

UDC 687.01:502.1
DOI: 10.15587/1729-4061.2023.273630

The study analyzes the stages and prospects of development the digital fashion industry, taking into account the growing raw material and environmental problems. In the course of analysis change the model of its functioning from linear to cyclic, multidisciplinary problems have been identified that it is advisable to solve based on an ecosystem common digital platform. To identify the essence, stages and role of digitalization in the fashion industry transformation, a content analysis of the digital design tools evolution was carried out, the results of which were compared with a historiographical analysis of fashion industry transformation of a post-industrial society.

As a result, it was found that the readiness of the fashion industry for transformation depends from the stage of digitalization, from the innovative ecological fashion design development and from the presence of motivated coherence actions among all fashion market subjects, as well as from the formation for them a new style of using clothes. In the course of the study, the structure of digital fashion industry innovative potential was determined as a part of the factors of art-aesthetic, technological, sociocultural, economic, environmental and administrative nature.

An approach to managing of the digital fashion industry transformation processes was proposed, based on the balance regulation between processes by redistributing the system total resources to eliminate the "bottleneck" and support the "weak element". Based on the formulated approach, a model of the strategy was proposed for managing the transformation of the fashion industry. The model is based on the decomposition of the main influence factors into relatively independent components, the regrouping of components based on the same nature with the regulation of the balance between these groups by redistributing common resources.

The model is based on the decomposition of the main influence factors into relatively independent components, the regrouping of components based on the same nature with the regulation of the balance between these groups by redistributing common resources

Keywords: innovation potential, transformation, fashion industry, decomposition, environmental safety, sustainable development, digital platform

FASHION INDUSTRY: EXPLORING THE STAGES OF DIGITALIZATION, INNOVATIVE POTENTIAL AND PROSPECTS OF TRANSFORMATION INTO AN ENVIRONMENTALLY SUSTAINABLE ECOSYSTEM

Iryna Hardabkhadze
Corresponding author

Senior Researcher, Associate Professor
Research Institute*

E-mail: irene.gard.fd@gmail.com

Sergey Bereznenko

Doctor of Technical Sciences, Professor**

Kateryna Kyselova

PhD, Associate Professor
Department of Design and Technology*

Larysa Bilotska

PhD, Associate Professor**

Oksana Vodzinska

PhD, Associate Professor**

*Kyiv National University of Culture and Arts

Yevhena Konovaltsia str., 36, Kyiv, Ukraine, 01601

**Department of Technology and Design of Sewing Products

Kyiv National University of Technologies and Design

Nemyrovycha-Danchenka str., 2, Kyiv, Ukraine, 01011

Received date 18.11.2022

How to Cite: Hardabkhadze, I., Bereznenko, S., Kyselova, K., Bilotska, L., Vodzinska, O. (2023). Fashion industry: exploring the

Accepted date 24.01.2023

stages of digitalization, innovative potential and prospects of transformation into an environmentally sustainable ecosystem.

Published date 28.02.2023

Eastern-European Journal of Enterprise Technologies, 1 (13 (121)), 86–101. doi: <https://doi.org/10.15587/1729-4061.2023.273630>

1. Introduction

Crises and social cataclysms of the 21st century last decade on the backdrop of a growing resource shortage stimulated transformational processes in a number of the economy leading sectors. According to the conclusions of the EU Strategy on Sustainable and Circular Textiles, Russia's unjustified military aggression against Ukraine has caused an enlargement the energy crisis, a shortage of raw materials and demonstrated the vulnerability of global supply chains [1].

Threats to peaceful existence, the energy and raw material crisis have led industries to the need to find ways for sustainable development in the face of turbulence.

Another driving force for industries transformation was the trends of economic, socio-cultural and everyday aspects digitalization of the society life. These two trends have come to full reflection in the more than two trillion dollar sector of the fashion industry, which is grow of accelerated temps despite the crises.

Based on the fashion design digital platform, the fashion industry in the twenty-first century has a unique chance to realize the results expected by consumers, which only yesterday seemed like impossible. However, the challenges of rapid growth and overconsumption not only exacerbate environmental risks, but also undermine the sustainable development of the fashion industry.

The fashion sector uses many resources and generates significant environmental risks. The environmental problems growing and the limitation of natural resources actualize the search for more resource-efficient and environmentally friendly ways to produce fashion products. Therefore, one of the main problems of fashion industry current stage development and related trends is its transformation into a sustainable environmentally safety ecosystem. The implementation of an effective strategy for the fashion industry transition to a new functioning model will reduce the risks of the transition period and increase the efficiency of the transformation. In practice, this will contribute to the continuity of fashion industry development in the course of transformation, a more rational use of natural resources and a decrease of production negative impact on the environment.

Another important trend of the fashion industry development is digitalization. The fashion industry is increasingly immersed in the information technology environment. In the fashion market the digital platforms and digital marketing strategies are dominated that can engage consumers to use augmented or virtual reality technologies [2].

There is an opinion that “the golden age of digital innovation provides unprecedented opportunities in the field of information systems” [3]. Therefore, it is expedience to look for an approach to implementing the sustainable development strategy of the fashion industry in the digital environment, which will create a common digital platform for interdisciplinary integration.

The considerable interest consist in the development the theoretical foundations of the fashion industry cyclic model [4] and analysis of international initiatives and trends to reduce the negative impact of fashion on the environment and society [5, 6]. The assessment of the digital fashion industry innovative potential and the concept formation of transformation management are relevant.

2. Analysis of literary sources and statement of the problem

In response to the risks of the fashion industry unsustainable development, in recent years publications have described several alternative ways to transform it into an environmentally friendly industry. In many sectors of the economy increasingly popular is the model of a full cycle or the circular economy, aimed at slowing down, narrowing and closing the use of resources.

The paper [7] presents the results of the fashion industry trends research aimed at maintaining competitiveness and sustainable development of the industry. The cyclic and slow models are singled out as the main trends in this direction. It is noted that the current fashion industry is recognized as unsustainable from both an environmental and social point of view. The slow fashion, which reduce the environmental impact of fast fashion, has become its viable alternative. Critical factors, problems, trends and the possibility of introducing a circular economy into the fashion industry are discussed. The slow fashion business model based on the principles of circular economy, low consumption, transparency and fair trade is described.

In this article, fashion has been studied in the context of the fashion industry features in the EU countries, based on the EU strategy for sustainable and circular textiles [1].

Therefore, the results of the study require generalization, taking into account the experience of other countries. In addition, the work does not establish a causal relationship between circular and slow fashion initiatives and indicators of sustainable development, the reason for which can be considered the qualitative-research nature of the work.

This shortcoming is partially eliminated in the work [8], which is devoted to features of design in the context of ensuring the cyclicity of the fashion industry. Based on the fact that innovative design is the creative basis and the main tool for creating circular fashion products, the article shows the impact of design on the industry sustainable functioning. An example of design application in the circular fashion illustrates how to develop clothing that at the end of its useful life can be used in the production of new fibers. According to the authors of [8], designers must expand in the terms of circular fashion their creativity beyond traditional practices. Although Materials Science is the part of the basic competencies in fashion design, the designer needs to have in the case of circular fashion a deeper understanding of the material structure, as well as at least a basic understanding of the processing fiber into new fibers possibility.

However, within a cyclical model innovative design is a necessary but not sufficient component for organizing a full cycle fashion product. For the successful organization of circular fashion functioning an important role are played the social component of success, the synchronization of partners interactions and the provision of textiles, which requires special research on these issues.

The thematic issue “Sustainable Chemistry for Circular Fashion” [9] explores the approach that Green Chemistry offers to designing textile products for use in circular fashion. The facts of the fashion industry influence on the environment are given. The industry produces around 2–8 % of the world’s greenhouse gas emissions, 20 % of the world’s wastewater, and 9 % of the annual loss of microplastics in the ocean. \$100 billion is wasted through unused products and lack of recycling. The approach is aimed at maximizing the efficiency of resource use and minimizing harmful impacts throughout the life cycle of products. However, as a result of the narrow focus of the topic, in research are not covered the social issues, the problems of synchronizing partner interactions and the role of innovation in creating a coordinated functioning an all parts of cycle.

In the article [10] by means of a systematic literature review, the significance is emphasized of breakthrough scientific discoveries, innovations and strategies for a circular textile economy. Various approaches are discussed to the textile waste reuse, recycling and reprofiling. Looking to the future, the proposals are made to solve the key problems of processing textile materials at different stages of their production process. 12 principles of the circular economy are formulated and the prospects of cleaner production achieving are considered in the fashion industry. In the article [11], along with discussion the factors reducing impact of the fashion industry on the environment, the problems, trends and role of technological innovations are analyzed for the introduction of a circular economy in the field of fashion. Due to the focus on the technological nature of innovations, the works [10, 11] does not consider the roles of participants in the fashion products creating cycle and other problems of socio-administrative nature processes of the transformation.

In the work [12], the results of a large number of studies are reviewed in order to understand the roles of participants and driving forces operating in the fashion value chain. It has been established that the cyclical concept in the field of fashion provides theoretical, economic, social and environmental benefits. The key factors for this concept effectiveness are innovation, cooperation, waste management system, communication with customers and changing clothing usage patterns. The concept of the fashion industry transition to a circular economy, proposed by the authors, consist of three levels – discrete, aggregate and peripheral. However, this concept does not consider all enablers on the transformation success. In particular, the role of digitalization has not been characterized in the collection and processing of information necessary to coordinate all participants' actions in the cycle.

In the considered works, due to their general theoretical nature, insufficient attention is paid to the theory and practice of organizing business specific forms in the fashion industry circular model.

The paper [13] notes the need to develop a new business cycle model for the fashion industry. The characteristics the potential of many economic opportunities in the framework of waste management are given. The regulatory weakening measures are considered for beginning of the synergistic cyclical production in the fashion industry. In the context of promoting the circular economic, a new strategy is proposed to attract customers, businesses and politicians to the fashion sector. However, this general approach to business model development needs further commercialization in order to move to the practice of business organization.

