

Second Chances: Design to Extend Clothing Lifespan with a Circular Approach

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Abstract

The fashion industry is one of the world's most polluting sectors, disposing of 92 million tons of textile waste annually, through landfilling or incineration. This research aims to address this issue by proposing a design with a circular approach to reduce clothing waste. The main question is how to increase the lifespan of clothing. Employing a combination of library and field research methods, it was found: 1. Slowing down the product life-cycle is a key strategy for reducing waste, 2. A significant amount of clothing is still usable when discarded, 3. Iran lacks a systematic and reliable solution for safe clothing disposal, 4. The youth are willing to exchange clothing with each other, due to a cultural shift. As a state-of-the-art contribution, a conceptual model was developed to address the research question and design solutions. Subsequently, a mobile phone application was presented to help people take better care of their clothing and facilitate swapping. To explore the application's profitability, a business model was also proposed.

Keywords

Circular Fashion, Product Life-Cycle, Sustainability.

Introduction

The fashion industry produces 92 million tons of textile waste annually. Every second, the equivalent of a truckload of textile waste is buried or burned worldwide (Seier, 2020). Only 15% of post-consumer textile waste is collected separately for recycling, and less than 1% of the total production is recycled within closed loops (A New Textiles Economy, 2017). Globally, textiles constitute up to 22% of mixed waste worldwide (Nørup et al., 2019). Also, 85% of all fibers were thrown into landfills at the end of their life-cycle (Igini, 2023).

This paper is aimed to design a solution to expand the lifespan of clothing, reducing its waste. We used a circular approach in which the products are used repeatedly and consumers are encouraged to take better care of them. The paper encompasses both research and design processes, with a greater focus on research, including a set of strategies to reduce waste in the fashion industry. Also, a key feature of this paper is a conceptual model proposed, outlining various possibilities for design innovations; one of which is provided in this paper. As a summary of a master's degree thesis, certain parts of the study were omitted, retaining only the most important sections for the readers. Nevertheless, we assume the content will be beneficiary for a variety of stakeholders:

- The Environment: Extending clothing lifespan will decrease the amount of textile waste in landfills, and reduce the need for raw materials, conserving natural resources.
- The Industry: Brands adopting sustainable practices can build stronger relationships with eco-conscious customers, increasing brand loyalty. They can also save budget by reducing their use of raw materials.
- Governments: Policymakers could regard the concepts of this study in their research and decision-making processes.
- The Economy: Longer-lasting clothing and the possibility of swaps help consumers spend less. Businesses are also encouraged to innovate in repair services, recycling, and resale markets.

Few studies have been done on this topic, none of them have studied Iranian consumers. This despite the fact that developing countries are a destination for a significant proportion of second-hand or unsold fashion goods (Niinimäki et al., 2020). To our knowledge, measures to address clothing waste in Iran, either for manufactured or imported clothes, are marginal. Neglecting the issue can lead to irreversible environmental effects in the near future.

Concepts

- Circular Fashion: In a circular economy, products are created and used in a manner that reduces resource consumption, minimizes waste, and lowers carbon emissions. Items are maintained in circulation for extended periods by means of repair, recycling, and redesign, enabling repeated use (Masterson & Shine, 2023). It offers an alternative to traditional linear economies, where resources are extracted, products are made and consumed, and then discarded, depleting finite raw materials and produce large amounts of waste (Masterson & Shine, 2023). Different versions of coding for circular economy have been provided so far (Kirchherr et al., 2017). This type of view has recently been proposed in the fashion industry too (Circular Economy Introduction, n.d.), the framework of which is shown in Figure 1.
- Digital Twin: A digital twin is a virtual representation of an entity or process in the real world. Three elements are involved in a digital twin model: the physical entity in real space, the digital version in the form of software, and the data that links the two (Essex, 2022). Many digital twin models have a computer-generated 2D or 3D image. However, visual representation is not mandatory. A digital model can include a database, a set of equations, or a spreadsheet (Essex, 2022). Since its initial introduction, digital twin has been considered as a basic element for product life cycle management (Grieves, 2002) and has also been considered in the context of increasing the lifespan of clothing (Riedelsheimer et al., 2020).

