SUSTAINABLE FASHION PRODUCT DEVELOPMENT: WITH APPLICATION IN FASHION SPORTSWEAR

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---------- (Signed)

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---------- (Name of student)

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Abstract

Product development is a critical part of all fashion business operations. In recent years, the growing healthy lifestyle draws the public awareness of fashion sustainability. Thus, the fashion product development processes (PDPs) need to be environmentally, socially, and economically sustainable. Meanwhile, growing awareness for fitness and health also promote a significant rising of sportswear market. How sports fashion companies improve their sportswear's PDPs and sustainability performance of their business become critical. In Chapter 1, an overview of the research motivations, objectives, and methodologies towards sustainable sports fashion product development is introduced.

In Chapter 2, we first identify the supply chain structures for the fashion industry. Then, by extensively reviewing the PDPs' related literature, we identify the essential steps in fashion PDPs, including planning, product design, manufacturing, and product launching. We further classify the product development process into three types, namely traditional product development process (TPDP), new product development process (NPDP), and sustainable product development process (SPDP). In addition, we analyze the key factors of achieving sustainable fashion based on the triple bottom line (TBL) model regarding the PDP. We discover that no previous studies have covered all three dimensions of TBL model throughout the whole fashion PDP. In Chapter 3, we further investigate how a fashion company can propose a successful sustainable business development strategy throughout the sustainable fashion PDPs with respect to the TBL. Via a case study with public data on the giant sports fashion brand Nike, we explore the application of our proposed sustainable business development strategy framework in Chapter 4.

Since the fashion apparel PDP is complicated and involves many interrelated steps and decision processes, how fashion suppliers identify the consumers' demands for sustainable fashion products and make the right decisions during the PDPs is highly important. Many prior studies have depicted different consumers' attitudes towards sustainable fashion and their effects on consumers' demands. It indicates the differences existing between the consumers' expectations and the developed sustainable sportswear products. Thus, in Chapter 5, gap analysis on the attitudes towards sustainable sportswear development between the sustainable sportswear suppliers' (SSSs) and the sustainable sportswear consumers' (SSCs) is conducted through the questionnaire survey and data collection. The results present that a significant difference exists between SSSs and SSCs' attitudes towards sustainable design, manufacture, product features, and branding. Based on the in-depth interview, the major causes for the attitude differences are further studied, which contribute to providing strategic insights for sustainable sportswear product management and business development.

After studying the attitude gap between SSSs and SSCs', a set of sustainability performance assessment indicators are determined to implement a sustainable business development strategy. Through the applications of the determined assessment indicators, the SSSs can evaluate the social, environmental, and economic sustainability performances of the PDPs and make the best decision that meets the needs of the SSCs'. As the development process of sustainable sportswear products is complicated, changes in the product components of sportswear (e.g., materials, manufacturing methods, and product design) will correspondingly influence supply chain activities and meanwhile affect environmental, economic, and social performances. Thus, the interrelations between different sustainability performances and how the interrelations can help SSSs

to strike a balance among the three sustainability dimensions are explored. Based on the findings in Chapter 6, a set of three-dimensional assessment indicators is introduced. To examine the applicability of the developed assessment indicators, a series of sportswear (legging products) are developed and investigated. The outcomes of Chapter 6 provide insights on the approach to balance sustainability and development of cost-effective and sustainable sportswear products for SSSs and SSCs.

Finally, to enhance our understanding of the research and industrial progress relating to sustainable fashion product development on a global scale, a knowledge network analysis (KNA) has been conducted in Chapter 7 to systematically investigate the related studies carried out by researchers and teams from different countries and regions. Meanwhile, through the main-path analysis (MPA), the correlations among these existing studies have been established, which shed light on the future research trends/interests and facilitate the strategic planning of industrial activities for sustainable fashion product development. After conducting the KNA and MPA, the gaps between the existing studies and the problems not being addressed are determined. These studies enhance our understanding of the current knowledge and future research directions on sustainable product development. To summarize, the major findings of the whole study towards sustainable sport fashion product development process and future works are presented in Chapter 8.