There are several forms of commercialization of the fashion business associated with the circular economy of the fashion industry. The article [14] discusses the main approaches and strategies of circular fashion based on the reuse and recycling of used clothing. The fashion trend, referred to as sustainable fashion, is seen as part of a circular economy concept in which textiles and clothing are maintained at the highest quality throughout their life cycle and then put back into circulation.

The article [15] describes a more specific form of fashion business organizing within the framework of a circular model. The study aims to develop a conceptual framework for fashion industry cyclical business models, with following application for the analysis of luxury models resale. According to the authors, the rise of interest in old fashion luxury will require a sophisticated dominant design in terms of a business model that standardizes products, services, processes, data, and controls. However, for the practical application of the proposed model, it is not enough to evaluate ways of customers attract, since there is a prestige barrier to the second-hand products perception as a potential acquisitions.

This shortcoming is partially eliminated in the article [16], in which it is proposed to attract customers using the possibilities of social networks. In addition to second-hand, there is another form of doing fashion business in the context of the circular economy, which is associated with the reuse of fashion products. Online clothing rental is relevant for luxury models Research [16] shows that consumer demand for this form of service is driven by the usefulness of online clothing rental platforms. This demand also depends from the ease of transactions, and the social support of cult personalities. Consumer attitudes towards the concept of “second hand” are greatly influenced by the comments of famous bloggers on Instagram and other social networks. Ce-

lebrity opinion encourages potential customers to overcome the threshold of distrust and use these platforms.

Based on the results of the analysis of literary sources [7–16], it can be noted that the fashion industry is at the epicenter of environmental problems. It is also clear that in order to solve these problems, the path of transformation into a sustainable environmentally friendly ecosystem has been chosen. Since the fashion industry is in the initial phase of functioning model changing, the transformation did not cover all the participants in the fashion market. However, the transformation has embraced separate “islands of activity” that have faced the problems of the pioneers.

The main problem is that transformational processes must cover all organizations and business processes that are creating a full cycle. “Key drivers of the closed fashion value chain are collaboration with partners, innovation, waste management, customer connectivity and changing usage models” [8].

From the research results published so far, it is not entirely clear what processes and actions are necessary and sufficient for the transformation of the fashion industry into a sustainable environmentally friendly ecosystem. No recommendations have been proposed for synchronizing the intentions of all heterogeneous environment subjects in which circulate the processes of the closed fashion industry value chain. The mechanism of balancing technological, economic, social and environmental factors has not been considered, the balance of which in relation to fixed resources provides the best result.

This means that in the face of increasing environmental risks and resource scarcity the available data are insufficient for effectively manage the sustainable development trajectory of the fashion industry.

Questions that remain relevant:

- what aspects are indicators of fashion industry sustainable functioning, what factors affect on sustainability management;
- how to coordinate the actions of all participants of transformation processes and how form a positive reaction of public opinion to the transition from prestiging of clothing overconsumption to rational creation of a wardrobe;
- how to meet the conflicting requirements of economic, technological, environmental, socio-cultural and administrative-organizational influence factors on transformation processes.

The transformations of the fashion industry has complex nature, therefore, for their comprehensive study requires an approach with a combination of socio-cultural, technological, economic and environmental areas is required.

The reformation of the fashion industry has complex nature, therefore, for its comprehensive study requires an approach with a combination of socio-cultural, technological, economic and environmental areas. Since already at the initial stage of reorganization, the fashion industry processes of transformation are based on the advantages of digital innovations, which are especially noticeable in a multidisciplinary environment [17], it is clear that further transformation will develop in the digital space.

3. The aim and objectives of the study

The aim of the study is to analyze the trajectory and prospects for the digital fashion industry development with

the definition of its innovative potential structure and the formation of a concept for managing of its transformation processes into a sustainable ecological ecosystem. This will enable management of the fashion industry sustainable development more effective.

To achieve the goals set, the following tasks are formulated:

- to analyze the state and prospects of the fashion industry development on the way of transition to a cyclical concept of functioning;
- to determine the essence of the stages and the role of digitalization in the transformation of the fashion industry;
- to evaluate the readiness of the digital fashion industry to transform into a cyclical concept of functioning;
- to determine the structure of the digital fashion industry innovative potential;
- to implement search of an approach to managing the processes of digital fashion industry transformation into a sustainable environmentally friendly ecosystem.

4. Materials and methods of research

4.1. Object and hypothesis of the study

The object of research is the digital fashion industry.

The approach to managing of the digital fashion industry transformation into a sustainable environmentally friendly ecosystem is based on the assumption that all participants in the process are ready and able to use appropriate digital technologies. It is also assumed that they all agree to act in accordance with a common strategy.

The assumption is formulated that the process of the fashion industry transformation can be represented by a set of main influence factors, followed by decomposition into independent components.

The research hypothesis refers to the formation the concept of the transformation process managing. It based on the fact, that the process of fashion industry transformation within the framework of common resources can be controlled by the method of productivity balancing through the redistribution of resources between independent processes groups of its functioning.

The base of sources includes resolutions and recommendations of state bodies, commissions and international organizations working groups [1, 4, 5, 18, 19]. The materials and reports were also used of non-governmental public organizations (NGOs) WRAP (Waste & Resources Action Program) [20–22], the World Economic Forum [23], and consulting agencies [24].

The materials of the considered sources include studies of dynamics development the fashion industry during periods of industrialization and studies of transformation from a linear into a cyclical economic platform.

4.2. Research methods

An analysis of the trajectory and prospects for the digital fashion industry development was implemented using an interdisciplinary systems analysis.

To identify the essence, stages and role of digitalization in the fashion industry transformation, a content analysis of the digital design tools evolution and a historiographical analysis of the fashion industry transformation were carried out during digitalization phases of the post-industrial society. For a detailed analysis, the process of creating a design product was presented by three stages, each of which deter-

mines the availability of digital technologies and services for both the design and the fashion industry. A comparison of these analyzes results was used to estimate the readiness of the fashion industry components for transformation.

To forming an approach to determining the structure of innovative potential and building a model of concept for managing of the fashion industry transformation, the decomposition method of a complex socio-technical system into relatively independent components was chosen. The regrouping of components into groups of the same nature was implemented based of filtering by attribute on compliance with a specific aspect. The information necessary for a comprehensive analysis was obtained based on the results of interdisciplinary research on design as a diversified multi-branch phenomenon that combines art-aesthetic, utilitarian and social aspects. To illustrate the structure of the digital fashion industry innovative potential, a graphical form of multi-component model proposed using a modified Euler-Venn diagram with quasi-orthogonal components.

5. The results of investigation the stages of digitalization, innovative potential and approach to managing the transformation of the fashion industry

5.1. Analysis the state and prospects of the fashion industry development

The fashion industry is a two trillion sector of the economy, aimed at providing society members the opportunity to express themselves by means of costume, taking into account fashion trends. In the course of its development from belonging to the upper world and the monopoly of famous Parisian couturiers up to the modern diversified fashion market, fashion has gone through several stages, over the years becoming more and more democratic. The main industries included in the functioning of the fashion industry are the textile, clothing, knitwear, perfumery and hairdressing industries, as well as the modeling business. In the structure of the fashion industry modern market, four main segments can be distinguished: the primary segment, which is represented by textile industry enterprises, the secondary segment – the segment of final fashion products manufacturers, as well as the retail and subsidiary segments [25].

The main trends of the fashion industry development in recent years are trends directly related to the problem of industry sustainable development. These are trends in energy and resource saving, as well as trends in the greening of fashion and the transformation from a linear production model into a cyclic one. More and more noticeable is becoming the desire for individualization, for the restoration of an individual approach to the formation of a person's style and image. In the context of informatization and under the influence of the circular economy transformational processes, the role of designers is being modernized and the sphere of their participation in the full cycle of creating, selling and reusing fashion products is expanding.

In a mass consumer society with a traditional linear economy, corporations maintain a high level of consumption using the social ambitions of consumers and design. The replication of new needs has become a key feature of the post-industrial economy and the main factor in the acceleration of consumption, which created a favorable situation for the emergence of a new fast-fashion business formula. Offering top-of-the-line clothing at an affordable price, the fast

fashion strategy boils down to a “buy-throw away-buy” paradigm [25]. Fast fashion increases consumption and shortens the life of a product, turning fashion into entertainment or a kind of “hunting” for fashion. Therefore, intensive consumption in the linear fast fashion model generates a huge unused resource and full cupboards of unnecessary clothes [3].

In the search of ways to transform of the fashion industry practice into a more environmentally friendly and socially responsible, the most attention of researchers is focused on the transition to a circular economy [3, 7, 9, 26].

Intensive network information exchange has created favorable conditions for interdisciplinary technology transfer, the convergence of cultural elements and the results of scientific achievements from various fields of activity. In fashion design, the tendency to create innovations through the synthesis of technology and the arts consist of develop new reasonable materials based on the transfer of technologies that expand the sphere of clothing. Designers are actively working with ecological trends in design at the intersection of ecology, biology, nanotechnology and art [27]. In addition, from the synergy of combining in one technology cycle the materials recovered from secondary raw, the additive manufacturing and ecodesign, leading 3D printing companies promise to achieve breakthrough results [28]. In this regard, wearable human-machine interfaces based on electronic skin technology (e-skin) and smart gloves with multifunctional diagnostic and tactile capabilities are of great interest [29].

Summarizing the materials of analysis, forecasts and reports [2, 4, 24, 26], it is advisable to divide the fashion industry trends into four groups:

- trends in the traditional segment of the fashion industry – the fast fashion, the desire for individualization, the ethnic motifs in design;
- digitalization and virtualization trends – online commerce, digital project instrumentarium for design, computer-aided design systems, online service and direct transaction platforms, mobility of consumer application, augmentation of visual marketing communications;
- greening trends – slow fashion, cyclical eco-design, lengthening the cycle of using fashion products, recycling of waste and used clothes, user participation in the creation of a suit, “clothes as a service”, rental of famous brands and “secondhand” products;
- tendencies of different cultures elements convergence and synthesis of technologies and arts based on interdisciplinary technology transfer.