- **Disposal Behavior:** Product disposal involves a consumer ceasing to use a still-functional product and discarding it through various means such as storing, donating, giving away, throwing away, or selling it (Hanson, 1980). From an environmental perspective, consumers' behavior regarding clothing disposal is crucial. Their choices about when and where to dispose of used clothing affect the lifespan of the garments, the amount of waste produced, and the potential for reuse and recycling (Laitala, 2014).
- **Generation Z:** Generation Z consists of individuals born between 1996 and 2010. Their identity has been shaped by the digital age, climate anxiety, changes in the financial landscape, and the COVID-19 pandemic (What is Gen Z, 2023). They are often referred to as *digital natives* because they are the first generation to grow up with the internet as an integral part of daily life (What is Gen Z, 2023).

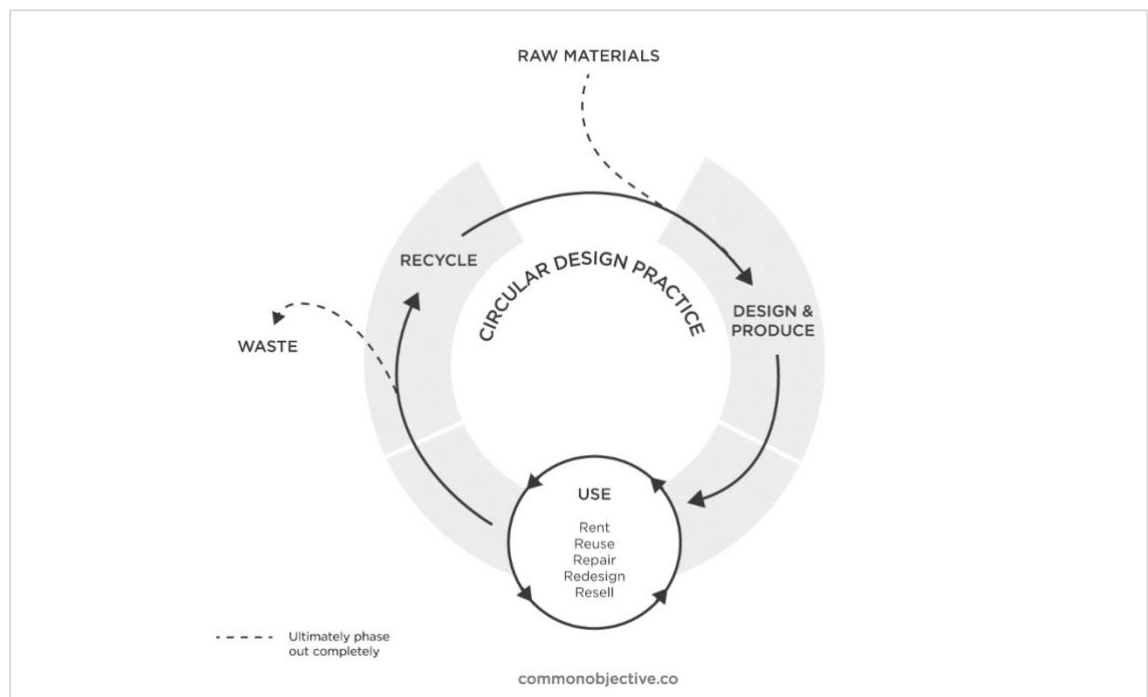


Figure 1: Circular economy model in the fashion industry.

Methodology

- Library research was done to study the environmental impacts of the fashion industry.
- A field study was conducted to explore the clothing disposal behavior of citizens of Tehran, interviewing 8 people chosen by convenient sampling.
- Strategies to reduce the fashion industry waste were studied through review research, based on 20 selected papers published between 2018 and 2022.
- A conceptual model was proposed based on the gathered insights, and the design was done according to that.

Results

Environmental Impacts of the Fashion Industry

The fashion industry has a long and complex supply chain, each part of which has its own environmental impact – from agriculture and petrochemical production to product manufacturing, logistics, and sales. Production of primary fibers and manufacturing of products mostly takes place in developing countries, while consumption usually occurs in developed those (Niinimäki et al., 2020).

