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Transformation of the Innovative and Sustainable Supply Chain with Upcoming Real-Time Fashion Systems

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Abstract: Technologies that are ready-to-use and adaptable in real time to customers' individual needs are influencing the supply chain of the future. This study proposes a supply chain framework for an innovative and sustainable real-time fashion system (RTFS) between enterprises, designers, and consumers in 3D clothing production systems, using information communication technology, artificial intelligence (AI), and virtual environments. In particular, the RTFS is targeted at customers actively involved in product purchasing, personalising, co-designing, and manufacturing planning. The fashion industry is oriented towards 3D services as a service model, owing to the automation and democratisation of product customisation and personalisation processes. Furthermore, AI offers referral services to prosumers or/and customers and companies, and proposes individual designs with perfect styles and measurements using new 3D computer aided design and AI-based product design technologies for fashion and design companies and customers. Consequently, 3D fashion products in the RTFS supply chain are entirely digital, saving time and money with sampling and tracking capabilities, secured, and trusted with personalised service delivery.

Keywords: real-time fashion system; personalisation; supply chain; AI; ICT

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1. Introduction

The COVID-19 pandemic has led to the expansion and acceleration of real-time Internet technology. The contemporary atmosphere is accelerating the connection between new collaborations in the fashion industry and broad research community in areas such as product design, engineering, and automotive development as well as hybrid product production, distribution, and sales systems. Therefore, the fashion industry is establishing a convergent design development and distribution system that combines various sciences and technologies, from product design and performance to consumer participation in production and consumption [1]. Additionally, in recent years, the fashion industry has seen innovations in communication in design thinking. Revolutionary changes have occurred in the business in recent years, for example, taking advantage of the designers' creative approaches. Fashion design products not only show the final aesthetic, but also play a pivotal role in addressing the innate desire for novelty and enjoyment, while harmonising personal, financial, social, and environmental needs [2].

This creative use of fashion products is being introduced as a convergence apparel ecosystem through the fusion of the fashion industry and information communication technology (ICT), an innovative approach to real-time fashion systems (RTFSs). When the convergence apparel ecosystem is created, all apparel can be purchased and managed through the Internet of Things. In other words, when one buys, wears, sells, lends, discards, gifts, washes, and repairs clothes, they receive help from the ecosystem. This is because ICT media can aid in the coordination and styling of clothes, produce designs, make and wash clothes, and provide digital clothes. In addition, the era of the Industry 4.0 has led to the advent of the 'prosumer era', in which suppliers become consumers because, in RTFS, products are immediately available and adoptable based on the customers' individual

needs [3] (p. 379). A representative example is Adidas, a leading company that has introduced an ICT convergence system. Recently, Adidas launched smart sneakers equipped with sensors and processors. In addition, companies are expanding customised services for consumers. Nike provides a service that allows consumers to make their own DIY shoes on the platform by choosing the colour and material of their sneakers at will, and Apple's online store offers various personalised laser-engraving services to create designs that suit consumers' preferences, to provide you with 34 different combinations of Apple Watch online products [4].

The positive relationship between product innovation and performance created through these innovations is that product innovation provides unique benefits to customers [5] and increases differentiation and exclusivity. These factors allow customers to pay higher premium prices to companies; consequently, companies achieve better performance. In addition, product innovation will open up the arena for present and future businesses to thrive in an evolving and turbulent market environment [6,7]. An essential characteristic of the fashion industry is that it must be continuously innovative. In fact, fashion companies develop and sell at least two new collections per year: a new set of clothing and accessories for the spring/summer and fall/winter collections [6]. Therefore, the combination of a fast-changing fashion system in real time and innovative sustainable ICT is inevitable. In this study, the scope of the use of innovative convergence technologies is to be understood through a sustainable fashion system. In addition, the difference between the traditional and RTFS is changing, which may suggest a reasonable direction for establishing a sustainable fashion system. For the practical use of a sustainable RTFS, it is essential to provide a practical and simple design using the latest technologies, such as artificial intelligence (AI) and 3D technologies, an eco-friendly and transparent manufacturing process, and a direct-to-consumer distribution process. Moreover, the system must provide fast and accurate information. Thus, the upcoming RTFS can be viewed as containing five key characteristics: it is real-time, delivers directly to consumers, is AI-based, uses 3D computer aided design (CAD), and supports supply chain tracking.