Each of these trends is influenced by the main trend – the transformation of the fashion industry into a sustainable industry.

5. 2. The essence, stages and role of digitalization in the fashion industry transformation

In the second decade of the 21st century, the progress of information technology has turned the process of digitalization from a technological trend into a dominant tool for achieving the competitiveness of all society members [30]. Therefore, in context of fashion industry evolution it is interesting to clarify the essence, role and impact mechanisms of digitalization on its transformation.

With the emergence of digitalization, its essence was understood as the transformation of information about an object, phenomenon or process into a machine-understandable form with the simultaneous elimination of redundant information. That is, at the initial stage of dis-

tribution, digitalization was associated with the procedure of analog-to-digital transform. The practical significance of this transform is to eliminate the redundancy of analog information about the object with the rounding of the digital values of the discreet samples with the accuracy necessary for the process correct representation in this particular task.

During its penetration into all areas of life in the second decade of the 21st century, the term “digitalization” has gained wide popularity in society. The proliferation sphere of digitalization has extended to participation in the creation of complex socio-technical systems capable of managing processes in the economic, social, cultural spheres and in everyday life [31–33].

The development of innovative ecodesign is recognized as a necessary condition for the fashion industry transformation into a sustainable ecosystem [5]. Based on the fact that the phenomenon of digitalization is generated by the development of digital innovative technologies [34, 35], the digitalization process can be represented as an ascending spiral of cause-and-effect relationships. This means that if digital innovations are aimed at the development of ecodesign, then digital ecodesign becomes a nexus in the innovation cycle and is able to generate innovations at a new round of the cycle. To overcome the difficulties in distinguishing between the processes and results of digitalization [17, 36], it is advisable to separately consider the impact of digitalization on the evolution of digital instrumentarium for design.

For a detailed analysis, both a creating design product process and the digital technologies elaboration progress are presented in three stages. A joint overview of the analysis results for these two systematized processes is presented in Table 1, the columns of which represent the stages of design, and the rows – the stages of digital technologies development in the design context. Column headings have been abbreviated for brevity. The cells of the table reflect the achievement of each digitalization stage for each stage of design.

Table 1

The stages of digital fashion design evolution

Stages of digital fashion design tools progress	Accessibility of digital methods by stages of creating design-artifact		
	1 stage of designing: transferring an idea to a sketch	2 of designing: three-dimensional modeling	3 stage of designing: development a collection of models in the material and documentation
1 stage: development of graphic editors for two-dimensional sketching (until 2000)	75 % – digital methods, 25 % traditional methods	0 % – digital models, 100 % – traditional three-dimensional modeling	0 % – digital methods of designing, 100 % – traditional collection and documentation development
2 stage: mastering 3D modeling programs (2000–2010)	90 % – digital methods, 10 % – traditional methods	50 % – digital models, 50 % – traditional three-dimensional modeling	25 % – automation of designing, 75 % – traditional collection and documentation development
3 stage: elaboration of systems for providing a full creating cycle (2010–until now)	100 % – digital methods	100 % – digital models and additive technologies for 3D printing of experimental samples of parts and accessories	75 % – automation of designing and documentation development, 25 % – traditional collection and documentation development

The process of creating a design product begins with idea origination into the imagination of the author. At the second stage, a three-dimensional model of the design-product is created based on a two-dimensional image. That is, the idea of the author materializes in a three-dimensional layout or a virtual three-dimensional image of design-product.

After finalizing the layout/image and preparation of project documentation, the idea and model can be transferred for manufacturing in serial industrial production or creating of individual product samples.

It is desirable to correlate the differentiation of digital tools by stages of the development trajectory under the influence of digitalization with the key achievements (milestones) of digital technologies in the field of design.

Such a milestone for identifying the first stage of the digital tools development can be called the mass familiarization of graphic editors for two-dimensional sketching. For the second stage – the development and familiarization of three-dimensional modeling programs, for the third – the elaboration of systems for providing a full cycle of designing and production.

At the first stage, the transfer of virtual images is implemented from the mind of the designer into two-dimensional sketches of the design artifact prototypes. Thanks to the design tools that became available at the initial stage of digitalization, their impact on this stage is associated with the following dynamics of progress – from a sketch on paper to computer processing of design artifacts images. For design, a digital encoding of images is especially important – at this stage, it has become possible to copy, store, process, transfer, create in graphic editors and reproduce design ideas and solutions on the screen. The modern vector and raster graphic editors, which are based on the methods of digital filtering, video compression and creating two-dimensional images, are used mostly.

At the next stage, the transformation of two-dimensional sketches into three-dimensional models of design artifacts in the material or in virtual space is implemented. The digital design instrumentarium for this phase is represented by 3D modeling software as well as 3D printing technology.

The interaction of digital imaging technologies, 3D rendering, and specialized design software has stimulated the acceleration of digital design progress in several directions.

The pre-production and documentation phase of fashion design is partially combined with the modeling phase because of forming and preparation the collections of models to show on the catwalk. At this stage, computer-aided design, 3D modeling and visualization systems, as well as 3D printing technologies for the attributes of experimental samples are used. Specialized design programs are beginning to be integrated into specialized digital platforms with support for the full product life cycle of a linear manufacturing model.

It is necessary to separately characterize the technology of 3D printing [37]. Specialized companies provide 3D printing solutions throughout the full additive manufacturing value chain, from custom design, digital simulation and prototype printing to finishing and component testing. Although this technology was primarily considered for the purpose of research, development, build of experimental samples and prototyping, additive manufacturing has shown its effectiveness and is considered as a real manufacturing tool [38]. “3D Printing is the shortest path between your ideas and a functional prototype in your hands and it can be used at each stage of your manufacturing process... Top luxury brands are now making the most of additive manufacturing for prototyping, small series and mass-production” [39].

According to the content in the Table 1 it can be seen that in the third stage of digitalization, digital design tools are mostly available for all three stages of design. The assessment of availability the design automation systems for implementation in design practice at the third stage is 75 %.

The analysis of digitalization impact on innovative changes in the fashion industry requires a wider field of research, compared with the definition results of its influence for the design creativity. For the fashion industry, the range of digitalization impact research covers the social sphere and business interactions of the commodity segment, the textile industry, fashion manufacturers, the retail segment and the consumer market. Since the fashion industry ecosystem is embedded in the overall economic system, its main development trends are depend on environmental trends with some phase mismatch.

For a detailed analysis of digital fashion industry evolution, the trajectory of its development is divided into stages. Digital technologies are represented by a set of applications and services necessary to ensure the functionality of the fashion industry. This set consist of the next components:

- 1) digital instrumentarium and/or cloud platforms for digital services;
- 2) systems for business process informatization;
- 3) automated technological systems;
- 4) platforms of online services;
- 5) presence in social networks.

The accessibility of these applications and services is analyzed for the main component organizations and processes of the fashion industry within each stage of its development. The main objects and processes of the fashion industry include:

- design;
- production of ready-made clothes;
- textiles;
- marketing;
- trade;
- logistics;
- consumers.

Historiographical analysis the dynamics of economy and culture transformation in the course of industrialization allows to distinguish conditionally three stages of digitalization. The periods of these stages are not clearly defined, but time limits can be tied in a certain way to the boundaries of industrial revolutions, which are also conditional.

The first stage can be attributed to the third quarter of the third industrial or digital revolution, covering the end of the twentieth century. The second stage of digitalization from the beginning of the 21st century continues until the second decade. The third stage most of all fit to the beginning of the fourth industrial revolution and continues from the second decade of the century to the present day.

The first two stages conformed to the development of the basic functionality of digital technologies, and at the third stage, the digital platform can be considered implemented. At the third stage, innovative achievements are mainly formed through the development of new services on this digital platform. Therefore, can be summarized that the first and second stages correspond to the digital, and the third to the post-digital stages of development of the post-industrial information society [40].

Stage I is the initial stage of digitalization. A characteristic feature of this stage is the euphoria of the success of information technology. Automation of business processes was at the initial stage, information exchange between fashion indus-

try objects was limited to statistical reporting, Internet access and mobile coverage did not cover all territories. Social networks just emerging and have not yet gained their popularity.

A fast fashion strategy has not yet formed, but fashion trends have been accelerating their cycles, and corporations have been spurring this acceleration to support overconsumption trends [40].

Stage II is the mature stage of digitalization. This stage is characterized by the replacement of euphoria from the possibilities of information technology to a practical attitude towards the sustainable development of digital platforms and informatization in the basic sectors of the economy. Based on the analysis of leading cultural figures opinions, it becomes obvious that as a result of the third industrial revolution, the beginning of the new century is characterized by the activation of innovation, which is developing at an accelerated pace. The factors influencing the sustainable development of society are the digitalization of familiar procedures, the informatization of business processes and mobility, which are changing almost all areas of activities.

The development of digital infrastructure continues, which, together with basic services, forms a digital platform for digitalization. The coverage of Internet access and mobile coverage of territories are increasing. Development mobile and cloud services are underway. Image visualization technologies based on 3D modeling and artifact materialization based on additive technologies are being developed. Virtual/augmented reality systems are emerging. There is an expansion of the artificial intelligence sphere from routine procedures to the performance of expert functions. The services of the digital platform facilitated the interaction of fashion industry segments and increased the throughput of business supply chains and the availability of raw materials. The trend of fast fashion, stimulating the shortening the garments life cycle, has fully emerged. Fashion industry enterprises increased the rate of production and production capacity by expanding the amount of resources using the extensive model of operation [40].

The development of social networks has provided people with the opportunity to actively use online platforms of various services, present themselves in virtual living spaces and use alternative sources of first-hand information.