There are four types of environmental damage the fashion industry causes (Niinimäki et al., 2020):

- **Water Consumption:** The amount of water used to produce each ton of textiles is estimated to be 200 tons on average (Anguelov, 2015), most of which is related to cotton cultivation and wet processes.
- **CO2 Emission:** The Intergovernmental Panel on Climate Change identifies the textile industry as the cause of 10% of greenhouse gas emissions in the world (UN Helps Fashion Industry, 2018). The high production of greenhouse gases in the fashion industry is caused by high energy consumption.
- **Chemical Pollution:** One-fifth of the total consumption of insecticides and one-tenth of the total consumption of pesticides is related to cotton production (Granskog et al., 2020). Textile production, including weaving and wet processes, causes pollution too. As an example, a European company uses more than 466 grams of chemicals to produce each kilogram of fabric (Schönberger, 2019).
- **Textile Waste:** Relying on cheap production, frequent purchases and short-term use of clothing leads to the production of large amounts of textile waste, most of which are burned or buried, or exported to developing countries (Niinimäki et al., 2020). There are two types of textile waste:
 - Pre-consumption – also called production waste– is produced during the cutting of the fabrics. It could be influenced by some factors, including design of the patterns and faults in assembly, and could waste up to 30% of the textile (Runnel et al., 2017).
 - Post-consumption includes clothes that are discarded by consumers (Remy et al., 2016), or are not sold at all (which is called *dead stock*) (Mathews, 2016). Both often are incinerated, buried, or exported to developing countries (Niinimäki et al., 2020).

These environmental impacts primarily affect the people of countries where clothing factories are located, while textile waste is found everywhere (Niinimäki et al., 2020).

Clothing Disposal Behavior

We chose post-consumption textile waste to work on. Interviews were done, asking people about their habits and practices in shopping, using and disposing of clothes, using a combination of closed and open questions (Table 1).

Table 1: Interviews' questions.

1. For what reason do you usually discard clothes?	
2. About how often do you discard clothes?	
3. How important are the following factors to you when you decide to dispose an item of clothing? Rate each item from 1 to 5 (1 = not important at all, 5 = very important):	a. Environmental impacts b. Social norms c. Your personal preferences about style d. Economic considerations e. Storage space f. Other reasons (please write)
4. How often do you dispose of your clothes in ways that are more environmentally sound? (e.g., donating to others or recycling)	a. Usually b. Sometimes c. Never
5. What is your definition of waste?	
6. When do you think clothes or accessories become waste?	
7. How familiar are you with sustainable practices in fashion, such as upcycling or buying second-hand clothes?	
8. Can you describe a fashion item you recently threw away, and explain why and how you did that?	

Four key points were found out:

- There is no systematic reliable way, in Iran, to discard clothes appropriately. Instead, people rely more on family networks to deliver clothes to the poor. They also downcycle the clothing or simply discard them through domestic trash cans (which is prohibited in developed countries).

- Youngers, especially Gen Z, show a high tendency to exchange clothes with each other. They are also more likely to adopt sustainable practices in general, confirming the existing literature e.g., ([The State of Fashion, 2019](#); [Wood, 2022](#)).
- However, this tendency was not mainly due to their higher environmental awareness, but was because of a cultural shift; i.e., they do not consider swapping clothes, or using second-hand those in general, negative, as their parents mostly do.
- Fashion trends, personal taste and boredom were the second reason for discarding clothes (after physical damage as the first one), which also approves the existing literature e.g., ([Laitala, 2014](#); [Zhang et al., 2020](#)).

Strategies to Reduce the Fashion Industry Waste

Questioning what are the practices to reduce the fashion industry waste, a review was done, using 20 papers ([Table 2](#)). The results are presented in the discussion.

Table 2: *Selected papers for the review.*

Paper	Strategy Type	Stage
Abdel Wahab, 2018	Internal (in-house: Practices are done inside the organization – the opposite is external)	Production
Ballie & Woods, 2018	Internal	Production
Brydges, 2021	External	Both
Daukantiene, 2022	Internal	Both
Dissanayake & Weerasinghe, 2021	Both	Both
ElShishtawy et al., 2021	Internal	Production
Enes & Kipöz, 2019	Internal	Production
Kerdlap et al., 2019	Both	Both
Khandual & Pradhan, 2018	Internal	Both
Ki et al., 2020	Both	Both
Kidd et al., 2020	External	Post-consumption
Mansour, 2020	Internal	Production
McQuillan, 2020	Internal	Production
McQuillan et al., 2018	Internal	Production
Mishra et al., 2020	Both	Both
Pasricha & Greeninger, 2018	Internal	Production
Ramkalaon & Sayem, 2020	Internal	Production
Shirvanimoghaddam et al., 2020	Internal	Both
Stanescu, 2021	External	Post-consumption
Vecchi, 2020	Both	Both

Discussion

Strategies and Practices

Synthesizing the contents, the previously mentioned review resulted in 8 strategies and 48 practices, presented in [Table 3](#).