This research is organised as follows. First, it presents the theoretical background related to the theory of changing fashion systems in an AI environment, and explores customer service and differentiation methods as a successful business strategy element to propose an innovative and sustainable RTFS. Second, by analysing how users, prosumers, or consumers actually perform purchase activities in personalised RTFS services, we define a method of providing diversity and innovation in shopping environments according to the level of use of personal customisation service (PCS) of RTFS users. We propose the differentiation of customer service. Finally, we derive a conceptual framework of the RTFS sustainable supply chain that can interact with users in an AI environment and ultimately drive marketing usage. Then, the results are presented, and the theoretical and practical implications of this study are discussed.

2. Literature Review

2.1. Direct to Consumer with 2D and 3D CAD Personalised System in RTFS

The rapidly changing context of fashion positions the user at the centre of the design process. Several technologies are used to reduce the number of cycles in manufacturing and retailing. Computer aided manufacturing equipment is used to reduce the cycle time from design to production [8]. It produces personalised fashion products using 3D body scanning and rapid prototyping techniques integrated with different production processes, such as the direct 3D manufacturing of seam-free knitwear, making of bespoke hand-crafted bags, and direct digital creation of body conformable seamless textile structures [9]. The creative designer system using CADs, such as Gerber, is one solution for fashion design. It is an elaborate graphics workstation with software and hardware that can extract images and colours from sketches, photos, fabrics, or real materials and edit them through a selection menu [10,11]. The production of most clothing is based on the use of two-dimensional patterns. The shapes are cut from a flat cloth, and sewn together on assembly lines [12].

The virtual world also has some areas set aside for fashion. Virtual reality (VR), which is archived by a computer system, can reduce the time and cost, which is required to make and test samples, and discard those deemed unsatisfactory. The captured body models can be transformed into virtual mannequins, and computers can make them walk like real fashion models. Users can acquire finely fitted clothes in 3D models and as 2D-pattern block representations. Fashion designers in VR or augmented reality (AR), similar to their real-life counterparts, need mannequins over which garments will be draped [12].

In the information and communications technology environment, the fashion industry has its own specific needs that must be integrated into an e-commerce platform through production strategies that are increasingly focused on individual customers in terms of personally customised design systems [13]. In a personalised customisation system, the consumer becomes a producer. The word *prosumer* is a portmanteau word coined from 'producer' and 'consumer'. The idea is based on the concept of *prosumption*, a combination of production and consumption [3] (p. 382) [14] (p. 4). However, educational, cultural, and social challenges arise when co-opting customers as designers. There is also the possibility that the majority of customers have no interest in becoming designers [15].

Therefore, the provision of differentiated AI services according to the level of customer participation in shopping should be considered. We examine the relevant literature on sustainable RTFS in Industry 4.0, providing quantitative evidence on current trends and in-depth empirical examples from prosumers.

2.2. AI-Driven Shopping in RTFS

2.2.1. Recommendation System

AI-based computer programs may become new fashion consultants that help prosumers determine ways in which a particular fashion choice can be implemented. Clothing fashion systems incorporating AI can process large amounts of data faster, learn a specific user's style, and memorise the user feedback [16]. AI stylist programmes are a good example of the deployment of AI technology in fashion. Further, AI-based fashion systems store descriptions of the users' items, and help them become more organised and efficient. AI has been used to calculate optimal scenarios within a shorter amount of time than traditional mathematical methods. AI using big data is helpful owing to its ability to predict and avoid uncertainty, which ensures smooth and stable production [17]. To date, changes have been geared towards realising the current major goals of this new revolution: (1) energy and resource efficiency as decisive factors of competition; (2) reduction in time-to-market through shorter innovation cycles of complex products and larger data volumes; (3) an increased flexibility towards realising almost individualised mass production within high-productivity and volatile markets; and (4) a gradual upgrade of the existing infrastructure by connecting different embedded systems with their individual mechanisms (machine to machine, wireless, etc.), towards a constant, self-prognostic, self-configuring, and self-deciding system [16].

