Silk Industry Value Chain and Circular Economy

R. Hassan [a)], S. Terzi [a)] and P. Rosa [a)]

a. Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Piazza Leonardo da Vinci 32, 20133 Milan - Italy

(rabia.hassan@polimi.it, sergio.terzi@polimi.it, paolo1.rosa@polimi.it)

Abstract: Silk exhibits a positive outlook and possesses the potential to drive transformative changes in the coming decades. The global demand for silk is on the rise, underscoring the importance of intensified stakeholder awareness, increased exchange of entrepreneurial knowledge, and enhanced consumer accessibility. However, in every facet of the silk industry, a certain amount of waste is generated. To make the silk industry SILKULAR it is influential to implement the circular economy keeping in view the whole value chain including all actors. The aim of this research is to explore silk value chain and recognizing the strategies that can support the silk industry in transitioning from linear to circular behaviors. This cannot be done without keeping in view the whole value chain's main actors.

Keywords: Circular economy, Silk, Value chain, LCA

I. INTRODUCTION

Currently, the world's economy operates upon a take-make-waste approach. We utilize the natural resources of our planet as primary ingredients to manufacture various items, only to eventually dispose of these products as waste. Most of this waste becomes irretrievable once it is discarded in landfills or subjected to incineration. The current approach to clothing production, distribution, and consumption primarily revolves around the concept of extracting resources, manufacturing garments, and then discarding them after use [1]. This linear model has adverse impacts on society across various scales, including local, regional, and global levels. It leads to missed economic opportunities, puts strain on resources, pollutes and degrades ecosystems, and depletes essential ecosystem services. To create a more sustainable society, it is essential to transition from the current linear model, which is detrimental to the environment, to a circular approach.

To foster a society which is sustainable, it is necessary to shift towards a circular economy model. This model emphasizes the establishment of closed-loop systems that enable the continuous flow of materials throughout the value chain. The objective is to ensure that materials remain within the loop instead of becoming waste, promoting greater circularity within the value chains [2]. The complexity of value chains in the textile industry for textiles and clothing arises from the dispersion of different stages across the globe, leading to the formation of global value chains [3]. In 2021, the textile and apparel industry emerged as a significant industrial sector, generating a substantial amount of global fiber production, reaching a staggering 113 million tons, and predictable to grow to 149 million tons by 2030. Thus, the contribution of pre- and post-consumer recycled textiles to the global fiber market was less than 1% in total [4].

However, among the major textile materials, silk fibers and silk fabrics are renowned for their exceptional quality. They are highly cherished by people for their exquisite beauty, luxurious softness, exceptional wearing comfort, warmth, gentle touch on the skin, and sustainable nature [5]. Furthermore, it possesses a neutral pH, exhibits a high absorption capacity, demonstrates elasticity, and possesses anti-static properties. Indeed, silk fabric is highly comfortable and finds versatile applications in clothing such as blouses, dresses, shirts, shawls, ties, and gloves. Additionally, it is utilized for decorative purposes in items like curtains, cushions, and upholstery. It also finds application in diverse industries such as electronics, aeronautics, and healthcare. However, silk's representation within the realm of textile fibers remains relatively limited, constituting a mere 0.17% with the production of raw silk in 2021 amounting to around 173,162 tons [4].

Silk has demonstrated a promising outlook and holds the potential to bring about revolutionary changes in the forthcoming decades. The global demand for silk is experiencing growth, which highlights the need for enhanced stakeholder awareness, increased sharing of entrepreneurial experience, and improved consumer accessibility [6]. On the other hand, in every sector of the silk industry, a certain quantity of waste is generated. Approximately 35% of the total weight of silk waste is generated within the reeling industry during the process of raw silk production [7]. In this context, Uddin Mahmud [8] claimed that most of the studies related to silk are focusing on silk production and the authors as well focused on the issues related to the silk production. However, there are studies on silk related to determining significant historical importance, environmental impacts related to silk production, silk waste recycling methods, Life-cycle assessment of silk production. This research seeks to investigate the silk value chain and identify effective strategies to facilitate the silk industry's that can help to transition from linear to circular practices.