Table 3: *Strategies and practices to reduce waste in the fashion industry.*

Strategies	Practices
Close the cycles	<ul style="list-style-type: none"> ▪ Design for disassembly ▪ Set up clothing recovery systems for resale or recycling ▪ Measure and monitor the environmental effects of production processes ▪ In-plant wastewater treatment for reuse ▪ Use the Internet of Things (IoT) in manufacturing and consuming the products ▪ Invest in waste sorting and recycling technologies
Slow down the cycles	<ul style="list-style-type: none"> ▪ Offer season less collections ▪ Design for longevity ▪ Made-to-order production ▪ Create platforms for shared consumption, rental or exchange of clothing ▪ Provide the possibility of making changes in clothing by the user ▪ Design services for maintenance and repair
Limit the resources	<ul style="list-style-type: none"> ▪ Limit the use of water and chemicals ▪ Use automatic dosing machines and controllers in different stages of production, instead of manually determining the dose of chemicals ▪ Reduce processes (e.g., painting and surface treatment) to save energy ▪ Pattern design and cutting aimed to minimize material wastage ▪ Creative pattern making ▪ Using additive manufacturing methods (3D printing or direct weaving of clothes) to the production waste ▪ Product customization instead of manufacturing based on default sizing (e.g., using body scanning and parametric design) ▪ Increase the use of renewable energies
Appropriate selection of resource	<ul style="list-style-type: none"> ▪ Replace chemical colors with natural those ▪ The use of enzyme biocatalysis (the use of living systems to accelerate (catalyze) chemical reactions), biopolymers (polymers made by or derived from living organisms (e.g., plants and microbes), instead of from petroleum) and biomasses in material processing and textile treatments ▪ Use recycled materials instead of new those ▪ Use renewable materials (e.g., regenerated cellulose (a class of materials produced by transforming natural cellulose to a soluble cellulosic derivative and subsequent regeneration) and biodegradable protein fibers) ▪ Using 100% natural cotton ▪ Avoid using mixed fibers ▪ Transparency and traceability of suppliers ▪ Local production to reduce greenhouse gases from transportation
Organizational policies	<ul style="list-style-type: none"> ▪ Place other employees near the material supply team to increase communication between them ▪ Share knowledge and resources between different departments ▪ Increase the value proposition using circular economy as a strategy to persuade stakeholders to become more involved in circular models ▪ coordination of the stakeholders at different stages of the supply chain to achieve a circular economy as a common goal
Create social awareness	<ul style="list-style-type: none"> ▪ Set up campaigns to buy less and use the products longer ▪ Inform people about the environmental impacts of the industry and sustainable consumption behaviors ▪ Educate the community about recycling practices ▪ Transparency and keeping the consumers aware

Conceptual Model

The study concluded in 4 key insights:

- Slowing down the product life-cycle is a strategy to reduce the waste. One way to do that is to provide the possibility of reuse through sale, rent or exchange.
- A major amount of the clothes is still usable when discarded, as fashion, taste, and boredom are the second reason for disposing of clothes.
- In the absence of a systematic solution, people mostly rely of family networks to give used clothing to the poor, or they simply discard them using domestic trash cans.
- The youth have a high tendency to swap clothing with each other, caused by not only their environmental awareness but also by a noticeable cultural shift.

After generating ideas, a design brief was prepared. Part of it was as follows:

- A mobile phone application is needed to:
 - Help people take care of clothing better, using a digital twin model. The model is basically a set of data, accompanied with an automatically generated diagram using artificial intelligence based on photos.
 - Increase the users' belonging through story telling
 - Create a space based on social capital and trust, motivating people to share a common goal
 - Enable them to offer clothing for exchange by sharing the stories.