Stage III is the post-digital stage of digitalization. It is assumed that at this stage a digital platform of various services has already been formed. The development of cloud technologies has eliminated access barriers to technological advances through remote provision of services. Computer-aided design programs for design artifacts and databases of reference and technological nature became available. Because of disruptive selection, the roles of the designer, technologist, materials scientist and other subcontractors gradually reduce their influence on the designing results, actually moving into execution by means of artificial

intelligence. Augmented/virtual reality technologies such as “magic mirror” and “virtual fitting room” have expanded the possibilities of design images visualization and marketing communications. The possibilities additive technologies of 3D printing have changed the modern approach to designing both layouts and the design products themselves. Mobility and access to scientific networks databases have simplified information exchange, which has created favorable conditions for interdisciplinary technology transfer and convergence cultural elements of different nature. A distinctive feature of modern design was the creation of innovations based on the synthesis of technology and the arts [40, 41].

During this period in segments of the fashion industry, the problems of resource shortages and environmental risks are growing due to the extensive model of functioning. There is a growing need for the transition to intensive functioning and in initiatives to support the transformation of industry enterprises to a cyclical production model [1, 4, 18–21].

The results of analysis the digital fashion industry development are summarized in Table 2.

Columns of Table 2 represent the main components of the objects and processes of the fashion industry and reflect the facts of certain digital technologies availability for them at each stage of digitalization.

Rows of Table 2 represent the stages of digitalization and reflect the facts of digital technologies and services availability for each object of the fashion industry at this stage.

Cells of Table 2 demonstrate the availability of a specific digital technology for each component of the fashion industry at each stage of digitalization.

The content of the Table 2 shows that at the third stage, the digitalization of the fashion industry is almost completed and digital technologies and services are mainly available in all components of the fashion industry.

Table 2

The stages of digital fashion industry development

Stages of the fashion industry digitalization		Accessibility of digital technologies and services (1)–(5): “0” – the level of information technology development is insufficient for the implementation of this application; “1” – the level of information technology development provides the practical implementation of this application; (1) digital toolkit and/or cloud platform of digital services; (2) informatization of business processes; (3) automated technological systems; (4) online service platforms; (5) presence in social media						
		Design	Manuf.	Text.	Mark.	Trade.	Logist.	User
Stage 1 – the initial stage of digitalization (until 2000)	(1)	1	1	1	0	0	0	0
	(2)	0	0	0	1	1	1	0
	(3)	0	1	1	0	0	0	0
	(4)	0	0	0	0	0	0	0
	(5)	0	0	0	0	0	0	0
Stage 2 – mature stage of digitalization (2000–2010)	(1)	1	1	1	1	1	0	0
	(2)	0	1	1	1	1	0	0
	(3)	1	1	1	1	1	1	0
	(4)	0	0	0	1	1	1	1
	(5)	1	1	1	1	1	1	1
Stage 3 – post-digital stage of digitalization (2010–to this day)	(1)	1	1	1	1	1	1	1
	(2)	1	1	1	1	1	1	0
	(3)	1	1	1	1	1	1	0
	(4)	1	1	1	1	1	1	1
	(5)	1	1	1	1	1	1	1

In Table. 2 the following abbreviations are used: “Prod-uct” – production; “Text.” – textiles; “Mark.” – marketing; “Trade” – trade; “Logis.” – logistics; “Sweat.” – consumers.

Based on the results of the analysis, it is possible to formulate in general terms the requirements for the transformation of the fashion industry in the context of digitalization: from the pursuit of novelty within the fast fashion trends of the linear model of mass consumption to the development of innovative eco-design, individualization and greening within the cyclical model of the fashion industry.

In post-digital fashion design, there is a need to go beyond the traditional frames of digital technologies towards the analysis of new problems that may arise because of threats to environmental safety and resource deficiency. These issues include problem of fashion industry sustainable development.

5.3. Assessment the readiness of the digital fashion industry to transform into a cyclical concept of functioning

As the analysis showed, it is possible to assess roughly the readiness of digital fashion design and the digital fashion industry to transform into a sustainable, environmentally friendly ecosystem of the fashion industry.

The consideration of the source materials made it possible to form factors that determine the conditions for achieving sustainable functioning of the fashion industry. The main issue with which all these factors are connected by cause-and-effect relationships is the choice of a functioning model.

Following this, it is possible to define a suite of components to determine the necessary conditions for achieving sustainable functioning of the fashion industry:

- model of functioning and consumption;
- technologies;
- resources;
- product management;
- manufacturer’s responsibility;
- public opinion.

In role of the functioning and consumption model of a sustainable fashion industry was chosen the full-cycle economy model.

In the study [12] formulated the principles of the circular economy, which for brevity can be called “4R”:

- reduction in clothing consumption, «Reduce»;
- repair of products, «Repair»;
- reuse of clothes, «Reuse»;
- recycling of products at the end of their useful life, «Recycle».

To include these principles in the value chain, it is necessary to redefine existing value criteria and transform different elements of the business model [12]. This fact indirectly indicates the insufficient readiness of the fashion industry to the social, administrative and organizational changes.

The functioning of the full-cycle fashion industry model requires the interaction of textile and clothing production, innovative digital design, marketing communications with the involvement of consumers.

The collection and processing of information necessary to coordinate the actions of participants implies the existence of a common digital platform with the provision of online services to both consumers and service providers.

From Table 2, it can be seen that the processes, functions and services used in the fashion industry model can be fully digitized. This indicates the technical feasibility of

organizing a management information system that will combine heterogeneous data flows as part of solving the general problem of managing the sustainable development of fashion ecosystem on a common digital platform.

Forecasts for textile technology evolution are also positive [9, 22].

The ability to provide the resources required for fashion industry transformation depends on its market size. As it is known that, the expected size of the global fashion industry market from 1.5 trillion USD in 2020 is likely to increase to 2.25 trillion USD in 2025. Since to maintain stable growth the need of fashion industry switching to a circular operating model is brewing, the industry should be interested, and economic indicators allow to hope that it is able to allocate the appropriate resources.

Product management factors, producer responsibility and public opinion depend on the coordination of the actions of the performers and on the attitude of producers and consumers to a new style of clothing consumption.

Due to the initial stage of transformation, these issues are not well understood, but existing publications speak about the need for policies of influence to public opinion formation and about increase professional responsibility for reducing environmental impacts and rational consumption of clothing. For these components, the transformation of the fashion industry is least ready.

5.4. Determination the structure of digital fashion industry innovative potential

There is no doubt that the transformation of the industry into an established ecosystem involves the implementation of a set of innovations that should cover all the constituent objects and processes of the fashion industry. It is also necessary to form a positive attitude among all participants to the new concept of using clothes. “This is a new challenge for industry, business and designers, but also for consumers, who need to critically consider their own consumption practices” [4]. It can be expected that in the process of transformation, for those fashion industry objects and processes affected by digitalization, its advantages will be available, and for other objects, digitalization will occur simultaneously with the transformation.

The fact of the necessity of complex innovative transformations for digital fashion industry into a sustainable ecosystem indicates the presence of an innovative potential that is formed as a result of digitalization and characterizes the ability of the industry to transform. As has already been shown, it is advisable to consider the transformation process as a system for the implementation of digital innovations.

Innovative sustainable fashion design is the creative foundation for creating fashion products in a sustainable fashion industry ecosystem. Therefore, its successful development and application in all components of the ecosystem of each stage of the fashion products life cycle is considered a necessary condition for the transformation of fashion industry linear economy into a full cycle economy [2, 4, 13, 18].

Fashion design is a necessary component of transformation because it influences to the satisfaction through rational cyclical use of resources of both art-aesthetic, economic and environmental requirements. However, it is not sufficient to manage the fashion industry sustainable development because it only indirectly affects to the social problems that may arise in the process of adaptation people to a new style of life. Social problems include the inclusion of public opinion

to the rational consumption model, the formation of attitudes towards the reuse of resources, the harmonization of the tastes and mentality of citizens with new values. In addition, although there is now a growing number of consumers willing to pay higher prices for clothes with a high substance of environmentally friendly materials [15], sociological data are not enough to manage of the transformation process. For the formation of a public opinion, targeted sociological actions are necessary (for which it is necessary to determine the factors of social nature). In addition, administration is required to organize coordinated actions of process all participants.

In this way, it is possible to determine the sets of groups of influence factors that are necessary to manage the transformation of the fashion industry into a sustainable ecosystem - these are economic, environmental, social, art-aesthetic, technological and administrative factors.

In design, innovations consist in the generation, visualization and materialization of design solutions that have a novelty of perception, as well as in the development of technologies, methods, algorithms, styles of project-creative activities that increase the effectiveness of fashion projects.

The innovative potential of digital fashion design can be understood as a measure of the efficiency of fashion design processes due to the benefits generated by the use of digital design tools and computer-aided design systems throughout all stages of the fashion product life cycle [42].

Similar to fashion design, the innovative potential of the digital fashion industry is determined by the increase in the efficiency of its functioning, which is created through the full use of the digital technologies potential in all components of the ecosystem.

In the case of digitalization the main functioning processes, the innovative potential of the digital fashion industry in its sense will no longer differ from the potential of its pre-digital stage. In the general case, it will be determined by the superposition of potentials the constituent objects and processes of the fashion industry. However, in terms of its creative capabilities, the innovative potential of an industry with a high level of digitalization will be higher to traditional ones due to the advantages of new technologies.

The structure of the fashion industry innovative potential can be determined by two ways. The first involves drawing up a structure of potential by reflecting in it the innovative potentials of fashion industry all objects and procedures, taking into account their mutual influence. The second tool proposes to group all influence factors and the associated with them processes of the fashion industry into relatively independent groups on the basis of identity their nature. Further, the structure of the overall innovation potential will be represented by a superposition of the innovation potentials of each group

The second method minimizes the influence of innovative potentials interconnections and is more difficult for the formation of control actions toward identical in nature objects and processes. In this instance, the structure of digital fashion industry innovative potential is understood as a set innovative potentials of groups processes of the industry functioning. In the case of assessing the fashion industry, innovative potential relative its transformation into a sustainable ecosystem, its structure will be the totality of the potentials of all processes groups involved in the transformation.

The condition of the hypothesis of this study is the possibility of regulating the balance of productivity be-

tween groups of different nature processes due to their redistribution without additional replenishment resources of ecosystem.

Confirmation of this statement is based on the fact of increasing the system performance by eliminating the “bottleneck” effect, and the proof comes down to the establishment of availability of the necessary means for the formation of control actions to maintain the “weak link”.