II. Literature Review

A. *Linear economy*

Currently, the prevailing economic model is characterized by the linear model. This model can be defined as a socioeconomic structure that consumes sources to manufacture products for consumer use, which are subsequently discarded once they no longer hold value [9]. The Ellen MacArthur Foundation further elaborates on this system as an economy that operates on the principles of "take-make-dispose". The linear model can be described as a straightforward trajectory that possesses a distinct beginning and end point. The central principle of this model revolves around the process of extracting raw materials from nature, converting them into consumer goods, and ultimately, generating waste as a result.

The emergence of the linear economy model can be attributed to the onset of the industrial revolution. This revolution commenced towards the end of the 18th century in Europe and experienced rapid growth. Therefore, there was a major growth in the mass production of goods, making it more cost-effective to purchase them rather than producing them individually. Textile goods serve as an exemplar of products that became more affordable to purchase during this period, as the term "fabric" originated from this era. Societies were transitioning from a pre-industrial era, where self-sufficient production of necessary goods was common, to an industrial society.

B. *Circular economy*

The Ellen MacArthur Foundation (2013) has provided the widely accepted definition of a circular economy as “an industrial system that is regenerative by intention and design”. According to some perspectives, the core of a circular economy lies in achieving a continuous and closed loop of materials, as well as the efficient utilization of raw materials and energy across various phases [10].

The primary distinction between a circular economy and a linear economy lies in the preservation of the value of materials and resources for as long as possible, primarily through their retention in the form of functional products. In a linear economy, the value chain begins with the extraction or production of raw materials, such as fiber and continues until the final stage of the product being sold to the consumer. After being purchased, the product serves its purpose for the user until it either malfunctions or the owner no longer finds it desirable for various reasons. At that point, the user replaces it with a new product and disposes of the old one, which is then discarded [11]. On the other hand, the circular economy as shown in figure 1 is distinguished by a comprehensive value chain that encompasses the entire lifespan of a product, including the reverse value chain. This reverse value chain generates value by reintegrating utilized products and materials back into the economic cycle through a series of phases like collection, maintenance, reuse, recover, recycle, and remanufacture [12].

In a circular economy, the goal is to maximize the lifespan of a product through durable design, repair options, and facilitating sharing or transferring to other users when the original user no longer requires it. This approach aims to extend the active usage period of a product as much as possible. Once a product has reached the end of its usable life, the materials it contains are transformed into valuable resources through recycling, which can be utilized in the production of new products. This process allows for the efficient extraction and repurposing of materials, ensuring their continued value in the circular economy.

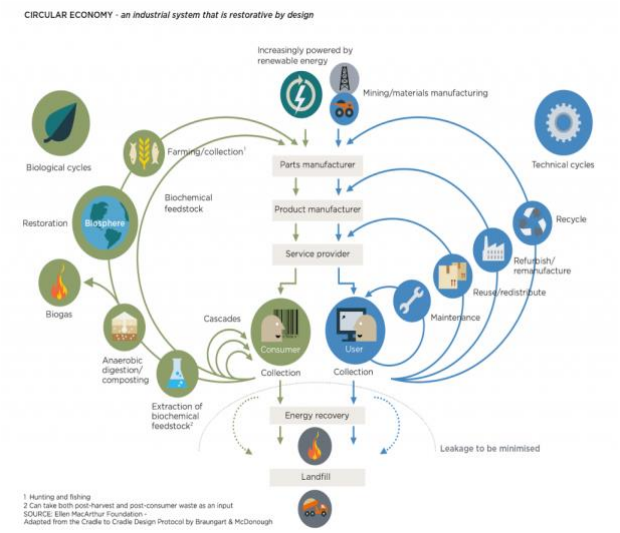


Figure 1 Circular economy butterfly model [12]

C. *Circular strategies in textile*

After studying the literature on strategies related to circular economy within the textile and fashion industry, it becomes evident that five primary circular strategies are more frequently implemented. These strategies, as defined by Reike [13] have generally observed in the textile and fashion background and include reselling, reusing, repairing, remanufacturing, and recycling.

a) Reselling

Reselling has emerged as a popular circular strategy in the fashion industry, effectively preventing garments from ending up in landfills. This approach is widely adopted by fashion businesses, operating in both business-to-consumer (B2C) and business-to-business (B2B) models, to extend the lifespan of clothing items [14], [15] . While the practice of reselling garments is predominantly carried out by businesses in the fashion industry, there is also a small number of individual users who participate in consumer-to-consumer (C2C) reselling to address their unwanted clothing items. However, the overall percentage of users actively involved in C2C reselling remains relatively low [16].