- Generation Z are the target group. Design must be done in accordance with their previous experiences in social apps like Instagram.
- The app has to do four main tasks:
 - Receive clothing health information
 - Narrating the stories of products using images, text and places
 - Connect people, enabling them to socialize and make friends
 - Exchange clothes

Connections between the key features were presented as a conceptual model, depicted in [Figure 2](#). According to this model, clothing damages are connected to stories, leading people to make friends. Socializing itself could form new stories, conversely. Making friends can lead to swaps, but swaps also could start new friendships. Storing the records of damages in the digital twin model, doing harm to clothes could cause social shame, whereas good maintenance brings admiration.

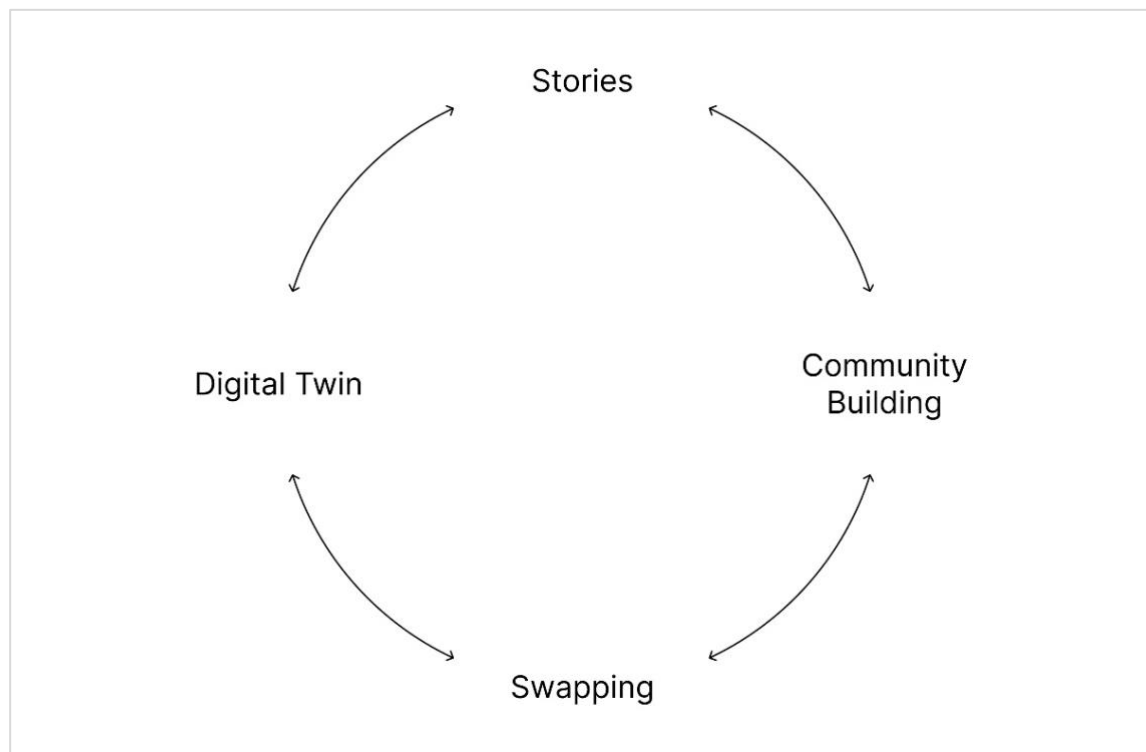


Figure 2: The conceptual model presented by the authors.

Design

Based on the conceptual model, a design was proposed, including a content map ([Figure 3](#)) and wireframes ([Figure 4 –7](#)). Using the software Figma, the app was tested by three individuals from the target group, and modifications were done when needed.

The scenario is as follows: Clothing is posted by the user either for exchange or for donation ([Figure 6](#)), including photos, specifications and a story. Then a digital twin model is created based on the photos, using AI, so the user can write about damages or changes to the garment by tapping everywhere on the diagram. Next, people can request that garment while offering an item from their own previous uploads for exchange ([Figure 5](#)), which then can be approved by the user. If so, the swap happens, either by sending the items remotely or by the two meeting each other in person.

Next, the possibilities of monetizing were explored through the stakeholder's map ([Figure 8](#)), system map ([Figure 9](#)) and business model canvas ([Figure 10](#)).