Publications

Book chapters

1) Liu, R., **Fung, Y. N.,** & Abida, Y. (2020). Evaluation of perceived comfort and functional performance of activewear. In Latest Material and Technological Developments for Activewear (pp. 89-118). Elsevier.

2) **Fung, Y. N.,** & Liu, R. (2019). Sustainable sports fashion and consumption. In Consumer Behaviour and Sustainable Fashion Consumption (pp. 39-67). Springer, Singapore.

3) **Fung, Y. N.,** & Choi, T. M. (2018). Product development process of an international luxury fashion brand: Implications to Hong Kong fashion trading and manufacturing companies. In Contemporary Case Studies on Fashion Production, Marketing and Operations (pp. 27-41). Springer, Singapore.

Conference publications

1) **Fung, Y. N.,** Liu, R., & Choi, T. M. (2021). A three-dimensional assessment approach on sustainable development process of sportswear products. World Academy of Science, Engineering and Technology. International Journal of Materials and Textile Engineering Vol:15, No:4.756

2) **Fung, Y. N.,** Liu, R., & Choi, T. M. (2021). A gap analysis of attitude towards sustainable sportswear product development between consumers and suppliers. World Academy of Science, Engineering and Technology. International Journal of Materials and Textile Engineering Vol:15, No:5.1482

Journal publications

1) **Fung, Y. N.,** Chan, H. L., Choi, T. M., & Liu, R. (2021). Sustainable product development processes in fashion: supply chains structures and classifications. International Journal of Production Economics, 231, 107911 **(Scientific Journal Rankings: Q1; Impact factor:7.885**).

2) **Fung, Y. N.,** Choi, T. M., & Liu, R. (2020). Sustainable planning strategies in supply chain systems: proposal and applications with a real case study in fashion. Production Planning & Control, 31(11-12), 883-902 **(Scientific Journal Rankings: Q1; Impact factor:7.044**).

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CHAPTER 1

Introduction

1.1 Research motivations and objectives

According to O'Connell (2019), the worldwide apparel industry market growth in 2017 was over 5%, with the estimated peak growth rate reaching 6.2% in 2020. Meanwhile, the global sportswear market is growing tremendously in the past ten years. Also, from the Grand view research (GVR, 2020a), the estimated global sportswear market size was USD 239.78 billion in 2018, which took up over 8% of the global fashion industry. Besides, according to Business Wire (Technavio, 2020a), although the outbreak of COVID-19 leads to significant negative sales impacts in the first quarter of 2019, the impact on the annual economic growth is limited. It is reported that the COVID-19 provides new business opportunities, during the period of 2020-2024, the expected growth in the sportswear market will be around USD 630 million. The significant market growth and market share imply that a massive amount of fashion and sportswear apparel products that are being made and disposed of would create a severe environmental issue.

According to the United Nations Conference on Trade and Development before the COVID-19 pandemic (UNCTAD, 2019), the fashion industry is considered as the world's second-largest polluting industry in 2019, where the fashion industry consumes 93 billion cubic meters of water annually. Also, around 500 thousand tons of microfiber (same as 3 million barrels of oil) are used for fashion and apparel materials production.

Meanwhile, industrial carbon emission is enormous (Chan et al.,2018). The total carbon emission of the fashion industry is more than the combination of all maritime shipping and international flights (Horne, 2011). These terrifying statistics raise consumers' demands for sustainable fashion, which further draws the fashion and apparel brands' attention to the seriousness of developing a sustainable business. Retailers need to analyze the environmental impact of the product they developed (Shi et al.,2018) and provide the corresponding service with respect to the market responses (Shen, Choi, & Chan, 2019). Apart from environmental considerations, many social and ethical issues are incurred. The fashion industry is a labor-intensive industry, where most fashion companies (especially for those who target low-cost fashion) aim to bring down the production cost by sourcing from manufacturers in countries with a lower salary range (Colucci, Tuan, & Visentin, 2020; Pedersen, Gwozdz, & Hvass, 2018). It is reported that some fashion companies violate the code of conduct in using child labors and "sweatshop operations" for production (Siegmann, 2008). This raises public awareness of fashion companies' corporate social responsibility (CSR). If any fashion brand fails to comply with the CSR requirements expected by the public, it will harm not only the brand's image but also the whole industry's reputation.