b) Reusing

The textile and fashion industry are actively incorporating reuse practices through charitable organizations and contributions. Industry faces external burden to adopt sustainable business practices and models, charities present a significant chance for promoting clothing reuse [17]. Moreover, studies indicate that a significant portion of consumers of fashion express a readiness to donate clothing items they no longer require. This willingness to donate further enhances the effectiveness of charities as a circular solution in the fashion industry [16]. Nevertheless, organizations of charity often prioritize accepting products with high-quality, which can pose a probable obstacle as low quality garments or those with slight damages may not be in high demand [17]. Besides charitable donations, textile and fashion reuse can be considered in various practices, including renting, swapping, borrowing, and trading. These activities can be initiated either by businesses or consumers, but they all should contribute to the sustainable reuse of fashion items. [18].

c) Repairing

The inclination to repair fashion garments differs amongst individuals depending on their personal clothing preferences and sensitive connection to the fashions [19]. Moreover, individuals are more likely to be willing to repair high-cost garments compared to cheaper textile and fashion items. However, there is still a readiness to renovation products of fast fashion [20].

d) Remanufacturing

In the fashion industry, remanufacturing refers to the process of transforming old garments into new clothing items that are either as good or even better than the products which are original. The remanufactured product is not required to retain the identical individuality as the initial item. This implies that a dress, for instance, could be transformed into a skirt or a scarf through the remanufacturing process [21].

e) Recycling

Textile and fashion recycling has been in practice for a considerable period; however, it relies on outdated mechanical technologies and methods for material extraction [22]. Therefore, the recycled resources produced often possess low quality. The potential for recycling different fibers of textile varies significantly [23]. As a result, the fabrics obtained from recycling are primarily utilized for purposes such as insulation, stuffing, or as elements of products which are not related to fashion, rather than being reintegrated into production of fashion.

D. *Value chain*

The term "value chain," coined by Michael E. Porter [24], encompasses the complete sequence of activities required to bring a product or service from its conception to its final disposal. This

includes all stages of manufacturing, distribution to customers, and the subsequent handling of the product after its use. It can be assumed that the value of a product is likely to increase as it transitions from one participant in the chain to another. [25]. Consequently, the value chain can be utilized as a methodology to dissect a company into its fundamental functions, facilitating the identification of sources of competitive advantage. [26].

The value chain of a firm and the way each activity is carried out are reflections of the firm's past, present, and future as well as of its approach and the methods used to accomplish it. The value chain exhibits the total value and comprises of the margins and value activities. Value activities include technologically and physically different activities which are performed by a firm. These are the elements that help a company produce a product that is beneficial to its customers. Alternatively, the margin refers to the disparity between the total value generated and the expenses incurred in carrying out the value-adding activities. The value activities are further divided into two main types, "primary activities" and "support activities" as shown in figure 2.

Figure 2 Elements of value chain [24]

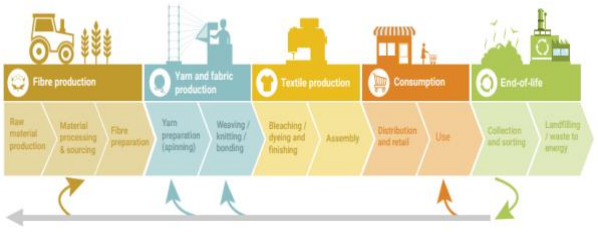
a) Textile value chain

The value chain of textile consists of activities that offer or get value through the designing, manufacturing, distributing, selling, and consuming products of textile (or through service offering that product of textile delivers). Including the raw materials extraction and supply in addition to activities that involve the textile after its useful service lifespan. In this perspective, the value chain includes all phases of the life of a product, from the raw materials supply to disposal after usage, and includes activities related to value production including business strategies, regulations, and investments.

The value chain for textile goods begins with the production of fiber. This may consist of extraction of crude oil and the production of chemicals through which synthetic fibers (such as polyester) originate, or it may include a conjunction of the two. Since textiles are often created through a blend of synthetic and natural fibers or encompass both organic materials and processes of chemical in their production [27].