The stakeholders were divided into three groups:

- Users and company (team members)
- Investors, logistics, maintenance, data analysis and advertising services
- Policymakers, competitors, non-governmental organizations and clothing manufacturers

The map then was used to create a business model canvas. It was shown that the app could be monetized mainly in two possible ways:

- Partnership with service such as dry cleaning and repairing
- Selling consumption data to manufacturers, which enables them to study the user experience and recognize the strengths and weaknesses of their products (users' personal information must not be disclosed)

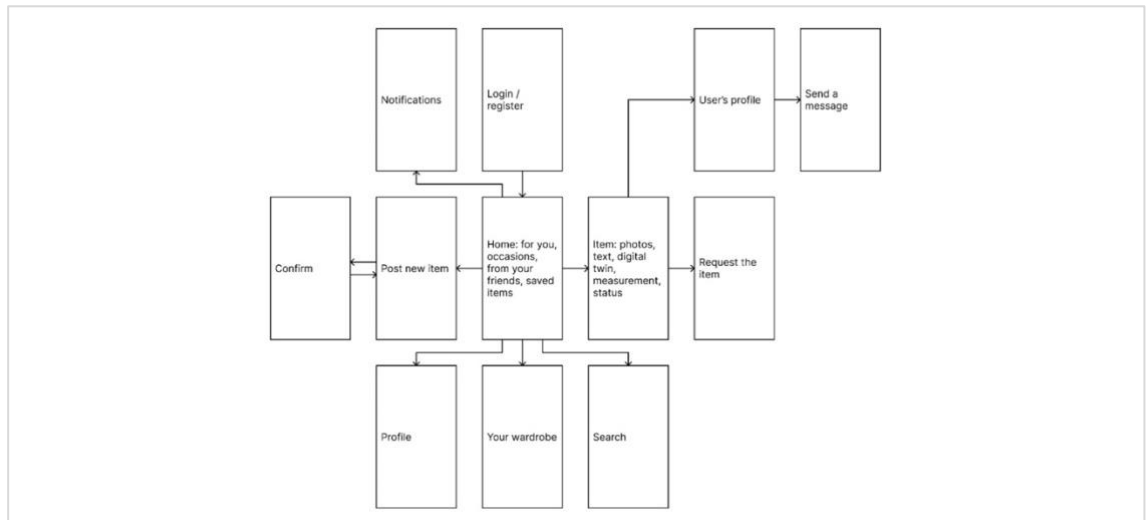


Figure 3: Content map, depicting the main pages and the relationships between them.