For example, FitForCommerce is encouraging the introduction of new digital in-store technologies that connect online and offline shopping experiences, and providing better training and tools to store employees. It aims to ensure better personalised customer support and improve shopping experiences [18]. It meets the expectations of today's digital savvy shoppers using customer data insights, inventory visibility, and access to merchandising content, to drive shoppers to increase shopping efficiency.

Likewise, in the fashion industry, guidelines and infrastructure must be designed such that more people can build personalised referral systems and applications using referral services through AI to provide a personalised customisation system [19]. Thus, the role of AI is to aid personalised engagement marketing, i.e., develop an approach to create, communicate, and deliver personalised offers to customers. It proposes that consumers are ready for a new journey, in which AI is a tool for endless options and information is narrowed and curated in a personalised way. It also provides predictions for managers

regarding AI-driven environments on branding and customer management practices in both developed and developing countries.

H1 AI-based recommendation system is effective for users with a low evaluation of their self-style and a strongly negative attitude towards using PCS. This recommendation system uses PCS to create designs that suit them directly.

2.2.2. Co-Creation System

Before AI-based systems can effectively support manufacturing machine design, it is necessary to develop techniques and methods to express and deduce each inferred partially defined shape of the design composition of clothes [20]. If, for example, fashion designers will be able to use personalisation and customisation, such as 'MADE FOR YOU' from Amazon, the focus will be on how to effectively match the design of clothing to the behaviours and interests of users. In addition, the completed fashion clothing styling activity includes several steps: choosing a theme, determining basic colours, mixing and matching clothing, choosing accessories, customising a model for a customer, and finally, styling hair and makeup. Therefore, the user can directly intervene in the design by actively participating in the design programme through a structured process including programme ordering, information linking, visual design, and interactive functions. Thus, the success of co-creation in AI-driven services depends on the convenience and user-friendliness of the service delivery.

Many studies on high-level customisation systems and distribution chains are based on the flexibility and agility of supply chains in customised environments and personalised services [21–24]. It is still an important prerequisite for managing product diversity and innovation issues. This implies that it is very important for prosumers, who are deeply involved in product design and production, to quickly and accurately grasp the characteristics of users through AI-based RTFSs and provide information tailored to the needs of the users. Personalised customisation in real-time systems is highly dependent on well-designed information systems that provide a direct link between internal work groups, such as manufacturing, design, and testing, and external work groups, which are represented by suppliers and customers. The implication is that the system will reduce complexity, increase flexibility, and enhance fault tolerance, which is needed to successfully implement a team of independent, but cooperative, producers. Various studies on co-creation between customers and companies have proven that, when customers and companies work together, schedule changes and requirements are reduced, resulting in improved company performance through its reactive ability to cope with changes, causing minimum or zero damage [25–31]. In addition, when integrated cooperation between manufacturing companies and customers is achieved, it has been found that a company's competitive advantage is created, and operating costs are reduced, which significantly contributes to the company's financial performance [32]. This collaboration between companies and customers has been found to contribute to increasing corporate income by creating new sales opportunities leading to a better environment for market and customer demand by bringing flexibility in distribution structures along with innovation in distribution networks [28,29].

H2 users with high ratings for their own style utilise AI-based co-creating systems, and show a positive attitude towards creating designs that suit them using PCS with a high interest in fashion trends.

2.3. Supply Chain Traceability

Fashion, learning from the influence of intrapersonal and interpersonal motivations, can act as social pressure and force people to own what others have. Especially in the digital realm, the adoption of new technologies or new devices can have a strong influence on the diffusion of fashion [33]. However, in AI environments, consumers' shopping methods are differentiated from the unconditional following form of existing fashion products. The education of designing and purchasing products according to individual

tastes and preferences leads to a shopping orientation, in which customers with different tastes purchase fashion products that suit their tastes, even for similar items. RTFS provides a more sustainable supply chain by providing customers with clearer and more reliable product information and product process information in the changing ways of shopping (Figure 1). Within RTFS, companies organise their organisational strategies, practices, and processes into collaborative and synchronised processes for manufacturers to meet customer requirements, and interact efficiently with suppliers through internal integration, while manufacturers are encouraged to cooperate on corporate activities and information sharing [30,34]. In addition, customers are required to have an active and flexible attitude while actively cooperating and coordinating with companies on product design, demand, and after-sales service [4,30,35]. Supply chain traceability is fully digital, traceable in real time, transparent, guaranteed by blockchain technology, and optimised for 100% trustworthy on-demand individualised service delivery. The dominance of market intermediaries, such as wholesalers or retailers, directs emphasis towards moving goods through channels and away from collecting data, which is required to make brand and customer management decisions. RTFS-based AI has been a powerful tool for personalised product recommendation that can subtly nudge consumer purchase decisions [36].