Figure 3 illustrates the linear value chain of textile, the subsequent stages in manufacturing entail fibers spinning into yarn and knitting, weaving, or fibers bonding to create fabric. The fabric is subsequently processed chemically, mechanically, or both (a process called finishing) to give it the required characteristics, such as softness or resistance to water. Cutting and stitching the fabric into the final item is the next stage in the value chain, which then proceeds by distribution and retailing to bring the product to the end user. The textile item can either be recycled for various purposes after its initial usage, as is the case with given secondhand apparel, or it can be reused again. A smaller percentage of textiles (less than 1%) are recycled into new garments in the existing, largely linear textile value chain. The remaining 12% are recycled in a cascaded fashion and utilized in items like insulating material, cleaning cloths, and mattress filling [28]. After one or more usage the cloth will eventually undergo some type of end-of-life treatment. Right now, a burning plant or a sanitary landfill are the most likely acts.

Figure 3 Textile value chain [28]



b) Silk value chain

The three primary phases of silk production are i) Upstream/Production, ii) Midstream/Process, and iii) Downstream/Distribution. Farming of sericulture, rearing of silk and reeling of silk includes in the upstream industry. The midstream industry includes fabric weaving, dying, and printing. In the countryside, this operation is carried out by hand, whereas in the industrial sector, massive machinery is used. The design, manufacture, retailing, and marketing of numerous silk items, including apparel, bedding, and home décor, are managed by the downstream industry

[29], [30]. Figure 4 illustrates the silk industry's three streams of the value chain.

According to the study [31] providing raw materials like silkworms, cocoons, and silk yarn for the manufacturing of silk is part of the upstream value chain. The midstream or process value chain refers to creating semi-finished items, such as silk fabric, and is significantly influenced by technical processes. On the other hand, the downstream value chain refers to delivery of finished and semi-finished silk products.

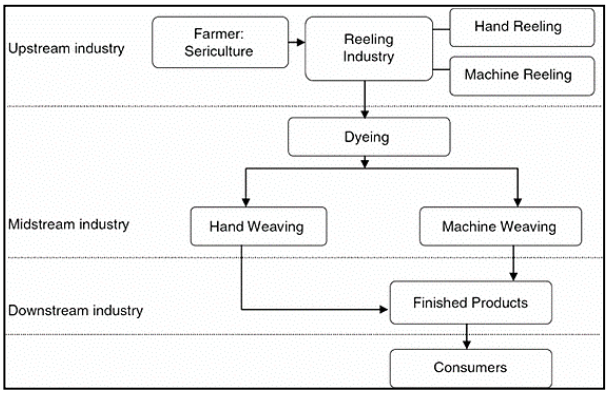


Figure 4 Value chain streams of silk industry [29], [30]

The authors also discussed the three main stakeholders of the net silk textile (silk farmers, silk weavers and silk traders) are involved in factory level decision making. The people in charge of raising silkworms are known as "silk farmers." Some farmers participate as well in the procedure of making silk fabrics and yarn. People who work with weaving are known as silk weavers. Silk traders are those who work as intermediaries by selling silk goods and running silk businesses. Figure 5 illustrates the detailed three streams of the value chain with its main stakeholders.

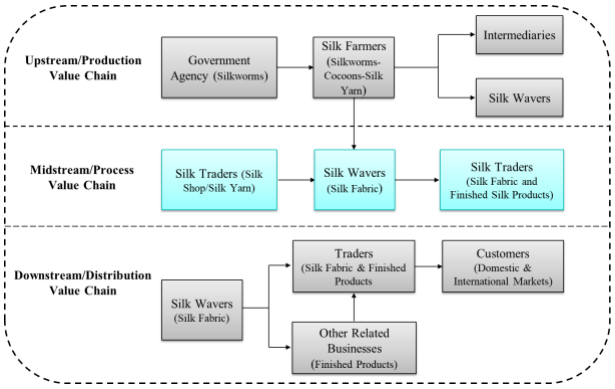
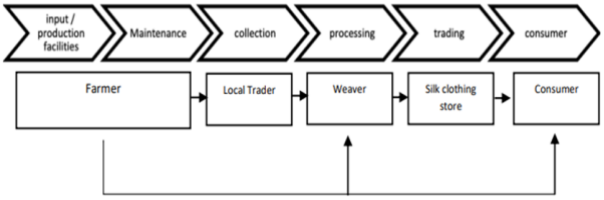