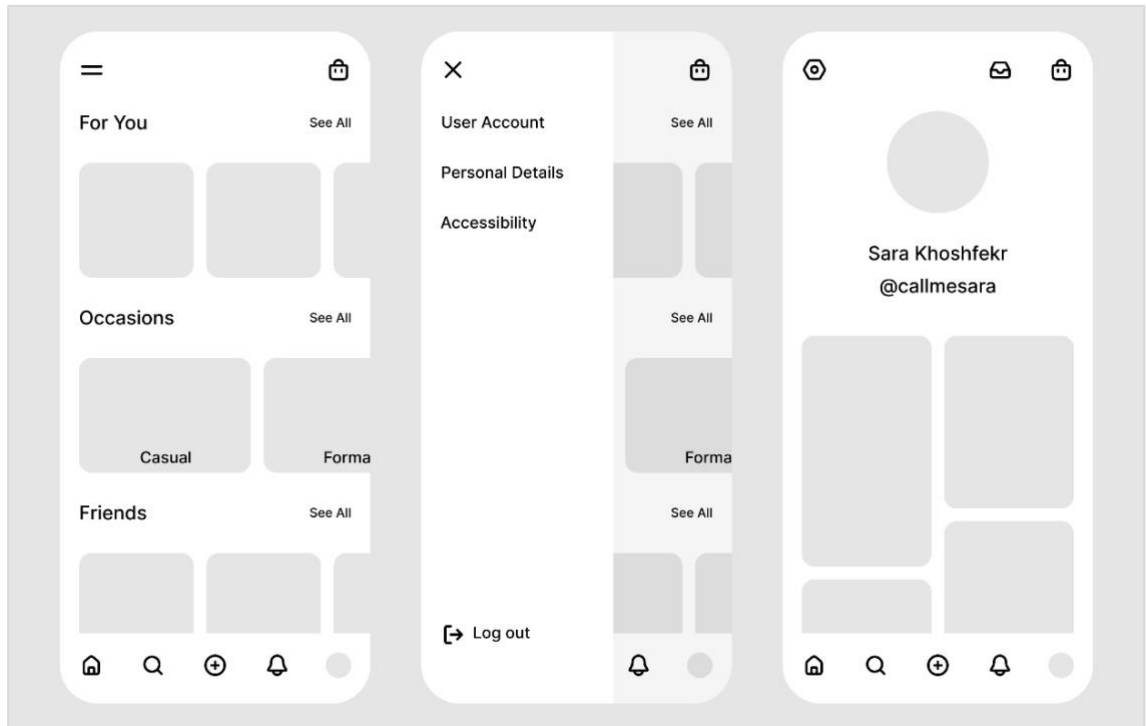


Figure 4: Home page and user profile.

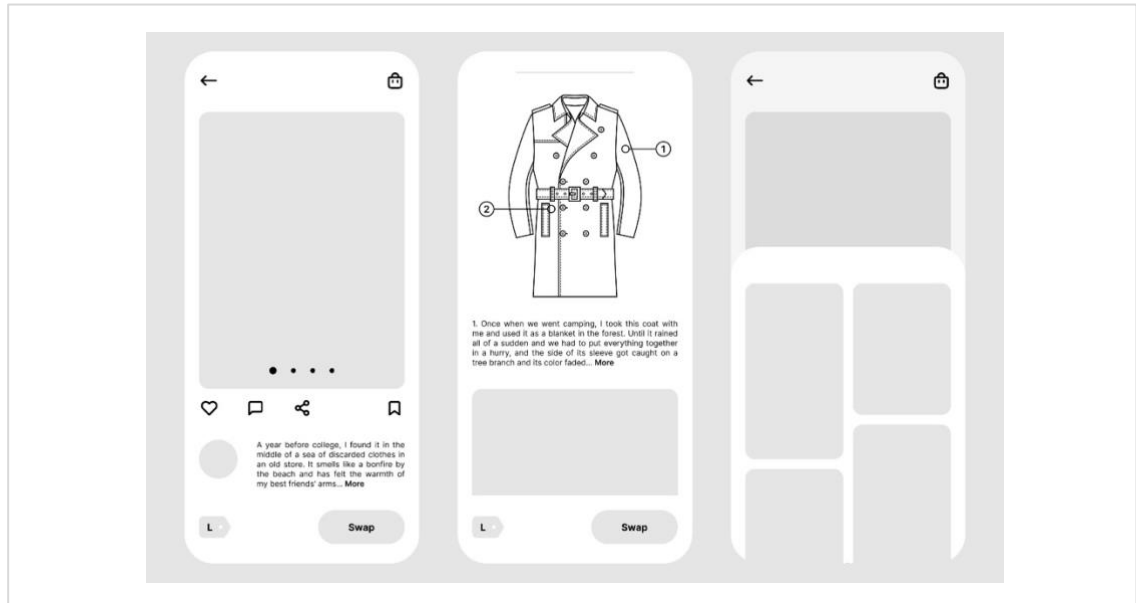


Figure 5: Viewing an item (including digital twin), and offering one for exchange.

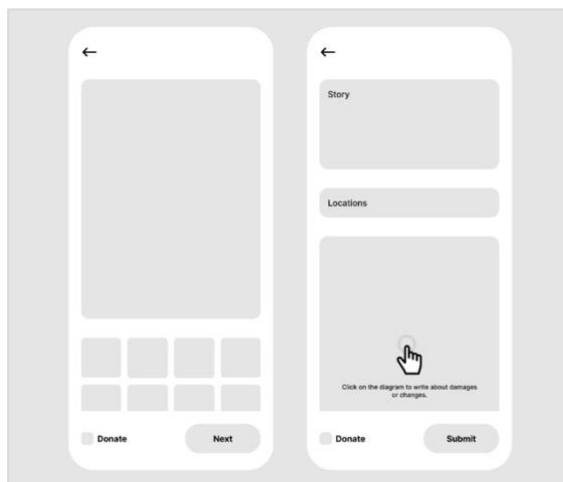


Figure 6: Posting an item.



Figure 7: Exchanging cart and search page.



Figure 8: Stakeholder's map.