The optimal balance is understood as such a state of the ecosystem elements totality, in which the “bottleneck” effect disappears, that is, the components of the fashion industry functioning provide each other with the necessary resources and services to achieve maximum system efficiency. The system of elements is brought to a balanced state by means of weight coefficients that take into account the contribution of the process to the overall performance and normalization the values of these coefficients in relation to the maximum available resources.

It is important that the transformation of the fashion industry into a sustainable ecosystem consist in a sequence of innovative transformations of its objects and processes. In the case when the transformations are predominantly innovative in nature, the innovative potential and the corresponding object/process/factor are changed synchronously, but with somewhat outrunning of the innovative potential. Therefore, in order to manage balancing, operations with a superposition of factors groups can be replaced by manipulation of a superposition of innovative potentials. For the example, based on the recommendations of the EU strategy, the process of balance regulation can be represented by means of balancing process the superposition of innovative potentials groups of economic, environmental, technological, art-aesthetic, socio-cultural and administrative factors.

For the clearness, the structure of innovation potential, corresponding to the superposition of these groups, is demonstrated by means of infographics. The circles of the modified Euler-Venn diagram are used to represent the superposition of potentials. The balanced state of the innovative potential structure for fashion industry ecosystem is shown in Fig. 1.

Since the factors of the selected groups are relatively independent, the circles have little overlap, reflecting the interdependence of these factors. Fig. 2 reflects the hypothetical state of the innovative potential of the process, which requires regulatory actions on certain groups of elements and processes.

The circles represent the constituent structure elements of the fashion industry ecosystem innovative potential – the innovative potentials of economic, environmental, technological, art-aesthetic, socio-cultural and administrative factors. The diameters of the circles conditionally reflect the estimates of the components values. Since the factors of the selected groups are relatively independent, the circles have little overlap, reflecting the interdependence of these factors. The circles corresponding to the factors innovative potentials are located in such a way that the potentials of the most interconnected factors are nearby. For example, the innovative potential of the art-aesthetic factor is located alongside of the innovative potential of the sociocultural factor.

If the balance is disturbed, a request on the resources redistribution is formed for the factors of weak link, which should eliminate the backlog of this factor. Such queries are shown in Fig. 2 by corresponding arrows.

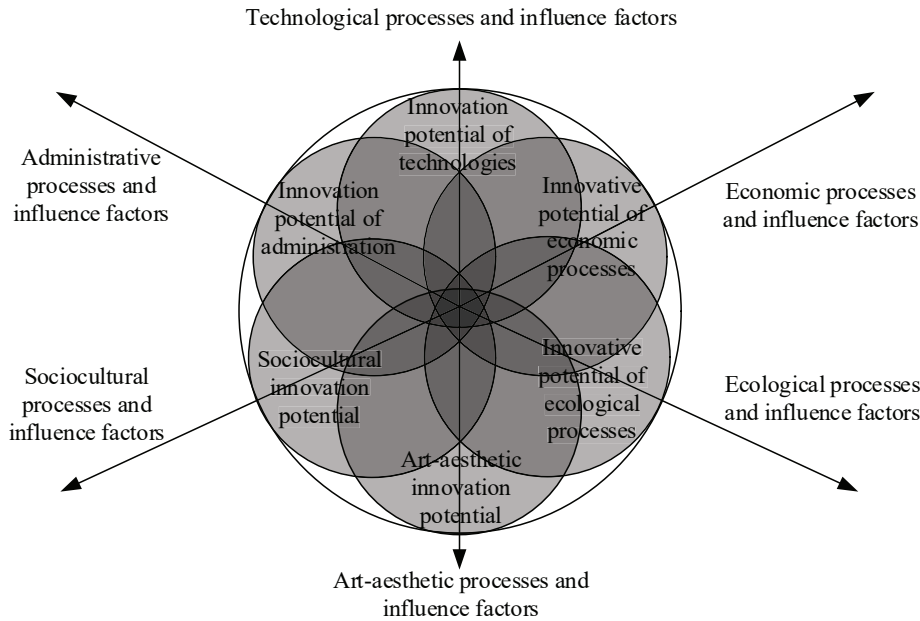


Fig. 1. Balanced state of the innovation potential structure

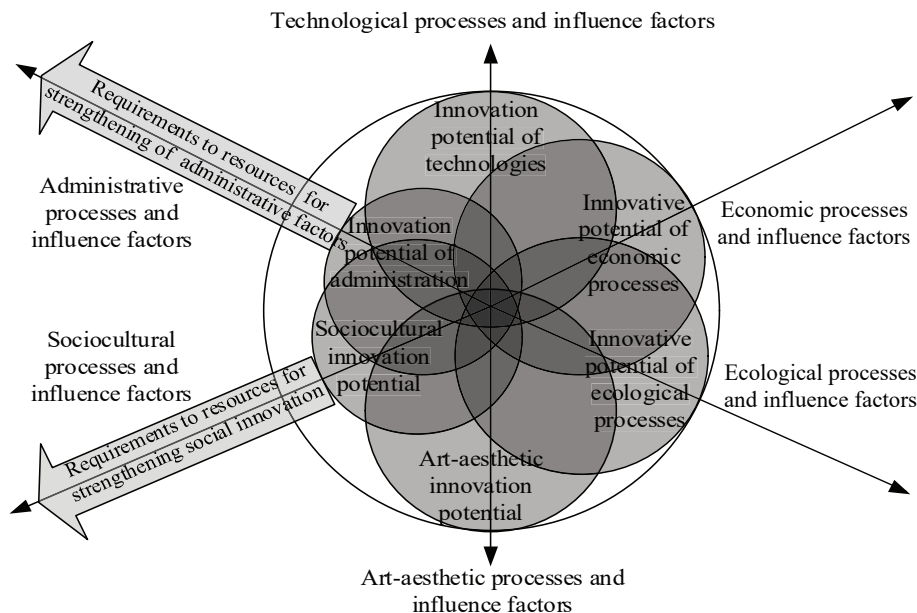


Fig. 2. Management of the unbalanced state of innovative potential structure by means of control factors

5. 5. Search for an approach to managing the transformation processes of the digital fashion industry into a sustainable environmentally friendly ecosystem

The fashion industry, together with the textile industry, is among the largest industries, that uses a lot of resources and generates many environmental problems. Therefore, the fashion industry, based on a linear model of a mass consumer society, is recognized as unsustainable from the standpoint of environmental, economic and social perspectives [1, 5, 9].

The number results of studies [2, 3, 9–11, 14, 15, 26] made it possible to identify influencing factors of practice of the global fashion industry on the sustainability of its development.

To the environmental factors are referred the high-cost use of natural resources, greenhouse gas emissions, waste generation during the production and after the use of fashion products. Social factors include the impact of fast fashion on

overconsumption and shortened product lifespans. Problematic factors also include the fashion industry’s misuse the personnel working at third-party manufacturing plants in countries with cheaper labor [22]. Recommendations to counteract these factors are published by the Commission of the European Union in the EU Strategy for Sustainable and Circular Textiles.

The strategy identifies four critical factors for a positive impact on the situation. These are the use of natural and recycled textiles, the development of design for the reuse and recycling of fashion products, the support of retail and second-hand repair, and the implementation of the “product as a service” model [1].

Together, the factors influencing on the sustainability and stabilization of the fashion industry development require the harmonization of economic, environmental and social aspects with administrative and organizational measures. This puts the problem of economic sectors sustainability among the most complex problems of society [7, 19, 26]. Therefore, the corresponding innovative transformations of the fashion industry should be of a complex nature with a combination of economic, technological, environmental, social and administrative measures, in of condition maintaining an optimal balance between them.

The complex interdisciplinary nature of these requirements emerge a number of contradictions that are typical for managing processes in complex social systems, for which refer the ecosystem of fashion industry.

Since it was previously established that the processes of fashion industry transformation are take a place in a digital environment, it is advisable to consider ways to manage them based on the level of digitalization of the fashion industry components. In this conditions the question arises of how in the innovative process of transforming the industry into a sustainable ecosystem all participants from government agencies, manufacturers, distributors up to users of fashion products can effectively use information technology. This question touches upon aspects the organization of innovation.

In the course of digitalization, new technologies not only changed the strategies and ways of organizing innovation [43], but also carrying out to “new combinations of digital and physical components to produce novel products” [44], and changed the character of innovation [3].

The relationship of digital technologies and social entities involved in digital innovation brought to the emergence of new complex socio-technical systems. [45–48]. To study them, should take into account “technical artifacts as well as the individuals/collectives that develop and use the artifacts in social contexts” [49].

If in context influence of digitalization, consider the fashion industry as such a complex socio-technical system, the study of digital innovation in the fashion industry will require an analysis of social and technological factors while focusing on human and technical artifacts [50].

The problem consists in the coverage all links and processes of the management strategy of fashion industry including consumers. These are the commodity-trade segment, the textile industry, logistics, investments, consulting agencies, as well as voluntary non-governmental societies, whose enthusiasm is a stimulus and an example for activating actions. Without special sociological research, it is impossible to foresee the behavior of all the players in the fashion market. To eliminate uncertainty, it is assumed that participants in the fashion industry ecosystem are interested in acting in accordance with the adopted strategy, providing the necessary information and performing regulatory actions (excluding the influence of relevant sociological factors).

This simplification opens up the possibility of organizing the interactions of transformation participants based on an information system due to its ability to combine heterogeneous sources and data flows as part of solving a general problem on a common digital platform. However, this is possible with the digitalization of all technological, business processes and interfaces between fashion industry objects and consumers.

One of the approaches to managing processes in complex socio-technical systems is the representation of a complex object by a set of influence factors, followed by a system decomposition of the main factors into relatively independent and non-contradictory groups of components.

Further, the components of the same type by nature are grouped. After grouping, the process of the system managing functioning is consist toward regulating the optimal balance between groups of mutually independent components. In the event of a balance “skew”, corrective actions of an appropriate nature are created to compensate of skewness corresponding components.