Figure 1. A supply chain in AI co-creation environment.

Because of various process changes that link retailing and manufacturing operations, responsiveness can be used to effectively substitute for fashion sense, forecasting ability, and/or inventory required for operating under uncertainty [8,37]. In addition to the information technologies mentioned above, a number of business practices are required for an ideal RTFS. Just-in-time shipping policies with frequent and small lots, pre-ticking, and drop shipments are necessary. On the manufacturing side, flexible, short-run, and high-speed processing, automated material handling, and modular by real-time manufacturers [8,38] are necessary. Consequently, 3D fashion products in the RTFS sustainable supply chain are entirely digital, saving time and money with sampling and tracking capabilities, secured with blockchain technology, and trusted with personalised service delivery.

3. Methodology

3.1. Participants

This study examined 14 prosumers; none of the prosumers was a fashion major, and they had no experience with apparel design techniques. They were recruited from as many different academic majors as possible. We selected 14 participants from 40 volunteers, who were verified at their workplaces in terms of their professionalism, based on their qualifications, job descriptions, and characteristics as consumers who were likely to shop according to their style, clothing behaviour, and purchase intentions (Appendix A). We collected data from voice recordings of interviews and by video-scanning each participant's personalised design work from a personalised RTFS. All participants were men and had at least seven years of work experience; the mean age was 31 years (range: 27–36 years). In daily life, clothing behaviour and personal creation factors were explored through their clothing choices based on their level of professionalism related to their major.

3.2. Production

This study examines how the convergence of individual participants, as prosumers with self-knowledge, shape their ideas into an apparel design, and how the use of their experience and clothing behaviour within a broader context lead to the exploration of different forms of a fashion product recommender service based on an AI system.

The apparel design session on the personalised RTFS was video-recorded for 30–60 min, and a full interview, 90 min long on average, was recorded for each participant. Each participant was examined as a consumer with individual clothing preferences and brain mechanisms converging to shape their idea into an apparel design. In this study, we suggest effective services for users of a personalised RTFS. Thereafter, their cognitive clothing behaviours and personal brain mechanisms were analysed as factors determining creative design outcomes. The participants contributed to the design process by manipulating variables such as the colour and print design of a t-shirt. In this study, basic t-shirt designs were developed because the participants were neither experienced nor qualified designers. Their own clothing choices appeared to be different in terms of the 'consideration of fashion trends' (on a 5-point scale from 1—no at all, to 5—very trendy) and 'evaluation of self-styling' (on a 5-point scale from 1—no at all, to 5—very good) scales.

In total, 14 male participants were interviewed after completing a three-part questionnaire. The first part of the questionnaire focused on gathering expert knowledge related to the participant's major, awareness of the use of personalised RTFS, and tracking personal information to identify the participants' personal clothing behavioural factors. In the second part, each participant was connected to the actual PCS in RTFS; they also participated in the process of designing the t-shirt that they would like to purchase, and explained the factors reflected in their design. The third part is environmental variables, where the interviewees identified prosumer behavioural factors and determinants in the role of AI experts in co-creation in relation to the role of AI in the process of custom design.

4. Result and Discussion

4.1. Hypothesis 1: Consumer Types

Participants of consumer type not interested in personalised customisation systems and participants with low or average fashion interest assembled designs similar to those of the clothes they had owned previously (Table 1). Consumer types needed various samples of accustomed fashion items for clothes shopping.