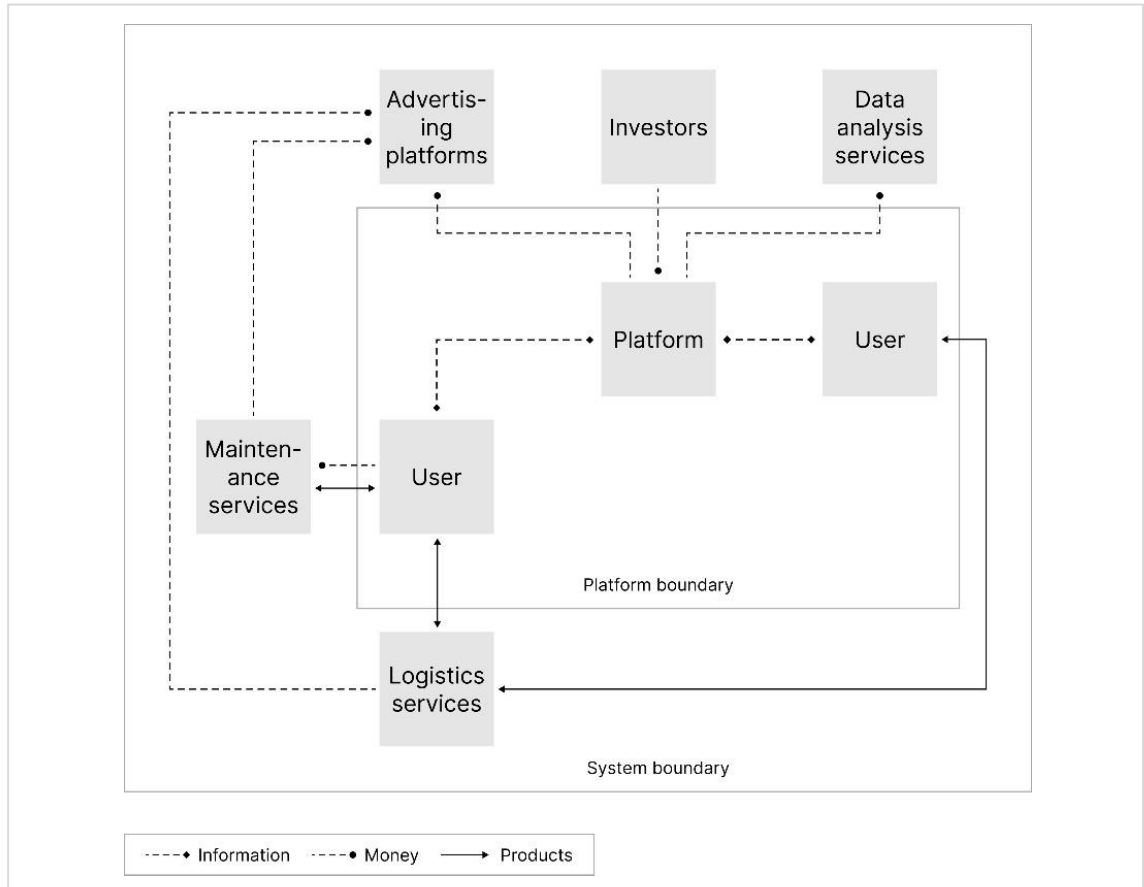


Figure 9: System map, showing how different service components and roles are connected and highlighting the values they exchange.

Key partners Shipping and logistics services, influencers and brands, data analysis services, legal and regulatory partners	Key activities Platform maintenance, algorithm development, user test, customer support	Value propositions Discovery and curation, promoting ethical consumption, community and social interaction, youthful and creative culture	Customer relationships Personalized interactions, customer support, education and resources	Customer segments The generation Z youth
	Key resources Technology infrastructure, human capital, data and analytics		Channels Mobile application, social media, influencer collaborations, word of mouth	
Cost structure Development and maintenance, server, legal and compliance, partnerships and collaborations			Revenue streams Advertising and partnerships, data monetization	

Figure 10: Business model canvas.

Conclusion

This paper aims to reduce fashion industry waste by extending the lifespan of clothing through a circular approach that encourages repeated use and better care by consumers. It presents a conceptual model to support the proposed solution, offering possibilities for various design innovations, with one detailed in the paper.

The study has certain limitations, offering opportunities for future research. These include the lack of an empirical study to evaluate the effectiveness of the proposed solution. Additionally, field studies are needed to assess the quantity and types of fashion waste in both Iranian households and manufacturing plants.

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