Figure 5 Value chain streams with main stakeholders (authors creation)

Agro-industrial processes are used to produce natural silk, starting with the plant of mulberry, which provides the silkworm nutrition and necessitates the care and upkeep of silkworms, followed by spinning yarn processing (cocoons into yarn), weaving and lastly silk fabrics marketing. Pratama [32] identifies the main business actors of silk value chain illustrated in figure 6, the actors in the silk industry play their separate parts in a variety of processes that result



in the product creation.

Figure 6 Silk value chain with business actors [32]

The detailed silk business actors primary & supportive activities illustrated in figure 7, the farmers play a key part in the business players' primary activity in the silk commodities sector as suppliers or manufacturers of coarse yarn from silkworms. Local traders represent the next stage of activity, and their primary activity is purchasing thread of silk from farmers and then selling it to craftsmen / weavers. Additionally, weavers and other craftspeople handle the procedure of transforming threads into finished products. Finally, apparel retailers with their weaving operations make up the major level of the silk commodities business participants. On the other hand, the farmers first grow plants of mulberry that serve as food for silkworms as supporting actions for the silk commodities business players. After that local traders carried out their activities to make it easier for farmers to distribute thread of silk to weavers / craftsmen. Weavers and craftsmen are knowledgeable in weaving, own automobiles, and build connections with silk apparel retailers.

The objective of this research, based on existing evidence in the literature, is to contribute towards the circularity of the Italian silk industry by examining and optimizing the value chain. It helps to enhance sustainability, minimize environmental impact, and foster a more circular economy within the silk industry.

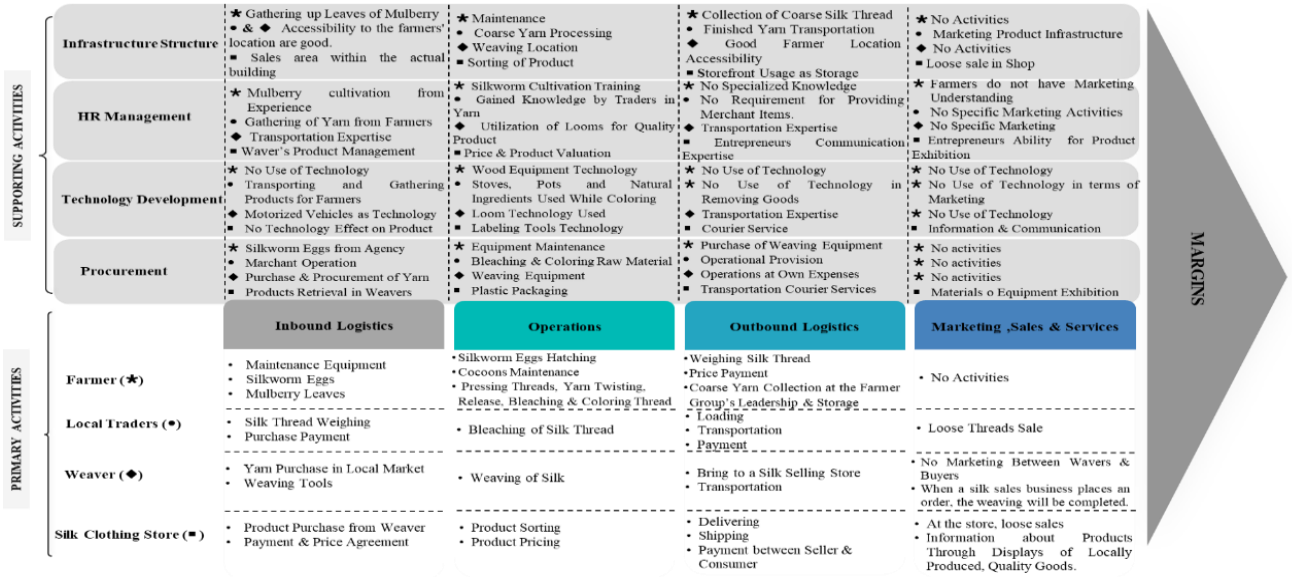


Figure 7 Silk business actors primary & supportive activities (authors creation)