Furthermore, they significantly considered others' feedback while choosing items for daily styling. Interviewee A1 began shopping for clothes when he became an adult with the aim to either conceal his body's weaknesses or complement his strengths. He stated that his dislike for spending money or time buying clothes and his imperviousness to seasonal trends. The idea of wearing clothes had a significant meaning for him. He heavily depended on others' evaluations, and was not clear about his own taste. He wore items and styles that did not hinder his physical activities, and received good feedback from others. As another example, interviewee K11 was very proud of his fashion sense. He reported that his fashion sense was shaped by that of his parents. His mother had a very good fashion sense, and repaired their clothing at home by changing buttons and altering sizes. His father also had good taste in clothing, and generally enjoyed formal wear. However, K11 not only had negative opinions for the use of PCS, but also showed difficulty in designing his own t-shirt. He also cited issues pertaining to product returns and quality while purchasing clothing items online. Thus, he did not enjoy shopping on e-commerce sites. This result supports the idea that knowledge of fashion affects clothing behaviour. Specifically, the participants belonging to consumer types conforming to high-fashion trends mentioned that creating a new design using the PCS was extremely complex, and they were uninterested. Instead, they selected designs from among the offered goods, and enjoyed shopping from among the designs of professional designers more. In addition, similar to all interviewees of consumer types who enjoyed online shopping, they did not want to use the PCS.

Table 1. T-shirts designed by consumer-type participants using personal customisation service (PCS) system.

Participant	**A1**	**B2**	**D4**	**F6**
Design task	 	 	 	 
Major	computer science	mathethematics	human science	material science
Considering fashion trends (degree: 5 to 1)	2	2	3	4
Evaluation of self-styling (degree: 5 to 1)	2	1	3	3
Preference of PCS	YES	YES	NO	NO
Duration of item use in years	2	2–3	4–5	3–4
Participant	**H8**	**I9**	**J10**	**K11**
Design task	 	 	 	 
Major	earth science	earth science	astronomy	astronomy
Considering fashion trends (degree: 5 to 1)	3	2	1	4
Evaluation of self-styling (degree: 5 to 1)	3	3	2	3
Preference of PCS	NO	NO	NO	NO
Duration of item use in years	2–3	2–4	until disposal	5

For consumers who have high resistance and low capacity for new designs, successful shopping is also possible using the recommendation service by providing information about their tastes to the AI co-creation system for analysis. This result can predict the differentiation of the types of services that must be provided, accounting for different preferences for new and innovative designs, for effective RTFS shopping in an AI environment.

4.2. Hypothesis 2: Prosumer Types

The creative participant–prosumer types were highly interested in fashion and personalised customisation systems, and enjoyed fashionable styles. They expressed their creative ideas freely in a variety of designs, and tried to show their favourite types of designs with new forms of t-shirts (Table 2). Most participant–prosumer types created fashionable designs with reasonable details and matching colour. Even when they ignored a sense of fashion and applied ambiguous symbols or matching colours, the result was still novel. The style choices of Interviewees E5 and L12 reflected the proven correlation

between styling choices in clothing and education. They followed their own independent fashion styling choices, rather than the current fashion trends.

Table 2. T-shirts designed by prosumer-type participants using PCS system.

Participant	C3	E5	G7	L12	M13	N14
Design task						
Major	nature sciences	music	administration	material science	human science	law
Considering fashion trends (degree: 5 to 1)	4	2	3	3	2	5
Evaluation of self-styling (degree: 5 to 1)	4	4	3	4	3	3
Preference of PCS	YES	YES	YES	YES	YES	YES
Duration of item use in years	5	10	3–5	3–4	3–4	4

They mentioned that their fashion considerations were inspired by fashion media, such as fashion magazines, fashion blogs, and social networking, rather than their parents' clothing behaviours. They had actively worked to identify their own style, and had found ways of shopping and looking good. Interviewee E5 said that he had a specific shopping pattern and indicated that he had a favourite style, recognising that the types of items were a good fit for him. He reported his interest in wearing jackets, blue jeans, shirts, coats, and leather items in black, brown, and white colours. He generally used his clothing for 10 years, and enjoyed and spent significant time shopping for clothes. However, he was oblivious to fashion trends because he chose items according to his own style, and had favourite clothing shops that he frequently visited, even if he had no plan to purchase any item. His shopping habits were not driven by the need to replace older items but to find matching items.