In the discourse of process regulation, one can single out the factors groups of the fashion industry functioning and use innovative and administrative influences on these groups to achieve its sustainability in the process of transformation.

Because is difficult to guarantee the independence of factors groups, it is easier to select relatively independent factors empirically, taking into account the experience with operating the main components of the fashion industry. Some factors may be formed by the market, and some will depend on public opinion. Others can be regulated through the art designing of clothing through innovative transformations. To manage the

transformation processes of the fashion industry, adjustments are also required on the part of the industry regulator or system administrating.

As an example for the formation of an approach to managing the fashion industry sustainability in the process of its transformation, the recommendations of the European Commission on sustainable and circular textiles are used [1, 5]. As mentioned above, the EU strategy highlights four critical factors influencing the achievement of sustainability:

1. Use of natural and recycled textiles.
2. Development of design for reuse and recycling of clothing.
3. Support for retail and repair of second-hand products.
4. Realization of the “product as a service” model for goods with a high turnover rate.

The criticalness of factors indicates their indicative properties. These factors can be viewed as a set of necessary but insufficient indicators of the sustainable state of the industry. To form a list of sufficient conditions, additional criteria are required, for example, criterion “the formation of a new strategy for the use of clothing”. The executive links of the fashion industry responsible for the implementation of these impact factors are given in Table 3 (using data on the level of digitalization from Table 2). It can be noted that at the third stage, the level of executive links digitalization of the fashion industry ecosystem is sufficient to maintain all the necessary functions.

Table 3

Links of the fashion industry responsible for the implementation of the main factors of influence

Use of natural and recycled textiles		Development of design for reuse and recycling		Support for retail and second-hand repair		Implementation of the “product as a service” model for goods with a high turnover rate	
Links of the fashion industry	Digit %	Links of the fashion industry	Digit %	Links of the fashion industry	Digit %	Links of the fashion industry	Digit %
textile	100	design	100	trade	100	design	100
produc.	100	textile	100	mark.	100	produc.	100
logis.	100	logis.	100	produc.	100	trade	100
cons.	0	mark.	100	logis.	100	logis.	100
–	–	trade	100	cons.	50	cons.	50
–	–	cons.	0	–	–	–	–

In Table 3 the following abbreviations are used: “indus.” – industry; “produc.” – production; “Digit. %” – percentage of digitalization; “logis.” – logistics; “cons.” – consumers; “mark.” – marketing.

Using the decomposition method, the main influencing factors can be represented as relatively independent derivative components (Table 4). Let’s group these components into relatively independent groups of factors. Each of the derived factors is assigned to one of the groups of economic (econ.), environmental (ecol.), technological (tech.), art-aesthetic (aes.), socio-cultural (socio.) and administrative (adm.) factors. In Table 4 the following abbreviations are used: “Deriv.” – Derivatives, “Avail” – Availability, “Certific.” – Certificates; “Internat.” – International.

Estimates of the values of factors are made according to methods corresponding to the nature of these factors, and are added up within each group. Thus, non-normalized assessments of economic, environmental, technological, art-aesthetic and socio-cultural factors are carried out.

At the next stage, they are multiplied by the influence coefficients of this group on the efficiency of the system

and normalized taking into account the value of the total resources. Management consist of eliminating the “bottle-neck effect”, i.e. impact on “weak links” by redistributing resources to bring estimates of factors groups to a symmetrical form.

The sequence of operations described in this example reflects the approach, formed taking into account the problems described above, to managing the transformation of the

digital fashion industry into a sustainable environmentally friendly ecosystem.

Changing the initial group of necessary factors to a set of sufficient factors allows proposing a concept model of transformation managing of the fashion industry based on this approach. The structure of the model of strategy for managing fashion industry ecosystem transformation is presented graphically in Fig. 3.

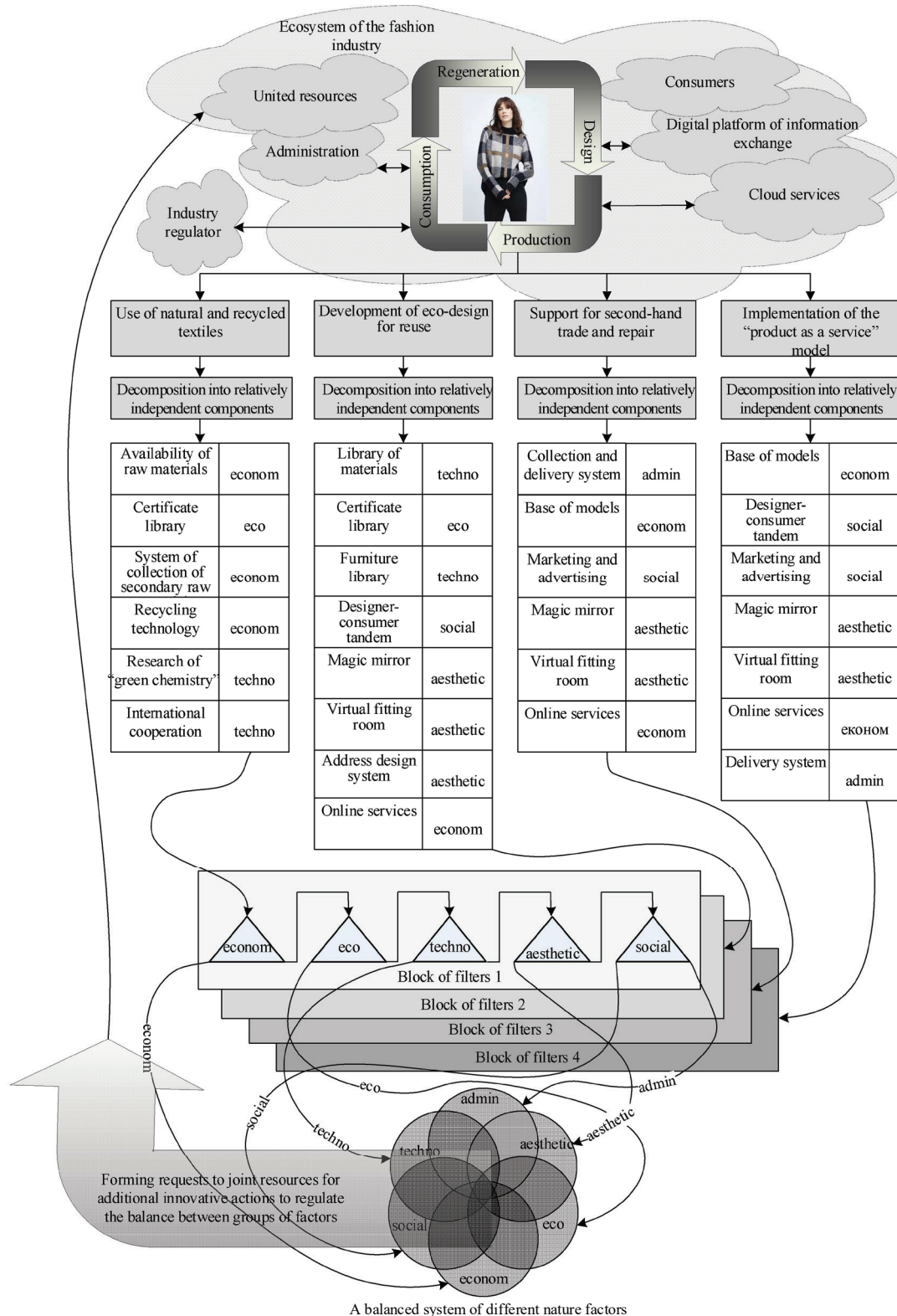


Fig. 3. Model of concept of the fashion industry transformation managing into a sustainable environmentally friendly ecosystem

Table4

Decomposition of the main factors of influence into independent components

Use of natural and recycled textiles		Development of design for reuse and recycling		Support for retail and second-hand repair		Realization of the “product as a service” model for goods with a high turnover rate	
Deriv. factors	Group type	Deriv. factors	Group type	Deriv. factors	Group type	Deriv. factors	Group type
Avail. of raw material base	econ.	Materials library	tech.	Collection and delivery system	adm.	Model base	econ.
Certific. library	ecol.	Certific. library	ecol.	Model base	econ.	Tandem designer-consumer	socio.
Recycling system	adm.	Furniture library	tech.	Marketing and advertising	socio.	Marketing and advertising	socio.
Recycling technology	tech.	Tandem designer-consumer	socio.	Magic mirror	aes.	Magic mirror	aes.
“Green chemistry” research	tech.	Magic mirror	aes.	Virtual fitting room	aes.	Virtual fitting room	aes.
Internat. cooperation	tech.	Virtual fitting room	aes.	Online services	econ.	Online services	econ.
Legal support	adm.	Addressed design system	aes.	Legal support	adm.	Delivery system	adm.
Regulation	adm.	Online services	econ.	Regulation	adm.	Legal support	adm.

In Fig. 3, the model of the management concept is reflected by the following sequence of operations: the functioning of the fashion industry ecosystem is represented by a set of influencing factors. These factors are the use of natural and recycled textiles, the development of design for the reuse and recycling of clothing, the support of retail and the repair of second-hand products, and the realization of the product as a service model for goods with a high turnover rate. At the next step, the system decomposition of the main factors is carried out with respect to independent and non-discrepant components. Further, the components are regrouped into groups of economic, environmental, technological, art-aesthetic and socio-cultural factors. The magnitude of the factors is estimated according to methods determined by the nature of these factors.

The assessment of each group factors total value is determined by the superposition of its components assessments.

Due to the assumption of relative independence of the components for simplify the methodology, their mutual influence is not taken into account, that is, the total value of each group is represented by the sum of its constituent components. The values of group factors are multiplied by the impact coefficients and normalized relative of the total resources of the ecosystem.

The state, in which the assessments of all factors meet the conditions for the sustainable, corresponds to the balanced assessment of the system. Management is consist of maintaining a rational balance between groups of mutually independent components. In the event of a balance skew, in order to compensate for it through the redistribution of resources, corrective actions of the corresponding nature are created on the components of the weak link.