III. Conclusion

This research endeavor plays a crucial role in advancing the knowledge and implementation of circular economy principles within the silk sector. It seeks to support the development of a more sustainable, circular, and competitive silk industry by looking at important factors, policies, and cutting-edge techniques. The objective of this research, based on existing evidence in the literature, is to contribute towards the circularity of the Italian silk industry by examining and optimizing the value chain. It helps to enhance sustainability, minimize environmental impact, and foster a more circular economy within the silk industry. The research's recommendations and findings can help stakeholders, legislators, and business professionals shift from linear to circular behaviors, reduce waste, improve resource efficiency, and have a minimal negative impact on the environment. Overall, this study can have a substantial impact on the future of the silk industry by promoting a more circular and sustainable method of managing the value chain of silk.

IV. References

[1] Ellen MacArthur Foundation, "A new textiles economy: Redesigning fashion's future," 2017.

[2] Y. Kalmykova, M. Sadagopan, and L. Rosado, "Circular economy - From review of theories and practices to development of implementation tools," *Resour. Conserv. Recycl.*, vol. 135, no. February 2017, pp. 190–201, 2018, doi: 10.1016/j.resconrec.2017.10.034.

[3] Š. Nikolina, "Environmental impact of the textile and clothing industry. What consumers need to know," 2019. [Online]. Available: https://www.europarl.europa.eu/portal/en.

[4] Textile Exchange, "Preferred Fiber & Materials: Market Report 2022," 2022.

[5] J. Y. Li *et al.*, "Comparative Proteomic Analysis of Posterior Silk Glands of Wild and Domesticated Silkworms Reveals Functional Evolution during Domestication," *J. Proteome Res.*, vol. 16, no. 7, pp. 2495–2507, 2017, doi: 10.1021/acs.jproteome.7b00077.

[6] K. M. Babu, "Silk reeling and silk fabric manufacture," in *Silk*, 2019, pp. 31–50.

[7] T. N. Sonwalkar, *Hand Book of Silk Technology*. 1993.

[8] R. Uddin Mahmud, A. Nabi Khan, M. Raijul Islam, R. Khan, M. Ashfakur Rahman Rome, and R. Islam, "A comparative study on the present challenges and solutions of the silk industries in Bangladesh," *BUFT J. Fash. Technol.*, no. January, 2022, [Online]. Available: https://www.researchgate.net/publication/357620390.

[9] G. Michelini, R. N. Moraes, R. N. Cunha, J. M. H. Costa, and A. R. Ometto, "From Linear to Circular Economy: PSS Conducting the Transition," *Procedia CIRP*, vol. 64, pp. 2–6, 2017, doi: 10.1016/j.procir.2017.03.012.

[10] Z. Yuan, J. Bi, and Y. Moriguichi, "The circular economy: A new development strategy in China," *J. Ind. Ecol.*, vol. 10, no. 1–2, pp. 4–8, 2006, doi: 10.1162/108819806775545321.

[11] L. Fernandes, A. M. Rosado da Cruz, E. F. Cruz, and S. I. Lopes, "A Review on Adopting Blockchain and IoT Technologies for Fostering the Circular Economy in the Electrical and Electronic Equipment Value Chain," *Sustain.*, vol. 15, no. 5, 2023, doi: 10.3390/su15054574.

[12] Ellen MacArthur Foundation, "Towards the circular economy," 2013. [Online]. Available: https://www.aquafil.com/assets/uploads/ellen-macarthur-foundation.pdf.

[13] D. Reike, W. J. V. Vermeulen, and S. Witjes, "The circular economy: New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options," *Resour. Conserv. Recycl.*, vol. 135, no. February 2017, pp. 246–264, 2018, doi: 10.1016/j.resconrec.2017.08.027.

[14] A. de A. Hugo, J. de Nadae, and R. da S. Lima, "Can fashion be circular? A literature review on circular economy

barriers, drivers, and practices in the fashion industry's productive chain," *Sustain.*, vol. 13, no. 21, 2021, doi: 10.3390/su132112246.

[15] L. Hedegård, E. Gustafsson, and M. K. Paras, "Management of sustainable fashion retail based on reuse– A struggle with multiple logics," *Int. Rev. Retail. Distrib. Consum. Res.*, vol. 30, no. 3, pp. 311–330, 2020, doi: 10.1080/09593969.2019.1667855.