Interviewee L12 said his fashion choices changed according to his level of education. He mentioned that his parents did not place much importance on carefully choosing clothes to wear or following a particular fashion; however, he had extensive knowledge on clothing fashion, including fashion trends, fashion styling, preference for items, etc. He was also fairly interested in fashion on websites and magazines. He enjoyed fashion in his daily life. In addition, Interviewee M13, who was extremely hesitant to shop offline, and only purchased clothing online, had an extremely positive attitude towards the use of a PCS. Therefore, he used specific items and fashion brands, including Zara, which offers a very good return system among e-commerce companies. In the case of self-directed prosumer-type customers, it is possible to create new designs and products that they want through collaboration with AI.

4.3. Readiness of Prosumers or/and Consumers to Use a Personalised RTFS

In this experiment, there was no correlation between design creativity and interest in clothes; however, prosumer-type customers who were deeply involved in clothes design showed great interest in the process of making their own designs. As shown in the final design using PCS, each t-shirt reflected the prosumer's experience in their field as well as their interests in fashion through a motif, colour, and/or arrangement. The PCS of a

clothing company should be developed as a system based on the analysis of the favourite styles and shopping types of their prosumers, in relation to their fields and hemispheric dominance. During the design process, participants A1, C3, E5, G7, H8, I9, J10, K11, and L12 tended to produce design results that reflected their preferred design, taste, and familiar colours. This suggests that a recommendation service can enhance purchasing power by analysing the past purchases of the prosumer-type consumers, suggesting a preferred style, and providing equivalent services by selecting similar designs and brands. Interviewees A1, D4, F6, G7, I9, J10, K11, and M13 drew a purchasing plan for their clothing, rather than buying on impulse, when they needed new items after a change of season. They also had a method of wardrobe management: wearing the same colour items, same items, and matching items in their daily life, irrespective of their fashion style considerations. After using the PCS, the participants mentioned the simplicity of its service, its ease of use, or a lower degree of freedom. The usability of the RTFS is an important factor for potential users. Narrow, but powerful choices, are successful points; otherwise, offering options that do not reflect the consumer's tastes, or providing too many samples, can lower the consumer's purchasing power. In addition to item familiarity, familiar styling, shopping habits, wardrobe management methods, clothes purchasing habits, preferred price ranges, brand identification, and a reflection of the individual's tastes were important factors. Users were provided access to a PCS through the RTFS, and wanted accurate information regarding body shape reflection, affordability, and product quality.

Prahalad and Ramaswamy [39] researched the distinctions between personalisation and customisation. In addition, successful collaborative shopping networks and social software, in general, must focus on relevant core functionalities along with an improvement in user experience. Platform-specific features must be deployed to motivate prosumers to participate actively. To win over prosumers, the main goal of a vendor must be to provide consumers with a functional environment. The customised designs could be produced relatively quickly by the manufacturer, and then, shipped to the customer, or even inexpensively manufactured using locally available digital production facilities. Personalised customisation is possible owing to the capabilities of modern manufacturing technology, including flexible manufacturing systems and modular product structures, which both reduce the trade-off between variety and productivity [40]. In a connected world where everybody interacts with each other almost independently of time and distance, the gap between the design team and the rest of the world has been bridged. Occasionally, different types of designers, who are able to develop their own design initiative, work together. As an open-ended design process, personalisation, also referred to as customisation or individualisation, addresses and meets the prosumer requirements by considering individual needs [41]. This is the distinction between the co-design process as a whole, with its open-ended nature and individual design initiatives that occur at definite times and in definite ways.

4.4. Framework of RTFS Sustainable Supply Chain

In RTFS, we can consider two types of co-creation services. The prosumer types have low resistance to customised services, and want to design the specific clothes they wear. These prosumer types need a way to receive information such as professional advice on suitable materials, fits, and designs through AI services in RTFS. This type of co-creation in an AI-based environment requires a practical co-creation role in which a product designed by a prosumer customer can satisfy the conditions as a fashion product. High-quality interactions that enable an individual user to co-create unique experiences with the company are the key to unlocking new sources of competitive advantage. The value will have to be jointly created by both the firm and user [42]. The main motivation behind the extensive use of communications and networks based on information technology is to provide direct links between work groups (e.g., design, analysis, manufacturing, and testing), and to improve their response time to customer requirements. Communication

and network technologies integrate previously isolated components of a production chain into coherent and coordinated competitive weapons [13].