6. Discussion of the digitalization stages study results and of the search the concept of managing fashion industry transformation

The study consistently analyzed the aspects that are considered essential for the successful transformation of the fashion industry into a sustainable ecological ecosystem. These aspects include its state and trends, stages and achievements of digitalization, innovative potential and readiness for transformation. As a result of the analysis, an approach was proposed to manage the process of industry transition to a sustainable ecological ecosystem with the construction of a model of the management concept.

Thanks to the analysis of literary sources, fashion forecast materials and agency reports, it was possible to show that the trends of the fashion industry traditional segment – digitalization, greening and synthesis of technologies and arts, have a common component. This component confirms that the fashion industry is at the epicenter of environmental problems, for the solution of which it has embarked on the path of transformation into an ecological ecosystem.

In the course of state analysis of the fashion industry, the multidisciplinary difficulties were identified that appropriate to decide based on a common digital platform of the ecosystem. The combination of content analysis of the evolution of digital design tools (Table 1) with the historiography of the digitalization phases of the fashion industry (Table 2) was the basis for assessing the industry’s readiness for transformation based on a common digital service platform.

As analysis result of the multidisciplinary transformation problem, it was revealed that it is advisable to present the structure of the fashion industry innovative potential as components that reflect the main aspects of the impact on industry sustainable development (Fig. 1, 2). It is shown that due to the innovative nature of transformational actions, operations for managing these actions can be replaced by operations with a set of corresponding innovative potentials.

The approach to the fashion industry transformation processes management is based on the representation of a complex object as set factors of influencing, followed by a system decomposition of the main factors with respect to independent and consistent groups of components (Tables 3, 4). After grouping, the process of system functioning management is reduced to regulating the optimal balance between groups of mutually independent components (Fig. 3). Representing the innovative potential of an ecosystem as superposition potentials of the independent factors groups of a identical nature minimizes the influence of the interconnections of innovative potentials and simplifies the formation of control actions on objects and processes that are identical in nature.

Most of the sources on this thematic are devoted to the discussion of transformation problems based on the “success story” of individual projects, which do not provide a general concept of process management. In [12], a three-level concept is proposed of the fashion industry transition to a circular economy. But the construction of the process control concept at the discrete, aggregate and peripheral levels covers mainly the technological and environmental components. In addition, although it is noted that the social

organizational component of transformation is a weak link, the management of social and administrative-organizational factors of this concept is not covered.

In contrast to the three-level concept, the process of fashion industry transformation into a sustainable, environmentally friendly ecosystem is viewed from the standpoint of a system at approach to balancing all the main components of success. Representation of the innovative potential of the fashion industry as a set of technological, art-aesthetic, social, economic, environmental and organizational aspects makes it possible to implement the management of the sustainable development of the industry with the optimization of resources. Management is carried out by redistributing the balance between the components to eliminate the “bottleneck”.

The lagging links are the administrative organization of the full cycle process and the social component in terms of preparing public opinion for a new style of wardrobe formation.

Since the solution to the complex problem of fashion industry transformation is at the starting position, it is new challenge for industry, business, designers and consumers alike. Therefore, to implement this program, a number of measures will be required to form a new attitude towards the use of clothing among all participants. Coordination of the heterogeneous environment of participants within the ecosystem requires developed tools of information exchange to manage a complex techno-social system.

It is clear that the transformation of the fashion industry will occur gradually, with the formation of activity centers that capable of implementing a cyclical model. The proposed approach is based on the use of a common digital service platform, assuming that all participants in the process are ready to use appropriate digital technologies and act in concert with a common strategy. This simplification creates a limitation that excludes the opposition of corporations interested in the fast fashion strategy, the influence of public opinion on the reuse of fashion products, the inertia of consumer thinking, and other sociological factors.

Therefore, the presented example of managing the fashion industry innovative potential using the initial data of the recommendations of the European Commission strategy is illustrative.

At the current level of development, the considered management information system can be used as a tool for collecting, processing, transmitting and reproducing information that is necessary to manage transformation processes. And it is advisable to leave administration and decision-making for control actions to regulatory bodies, interested businesses and leaders of targeted non-governmental organizations.

The disadvantages of the study include the use in the example of the approach formation to fashion industry sustainability managing a set of necessary, but insufficient factors influencing its sustainable development. The reason for this simplification is that the transformation of the fashion industry is at an early stage and additional research is required to form a list of sufficient conditions.

Despite the considered limitations and shortcomings, the described approach reveals important aspects and provides answers to questions related to assessing the readiness the components of fashion industry ecosystem for transformation by analyzing the level of their digitalization.

The proposed transformation management strategy by balancing the components of the common innovation potential of the ecosystem can be a starting point for further innovation in moving the fashion industry towards a sustainable

environmentally friendly ecosystem. One of the directions for further research can be aimed at clarifying the composition of sufficient factors influencing the sustainable development of the system. Such clarification is possible based on the accumulation of “success stories” of innovative projects in this area with subsequent analysis and generalization of their results.

7. Conclusions

1. The current state, trends and prospects for the development of the digital fashion industry are analyzed, taking into account the growing raw material and environmental problems. It is shown that the current state of digitalization of the fashion industry has created wide area opportunities for design creativity, freeing the designer from routine processes. However, due to environmental problems and high resource intensity, the fashion industry is recognized as unsustainable, which created the prerequisites for changing the model of its functioning from linear to cyclical. Since the fashion industry is at the epicenter of environmental problems, the trends of the fashion industry traditional segment – digitalization, greening and synthesis of technologies and arts, reflect the main trend – the transformation of the fashion industry into a sustainable ecological ecosystem.

2. In the course of analyzing the essence and role of fashion industry digitalization, the phased development of digital methods for processing and visualizing design images is presented in comparison with the initial, mature digital and post-digital stages of digitalization. It is shown that at the third stage, the digitalization of the fashion industry is almost completed and digital technologies and services are mainly available in all components of the fashion industry.

3. It is revealed that the readiness of the fashion industry for transformation depends on the stage of digitalization, the development of innovative ecological fashion design and the formation of a new attitude towards the use of clothing among all participants. It is shown that as a result of the achievements of textile technologies and the development of information technology, cloud services and social networks, the fashion industry has the necessary technological means for transformation. But the transformation is hampered by the inertia of professional and public opinion, social and administrative problems.

4. It is revealed that the structure of the fashion industry innovative potential should be expedient to present as a superposition innovative potentials of components that reflect the main aspects of the impact on the sustainable industry development. Representation of the fashion industry innovative potential as a set of technological, art-aesthetic, social, economic, environmental and organizational aspects makes it possible to implement the management of the industry sustainable development with the optimization of resources. Management is carried out by redistributing the balance between the innovative potentials of components to eliminate the “bottleneck”.

5. When looking for an approach to managing the fashion industry transformation into a sustainable environmentally friendly ecosystem, many conflicting problems of a technological, environmental, social and organizational nature are identified. These problems, together with the corresponding transformation processes and influence factors, are taken into account in the course of developing an approach to managing transformation. It is shown that the fashion industry transformation from a linear form of organization into a cyclic form

can be controlled by regulating the balance between relatively independent groups of factors influencing to transformation processes. This is done through redeployment, not by acquisition of additional resources. It is proved that in order to implement the management of fashion industry transformation innovative processes, the superposition groups of processes or influence factors can be replaced by the superposition of the corresponding innovative potentials.

Based on the formulated approach, the model of concept for managing the fashion industry transformation into a sustainable environmentally friendly ecosystem is proposed.

Since the solution to the complex problem of the fashion industry transformation is at the starting point, the practical implementation of the proposed approach will require a series of activities to form the motivation of all participants in a new attitude to the use of clothing.

Conflict of interest

The authors declare that there is no conflict of interest regarding this study, including financial, personal nature, authorship or other nature that could affect the research and its results presented in this article.

Financing

The study was conducted without financial support.

Data availability

The manuscript has no associated data.