[16] S. Weber, J. Lynes, and S. B. Young, "Fashion interest as a driver for consumer textile waste management: reuse, recycle or disposal," *Int. J. Consum. Stud.*, vol. 41, no. 2, pp. 207–215, 2017, doi: 10.1111/ijcs.12328.

[17] R. Zanjirani Farahani, N. Asgari, and L. N. Van Wassenhove, "Fast Fashion, Charities, and the Circular Economy: Challenges for Operations Management," *Prod. Oper. Manag.*, vol. 31, no. 3, pp. 1089–1114, 2022, doi: 10.1111/poms.13596.

[18] K. Shirvanimoghaddam, B. Motamed, S. Ramakrishna, and M. Naebe, "Death by waste: Fashion and textile circular economy case," *Sci. Total Environ.*, vol. 718, p. 137317, 2020, doi: 10.1016/j.scitotenv.2020.137317.

[19] L. S. McNeill *et al.*, "Fashion sensitive young consumers and fashion garment repair: Emotional connections to garments as a sustainability strategy," *Int. J. Consum. Stud.*, vol. 44, no. 4, pp. 361–368, 2020, doi: 10.1111/ijcs.12572.

[20] S. Diddi and R. N. Yan, "Consumer perceptions related to clothing repair and community mending events: A circular economy perspective," *Sustain.*, vol. 11, no. 19, 2019, doi: 10.3390/su11195306.

[21] P. Sinha, S. S. Muthu, and G. Dissanayake, "The Remanufacturing Industry and Fashion," in *Environmental Footprints and Eco-design of Products and Processes*, 2016.

[22] L. Norris, "Urban prototypes: Growing local circular cloth economies," *Bus. Hist.*, vol. 61, no. 1, pp. 205–224, 2019, doi: 10.1080/00076791.2017.1389902.

[23] S. S. Muthu, Y. Li, J. Y. Hu, and P. Y. Mok, "Recyclability Potential Index (RPI): The concept and quantification of RPI for textile fibres," *Ecol. Indic.*, vol. 18, pp. 58–62, 2012, doi: 10.1016/j.ecolind.2011.10.003.

[24] Michael E. Porter, *Competitive Advantage*. 1985.

[25] J. Hellin and M. Meijer, "Guidelines for value chain analysis," *Analysis*, no. November, 2006.

[26] S. Dubey, R. Singh, S. Singh, A. Mishra, and N. Singh, "A BRIEF STUDY OF VALUE CHAIN AND SUPPLY CHAIN," in *Agriculture Development and Economic Transformation in Global Scenario*, no. September, 2020, pp. 177–183.

[27] M. A. Franco, "Circular economy at the micro level: A dynamic view of incumbents' struggles and challenges in the textile industry," *J. Clean. Prod.*, vol. 168, pp. 833–845, 2017, doi: 10.1016/j.jclepro.2017.09.056.

[28] Uited Nations, "Sustainability and Circularity in the Textile Value Chain," 2020.

[29] P. Patichol, W. Wongsurawat, and L. M. Johri, "Upgrade strategies in the Thai silk industry: Balancing value promotion and cultural heritage," *J. Fash. Mark. Manag.*, vol. 18, no. 1, pp. 20–35, 2014, doi: 10.1108/JFMM-09-2011-0059.

[30] N. Jatuphatwarodom, D. F. Jones, and D. Ouelhadj, "A mixed-model multi-objective analysis of strategic supply chain decision support in the Thai silk industry," *Ann. Oper. Res.*, vol. 267, no. 1–2, pp. 221–247, 2018, doi: 10.1007/s10479-018-2774-6.

[31] P. Siewsamdangdet, S. Vemuri, and P. Bretherton, "Strategies for sustainable development of silk industry in Northeast Thailand," *Int. J. Strateg. Manag.*, vol. 10, no. 1, pp. 1–11, 2010.

[32] A. G. Pratama, S. Supratman, and M. Makkarennu, "Examining forest economies: A case study of silk value chain analysis in Wajo District," *For. Soc.*, vol. 3, no. 1, pp. 22–33, 2019, doi: 10.24259/fs.v3i1.4912.