The degree of co-creation must be determined based on the degree of interest in clothing. As users, the participants need to interact with a professional designer from a fashion company. However, designers' recommendations should be reasonable and worthy of reference. First, professional designers should apply a high-capacity design and styling space. Second, designers should completely understand the consumer's features: size, outfit, body type, taste, and fashion cognition. As this study has shown, creating a design is a type of cultural practice that involves pondering how the desired functions and meanings should be attained. This occurs within an open-ended co-design process, in which all the factors involved play different roles and are based on a human capability that everyone can cultivate; for some, namely, design experts, it becomes a profession [43]. Thus, the role of a design expert is to trigger and support these open-ended design processes, using their design knowledge to conceive and enhance clear-cut and focused design initiatives [43].

In the AI supply chain environment, the way consumers shop is differentiated from the purchase form of traditional fashion products. Depending on the characteristics of the customer, the prosumer can design a product that suits each individual's taste and preference, or receive the product that suits the customer's taste and preference through the AI recommendation service. The RTFS solves the problems of inventory products and unnecessary manufacturing processes that have been revived in the traditional distribution chain by providing customers with clearer and more reliable product information and product process information in a changing shopping method, and provides an efficient and sustainable supply chain (Figure 2).

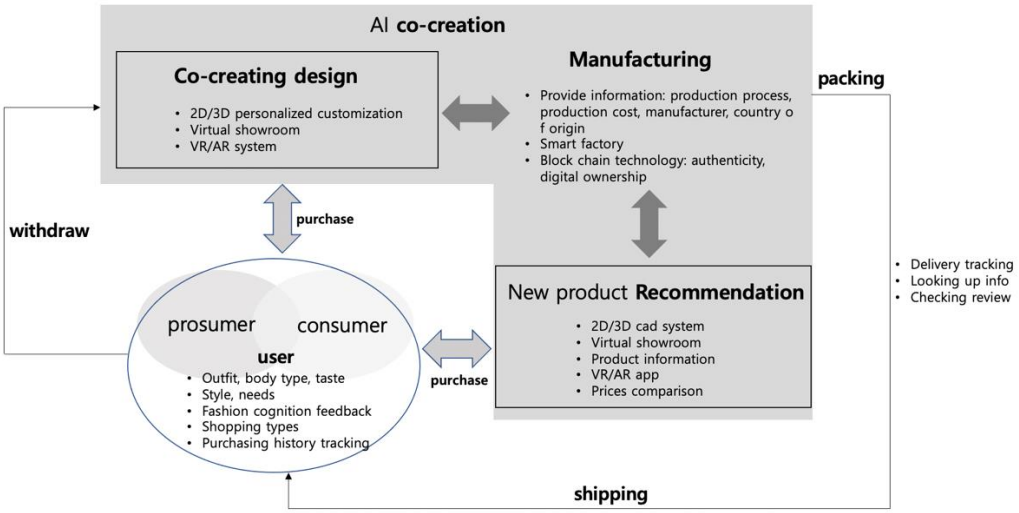

Figure 2. A framework of real-time fashion system (RTFS) sustainable supply chain in an AI environment.

5. Conclusions

In the fashion industry, guidelines and infrastructure must be designed in a way that allows people to build personalised referral systems and applications using referral services through AI to provide a PCS [19]. Therefore, before AI-based systems can effectively support manufacturing machine design, it is necessary to develop techniques and methods to express and deduce each inferred partially defined shape of the design composition of clothes [20]. Fashion companies in RTFS will be able to use personalisation and customisation, and the focus will be on how to effectively match the design of clothing to the behaviours and interests of users according to consumers or prosumers. Therefore, the user can directly intervene in the design by actively participating in the design programme through a structured process including programme ordering, information linking, visual

design, and interactive functions using a 2D/3D personalised customisation system with a virtual showroom.