References

1. EU Strategy for Sustainable and Circular Textiles (2022). European Commission. Available at: https://eur-lex.europa.eu/resource.html?uri=cellar:9d2e47d1-b0f3-11ec-83e1-01aa75ed71a1.0001.02/DOC_1&format=PDF
2. Gazzola, P., Pavione, E., Pezzetti, R., Grechi, D. (2020). Trends in the Fashion Industry. The Perception of Sustainability and Circular Economy: A Gender/Generation Quantitative Approach. *Sustainability*, 12 (7), 2809. doi: <https://doi.org/10.3390/su12072809>
3. Fichman, R. G., Dos Santos, B. L., Zheng, Z. (Eric). (2014). Digital Innovation as a Fundamental and Powerful Concept in the Information Systems Curriculum. *MIS Quarterly*, 38 (2), 329–343. doi: <https://doi.org/10.25300/misq/2014/38.2.01>
4. Niinimäki, K.; Niinimäki, K. (Ed.) (2018). Sustainable Fashion in a Circular Economy. *Sustainable Fashion in a Circular Economy*. Aalto University, 12–41. Available at: <https://core.ac.uk/download/pdf/301138773.pdf>
5. UN Alliance for Sustainable Fashion. Available at: <https://unfashionalliance.org/>
6. Sustainable and circular textiles by 2030 (2022). Available at: <https://op.europa.eu/en/publication-detail/-/publication/9f3fc2a6-b02f-11ec-83e1-01aa75ed71a1/language-en>
7. Centobelli, P., Abbate, S., Nadeem, S. P., Garza-Reyes, J. A. (2022). Slowing the fast fashion industry: An all-round perspective. *Current Opinion in Green and Sustainable Chemistry*, 38, 100684. doi: <https://doi.org/10.1016/j.cogsc.2022.100684>
8. Karel, E.; Niinimäki, K. (Ed.) (2018). Design for Circularity: The Case of circular.fashion. *Sustainable Fashion in a Circular Economy*. Aalto University, 96–127. Available at: <https://core.ac.uk/download/pdf/301138773.pdf>
9. Morone, P. (Ed.) (2022). Sustainable chemistry for a circular fashion Industry. *Current Opinion in Green and Sustainable Chemistry*. Available at: <https://www.sciencedirect.com/journal/current-opinion-in-green-and-sustainable-chemistry/special-issue/10JRD9PB7R2>
10. Shirvanimoghaddam, K., Motamed, B., Ramakrishna, S., Naebe, M. (2020). Death by waste: Fashion and textile circular economy case. *Science of The Total Environment*, 718, 137317. doi: <https://doi.org/10.1016/j.scitotenv.2020.137317>
11. Ikram, M. (2022). Transition toward green economy: Technological Innovation's role in the fashion industry. *Current Opinion in Green and Sustainable Chemistry*. doi: <https://doi.org/10.1016/j.cogsc.2022.100657>
12. Mishra, S., Jain, S., Malhotra, G. (2020). The anatomy of circular economy transition in the fashion industry. *Social Responsibility Journal*, 17 (4), 524–542. doi: <https://doi.org/10.1108/srj-06-2019-0216>
13. Papamichael, I., Chatziparaskeva, G., Pedreño, J. N., Voukkali, I., Almendro Candel, M. B., Zorpas, A. A. (2022). Building a new mind set in tomorrow fashion development through circular strategy models in the framework of waste management. *Current Opinion in Green and Sustainable Chemistry*, 36, 100638. doi: <https://doi.org/10.1016/j.cogsc.2022.100638>
14. Matušovičová, M. (2020). Sustainable fashion as a part of the circular economy concept. *Studia Commercialia Bratislavensia*, 13 (45), 215–223. doi: <https://doi.org/10.2478/stcb-2020-0009>
15. Arribas-Ibar, M., Nylund, P. A., Brem, A. (2022). Circular business models in the luxury fashion industry: Toward an ecosystemic dominant design? *Current Opinion in Green and Sustainable Chemistry*, 37, 100673. doi: <https://doi.org/10.1016/j.cogsc.2022.100673>
16. Shrivastava, A., Jain, G., Kamble, S. S., Belhadi, A. (2021). Sustainability through online renting clothing: Circular fashion fueled by instagram micro-celebrities. *Journal of Cleaner Production*, 278, 123772. doi: <https://doi.org/10.1016/j.jclepro.2020.123772>
17. Nambisan, S., Lyytinen, K., Yoo, Y. (2020). Digital innovation: towards a transdisciplinary perspective. *Handbook of Digital Innovation*, 2–12. doi: <https://doi.org/10.4337/9781788119986.00008>
18. National Clothing Product Stewardship Scheme Design. Global Scan Report. Australian Fashion Council. Available at: https://drive.google.com/file/d/1LkSesXkvSI1v1xr799XG3cvGyHH3_uvU/view
19. National Clothing Product Stewardship Scheme. Available at: <https://ausfashioncouncil.com/product-stewardship/>
20. WRAP's vision for the UK circular economy. Available at: <https://wrap.org.uk/taking-action/climate-change/circular-economy/wraps-vision-uk-circular-economy>
21. Sustainable clothing design. WRAP. Available at: <https://wrap.org.uk/taking-action/textiles/actions/sustainable-clothing-design>

22. Sustainable clothing business models. WRAP. Available at: <https://wrap.org.uk/taking-action/textiles/actions/sustainable-clothing-business-models>
23. The Fourth Industrial Revolution: what it means, how to respond (2016). World Economic Forum. Available at: <https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond>
24. The State of Fashion 2022. BOF & McKinsey. Available at: <https://www.mckinsey.com/~media/mckinsey/industries/retail/our%20insights/state%20of%20fashion/2022/the-state-of-fashion-2022.pdf>
25. Hardabkhadze, I. A. (2013). Suchasnyi Odiah: naukovyi pidkhid do vyrishennia problem dyzainu. Kyiv: «Yzdatelskyi dom Vynychenko», 275.
26. Adamkiewicz, J., Kochańska, E., Adamkiewicz, I., Łukasik, R. M. (2022). Greenwashing and sustainable fashion industry. *Current Opinion in Green and Sustainable Chemistry*, 38, 100710. doi: <https://doi.org/10.1016/j.cogsc.2022.100710>
27. Oxman, N. (2015). Design at the intersection of technology and biology. Mit media lab. Available at: <https://www.media.mit.edu/articles/design-at-the-intersection-of-technology-and-biology-2/>
28. BASF 3D Printing Solutions. Available at: <https://forward-am.com/about-us/our-story/>
29. Ozioko, O., Dahiya, R. (2021). Smart Tactile Gloves for Haptic Interaction, Communication, and Rehabilitation. *Advanced Intelligent Systems*, 4 (2), 2100091. doi: <https://doi.org/10.1002/aisy.202100091>
30. Autio, E., Nambisan, S., Thomas, L. D. W., Wright, M. (2018). Digital affordances, spatial affordances, and the genesis of entrepreneurial ecosystems. *Strategic Entrepreneurship Journal*, 12 (1), 72–95. doi: <https://doi.org/10.1002/sej.1266>
31. Faulkner, P., Runde, J. (2019). Theorizing the Digital Object. *MIS Quarterly*, 43 (4), 1279–1302. Available at: <https://misq.umn.edu/theorizing-the-digital-object.html>
32. Hund, A., Wagner, H.-T., Beimborn, D., Weitzel, T. (2021). Digital innovation: Review and novel perspective. *The Journal of Strategic Information Systems*, 30 (4), 101695. doi: <https://doi.org/10.1016/j.jsis.2021.101695>
33. Kotler, P., Kartajaya, H., Setiawan, I. (2016). *Marketing 4.0: Moving from Traditional to Digital*. Wiley & Sons Inc.
34. Konya-Baumbach, E., Schuhmacher, M. C., Kuester, S., Kuharev, V. (2019). Making a first impression as a start-up: Strategies to overcome low initial trust perceptions in digital innovation adoption. *International Journal of Research in Marketing*, 36 (3), 385–399. doi: <https://doi.org/10.1016/j.ijresmar.2019.01.008>
35. Lyytinen, K., Nambisan, S., Yoo, Y. (2020). A transdisciplinary research agenda for digital innovation: key themes and directions for future research. *Handbook of Digital Innovation*, 279–286. doi: <https://doi.org/10.4337/9781788119986.00034>
36. Nambisan, S., Lyytinen, K., Majchrzak, A., Song, M. (2017). Digital Innovation Management: Reinventing Innovation Management Research in a Digital World. *MIS Quarterly*, 41 (1), 223–238. doi: <https://doi.org/10.25300/misq/2017/41.1.03>
37. Beltagui, A., Rosli, A., Candi, M. (2020). Exaptation in a digital innovation ecosystem: The disruptive impacts of 3D printing. *Research Policy*, 49 (1), 103833. doi: <https://doi.org/10.1016/j.respol.2019.103833>
38. Online 3D Printing Service. Sculpteo. Available at: <https://www.sculpteo.com/en/>
39. The State of 3D Printing Report: 2021. Sculpteo. Available at: <https://www.sculpteo.com/en/ebooks/state-of-3d-printing-report-2021/>
40. Hardabkhadze, I. A. (2020). Dyzain maibutnoho: vid tsyfrovoi eiforiyi do konverhentsiyi naturalnoho i shtuchnoho intelektu. *Sotsiokulturna dynamika ukrainskoho suspilstva. Rozdil 1. Teoriya ta istoriia sotsialnykh komunikatsiy*. Kyiv: KNUKiM, 97–119.
41. Hardabkhadze, I. (2019). Contemporary design. Synthesis of arts, technology, ethnoculture, and ecology. *Issues in cultural studies*, 35, 21–33. doi: <https://doi.org/10.31866/2410-1311.35.2019.188781>
42. Gardabkhadze, I. (2020). The innovative potential of digital fashion design. *Visnyk KhDADM*, 2, 5–12. Available at: <https://visnik.org.ua/pdf/v2020-02-01-Gardabkhadze.pdf>
43. Lyytinen, K., Yoo, Y., Boland Jr., R. J. (2015). Digital product innovation within four classes of innovation networks. *Information Systems Journal*, 26 (1), 47–75. doi: <https://doi.org/10.1111/isj.12093>
44. Yoo, Y., Henfridsson, O., Lyytinen, K. (2010). Research Commentary – The New Organizing Logic of Digital Innovation: An Agenda for Information Systems Research. *Information Systems Research*, 21 (4), 724–735. doi: <https://doi.org/10.1287/isre.1100.0322>
45. Sandberg, J., Holmstrom, J., Lyytinen, K. (2020). Digitization and Phase Transitions in Platform Organizing Logics: Evidence from the Process Automation Industry. *MIS Quarterly*, 44 (1), 129–153. doi: <https://doi.org/10.25300/misq/2020/14520>
46. Wang, P. (2021). Connecting the Parts with the Whole: Toward an Information Ecology Theory of Digital Innovation Ecosystems. *MIS Quarterly*, 45 (1), 397–422. doi: <https://doi.org/10.25300/misq/2021/15864>
47. Mousavi Baygi, R., Introna, L. D., Hultin, L. (2021). Everything Flows: Studying Continuous Socio-Technological Transformation in a Fluid and Dynamic Digital World. *MIS Quarterly*, 45 (1), 423–452. doi: <https://doi.org/10.25300/misq/2021/15887>
48. Tilson, D., Lyytinen, K., Sørensen, C. (2010). Research Commentary – Digital Infrastructures: The Missing IS Research Agenda. *Information Systems Research*, 21 (4), 748–759. doi: <https://doi.org/10.1287/isre.1100.0318>
49. Sarker, S., Chatterjee, S., Xiao, X., Elbanna, A. (2019). The Sociotechnical Axis of Cohesion for the IS Discipline: Its Historical Legacy and its Continued Relevance. *MIS Quarterly*, 43 (3), 695–719. doi: <https://doi.org/10.25300/misq/2019/13747>
50. Majchrzak, A., Griffith, T. L. (2020). The new wave of digital innovation: the need for a theory of sociotechnical self-orchestration. *Handbook of Digital Innovation*, 17–40. doi: <https://doi.org/10.4337/9781788119986.00011>