIC IMPACTS OF AI-ENABLED SUSTAINABLE UX

AI-enabled sustainable UX design produces multidimensional effects that go further than the immediate waste reduction consequences. Ecologically, AI-powered recycling systems have been depicted to significantly lower landfill dependence by improving screen accuracy and

increasing recycling engagement. Deep learning-based waste categorization tools contribute directly to material recovery and emission reduction, thereby contributing to the goal of reducing carbon emissions (Zhao et al., 2025).

Socially, artificial intelligence-powered UX platforms enable the way resilience is observed and practiced within urban communities. The persuasive and community-oriented interface contributes to share accountability and corporate distinctiveness in close cooperation with sustainable conservation. A study on persuasive longevity functions shows that users who connect to socially structured feedback, such as neighborhood improvement indicators, develop strong and excessive persistent green habits (Daz et al., 2021). This interpersonal support transforms longevity into a corporate culture practice.

Economically, AI-enabled waste management arrangements contribute to cost effectiveness and resource optimization. Predictive data analysis reduces labor costs by optimizing aggregate paths and preventing soil overload, while increased recycling productivity increases the economic value of the cured substances (Khan et al., 2022). Such financial gains are magnified by increased user adherence and reduced structure misuse when combined with intuitive UX design.

The integration of UX design ensures that the aforementioned green, social, and economic rewards are never sabotaged by the abandonment or misinterpretation of the customer. Eco-friendly UX analysis systematically shows that well-designed interface addition systems embracement and longevity, thus maximizing the tax return upon acquisition for the municipality and the participants (Rahman & Al-Sayed, 2024).

Generally speaking, AI-enabled green UX works as a catalyst for systemic change by aligning digital effectiveness with human deportment. Their influence extends ecological conservation, interpersonal solidarity, and fiscal strength, thereby enhancing the calculated value of human-centered automated reasoning in urban sustainability programs.

X. FUTURE DIRECTIONS FOR AI-UX INTEGRATION IN URBAN SUSTAINABILITY ECOSYSTEMS

The future of AI-UX integration in urban sustainability lies in the development of adaptive, human-centered ecosystems that seamlessly embed environmentally responsible behavior into everyday city life. As AI capabilities mature, sustainability platforms are expected to move beyond reactive guidance toward anticipatory and preventive design. Predictive models will increasingly forecast waste generation patterns, recycling errors, and behavioral drop-offs before they occur, allowing systems to intervene proactively through UX-driven prompts and interface adjustments (Khan et al., 2022).

Conversational and multimodal interfaces represent a significant future direction for sustainable UX design. Research on anthropomorphic conversational agents suggests that users are more receptive to guidance delivered through human-like, empathetic interactions, particularly in behavior-change contexts (Park et al., 2025). When integrated into recycling and waste-reduction platforms, conversational AI can provide real-time assistance, answer context-specific questions, and reinforce sustainable habits through ongoing dialogue.

Another critical direction is the deeper integration of sustainability platforms with broader urban digital ecosystems. AI-enabled UX systems can be connected to smart home technologies, public transportation networks, and municipal service platforms to create cohesive sustainability experiences. Circular economy research emphasizes that cross-system integration enhances material efficiency and strengthens behavioral consistency across different aspects of urban life (Research Corridor, 2024). UX design will play a central role in ensuring that such integrations remain intuitive rather than overwhelming.

Ethical AI and responsible design will also shape future development. As personalization becomes more sophisticated, ensuring data privacy, algorithmic fairness, and user autonomy will be paramount. Sustainable UX literature underscores that trust and transparency must evolve alongside technological capability to maintain public confidence in AI-driven sustainability initiatives (Rahman & Al-Sayed, 2024).

Future systems will need to provide users with meaningful control over data use while clearly communicating environmental benefits.

Ultimately, the future of AI-UX integration in urban sustainability ecosystems will depend on interdisciplinary collaboration among technologists, designers, policymakers, and communities. By aligning AI intelligence with inclusive and ethical UX design principles, cities can create resilient systems that support long-term environmental stewardship.

XI. CONCLUSION

This research has examined the role of artificial intelligence and UX design in promoting sustainability through recycling, waste reduction, and eco-friendly behaviors in U.S. cities. The findings underscore that technological advancement alone is insufficient to address urban sustainability challenges. Instead, meaningful impact emerges when AI capabilities are paired with user-centered, persuasive, and accessible UX design principles.

AI enables personalization, prediction, and optimization across waste management systems, while UX design determines how these capabilities are perceived, trusted, and acted upon by users. Intelligent interfaces, adaptive feedback loops, and gamified engagement strategies transform sustainability from a policy mandate into an intuitive and socially reinforced practice. Importantly, considerations of equity, accessibility, and trust ensure that AI-enabled sustainability platforms serve diverse urban populations rather than amplifying existing disparities.

The integration of AI and sustainable UX design offers environmental benefits through improved recycling efficiency, social benefits through collective behavior change, and economic benefits through resource optimization and cost reduction. As U.S. cities continue to pursue smart and sustainable development, the alignment of human behavior with intelligent systems will remain a decisive factor in achieving long-term sustainability goals.

In conclusion, AI for sustainability is most effective when designed not just for efficiency, but for people. By embedding ethical, inclusive, and behavior-aware UX principles into AI-driven systems, urban

sustainability can evolve from an aspirational ideal into an everyday reality.

REFERENCES

- [1] Díaz, J., Martín, A., & Rubio, B. (2021). Persuasive apps for sustainable waste management: A comparative systematic evaluation. *Frontiers in Artificial Intelligence*, 4, Article 748454.
- [2] <https://www.frontiersin.org/articles/10.3389/frai.2021.748454/full>
- [3] Khan, S., Ahmad, T., & Babar, M. (2022). Machine learning and artificial intelligence in the circular economy: A systematic literature review. *arXiv*. <https://arxiv.org/abs/2205.01042>
- [4] Kumar, A., Zhang, Z., & Kumar, R. (2023). Artificial intelligence for waste management in smart cities: A review. *Environmental Chemistry Letters*. <https://www.researchgate.net/publication/370680681>
- [5] Lappeenranta–Lahti University of Technology. (2024). AI as a tool to reduce waste and improve sustainability in logistics (Technology report). <https://www.researchgate.net/publication/388314266>
- [6] Li, X., & Chen, Y. (2023). Sustainable and eco-conscious UX design: Promoting sustainable behavior and reducing digital waste. *Design Practice*, 5(2), 1–15. <https://journal.hep.com.cn/design/EN/PDF/10.36922/dp.5015>
- [7] Park, J., Lee, S., & Kim, H. (2025). Exploring anthropomorphism in conversational agents for environmental sustainability. *arXiv*. <https://arxiv.org/abs/2505.07142>
- [8] Rahman, M., & Al-Sayed, S. (2024). Designing sustainable UI/UX: An approach to reducing the environmental impact of digital products. <https://www.researchgate.net/publication/382634724>
- [9] Research Corridor. (2024). Artificial intelligence and the circular economy: How AI advances waste reduction. *Research Corridor*. <https://www.researchcorridor.org/index.php/get/article/download/214/205>
- [10] Zhao, L., Wang, H., & Liu, J. (2025). Intelligent waste sorting for urban sustainability using deep learning. *Scientific Reports*, 15, Article 8461. <https://www.nature.com/articles/s41598-025-08461-w>
- [11] Zhang, Y., & Wu, M. (2025). A user-centered recycling fashion design process. *Fashion and Textiles*, 12(23). <https://link.springer.com/article/10.1186/s40691-025-00423-0>