Thus, there are five elements to the upcoming RTFS. First, the system allows users to immediately purchase and use products in real time, as well as applying the individual needs of customers in real time. Second, consumers are deeply involved in product purchase, personalisation, joint design, and manufacturing planning. Third, AI-based interactions between customers and companies are present, suggesting individual designs with perfect style and size. Fourth, the system contains a new 3D CAD and AI-based product design process for fashion and design companies and customers. Fifth, with the provision of real-time supply chain tracking services, it is fully digital, traceable in real time, transparent, guaranteed by blockchain technology, and optimised for providing on-demand customised services that are 100% reliable.

This RTFS sustainable supply chain has the advantage of satisfying customers' needs as much as possible by reducing the distance to the customer, utilising technology of higher complexity compared with the existing distribution supply chain. In addition, the production process and product procurement method are transparently disclosed to consumers in real time, thereby enhancing the reliability of companies and customers. Furthermore, fashion companies can improve customer satisfaction by providing customised services according to the type of customer. The biggest advantage of RTFS is the direct trade between customers and companies, omitting unnecessary intermediate distribution processes, which saves energy and provides a reasonable price for products. In addition, 3D fashion products are fully digitised, saving time and money in sampling and tracking functions, protected by blockchain technology, and trusted by customers to deliver personalised services.

5.1. Theoretical Implications of the Study

The results of this study support the findings of a study conducted by Wang and Cho [44], wherein they argued that fashion innovators with a very positive attitude are more willing to accept personalisation of user-initiated online fashion items. The benefits of this can increase the willingness of users to surf the web and realise their buying needs by promoting the brand and introducing the latest fashions, to improve product and service quality, build brand image, and increase user awareness. High-quality interactions within RTFS that allow individual users to collaborate on a unique experience with the company play a key role in gaining a new competitive advantage. The value is created jointly by both companies and users, which can improve productivity by saving energy and shortening unnecessary distribution networks [42]. Clearly, the proposed AI-based RTFS will help to reduce the cost of apparel production by reducing time and labour required for production and distribution. In addition, resizing and mass customisation can further increase user satisfaction. Moreover, if the dimension-collection process can be upgraded to full automation by utilising 2D and 3D CAD systems and virtual showrooms through VR/AR technology, the system will provide better usability and production. To realise the positive effects of such an innovative sustainable supply chain more quickly, a variety of services that allow ordinary consumers to become more familiar with RTFS and efficient services based on an accurate understanding of the needs and demands of consumers are provided together.

5.2. Limitations and Future Research Avenues

This study proposes a subdivided process for methods to improve consumers' purchasing power and design needs using an exploratory review of how general consumers use their systems in RTFS. If the consumers themselves show a low level of involvement in their preferred fashion styles or trends, it is suggested that the customised service for consumers should analyse users based on more diverse customer information. In addition, for prosumer customers, personalised service can be more effective within RTFS by providing users with customised services that account for the consumer's work site, everyday clothing behaviour, and design preferences in the market. However, the limitation of this

study is that, owing to the small sample size, the participants do not represent all of the users of each discipline. Therefore, to investigate various factors arising from these results, further studies using RTFS based on more consumer characteristics are needed.

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Appendix A

Table A1. Background of the participants.

Participants	Majors	Work Year	Considering Fashion Trends (Degree: 5 to 1)	Evaluation of Self-Styling (Degree: 5 to 1)	Duration of Item Use in Years	Age
A1	engineer in computer science	12	2	2	2	35
B2	researcher in mathematics	12	2	1	2–3	34
C3	researcher in nature sciences	12	4	4	5	32
D4	writer in human science	11	3	3	4–5	33
E5	composer in music art	15	2	4	10	33
F6	researcher in material science and engineering	10	4	3	3–4	30
G7	public administration	9	3	3	3–5	29
H8	researcher in earth and environmental science	7	3	3	2–3	29
I9	researcher in earth and environmental science	10	2	3	2–4	29
J10	researcher in astronomy	7	1	2	until disposal	29
K11	researcher in astronomy	7	4	3	5	27
L12	researcher in material science and engineering	8	3	4	3–4	29
M13	writer in human science	10	2	3	3–4	29
N14	researcher in law	18	5	3	4	36

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