The rapid growth of the fashion and apparel industry and the emergence of the corresponding economic and social sustainability issues, raise public awareness and demands for sustainable fashion, which also trigger keen competition (Guo et al., 2020). However, fashion and apparel products are characterized by their complicated business structures with huge product varieties and short product life cycles (Wen et al., 2019). Due to the intricate characteristics of the fashion industry and apparel products, diverse aspects are associated with the implementation of sustainable fashion (Wang, Chan, Yee,

& Diaz, 2021). For example, it often involves different kinds of materials in the same garment or apparel product. A single fabric or yarn often includes various fibers, such as plant-based fiber (e.g., cotton, linen), animal fiber (e.g., wool, alpaca), and synthetic fiber (e.g., polyester, nylon). The supply of raw materials may come from different geographical locations with different sustainable standards and implications. For example, fashion brands can source sustainable cotton with less water consumption and time for growing; however, they may be genetically modified, which may bring out another sustainability and ethical concern. Thus, fashion brands need to give clear instructions to the designers upon sustainable materials selection. Meanwhile, the manufacturers need to verify if the source of sustainable materials meets the brands' sustainability standards and the designers' aesthetics expectations.

Furthermore, to make sure the source of sustainable materials can be trackable and verifiable, high supply chain transparency is needed. For example, if the designer decides to use sustainable Australian cotton, the yarn supplier will order the raw materials from Cotton Australia. Each batch of raw materials would be recorded and coded. After spinning the yarn, the yarn supplier needs to provide the code to the garment manufacturers, so that they can apply for “certification” from Cotton Australia. With the certification, the retail company can put hang tags on the garments, so that customers can know the source of sustainable raw material. However, as the garment may be made by other fabrics other than the one from Australian cotton (e.g., 60% Australian cotton; 40 % polyester) and there may be some fabric leftovers that could be saved for producing other styles, a tricky situation may be formed. To be specific, multiple styles may use the same “production batch”, which may imply that back and forward verifications are necessary before getting the formal certification. As a result,

to facilitate the transparency and traceability of the fashion supply chain system, blockchain technology can be applied. Blockchain is a trendy information technology, with which information can be tracked and disclosed to all channel members. As the information is permanently recorded in the system, channel members need to pay special attention to the accuracy of the information being uploaded and stored (Choi et al., 2020). If any mistakes are being made, all channel members will be affected. Thus, to develop a sustainable fashion business, fashion brands must cooperate with all the members in the product development processes (PDPs). Starting from the business planning of the fashion brand, product design, material selection, manufacturing, and supply chain management, all steps in the PDPs need to fully cooperate. Despite the growing awareness of sustainable fashion, prior literature that discusses the whole fashion PDP is still limited. As a result, this study aims to fill this important gap.

Based on the market demand for sustainable fashion, the focus of our study is to explore the structure of the fashion PDP and the key participants within the SPDP as well as to study how we can enhance the management and performance of the sustainable fashion product development process. To be specific, this study aims to conduct empirical research and achieve the following objectives:

(1) To study the structures of the fashion industry and critical steps of the fashion product development process.
(2) To explore the applications of management theories in the sustainable fashion industry and establish a theory-based sustainable fashion management framework.
(3) To examine the applicability of the sustainable fashion management framework through public data-based case studies towards a sportswear brand.
(4) To explore the difficulties in the implementation of management framework by

analyzing the attitude gaps towards sustainability between the key participants of the sustainable product development process.

(5) To study and identify the assessment approaches for the sustainability performance of the fashion industry and develop the corresponding indicators for performance assessment of sustainable sports fashion development.

(6) To study the current academic focuses and explore future research opportunities.

1.2 Research methodologies and flow

To achieve the research objectives, a logic structure and research flow of the thesis is designed as shown in Figure 1. Motivated by the real-world demands on sustainable fashion and the growing sportswear market, this dissertation aims to provide the insights for sustainable fashion business implementation and performance evaluations. In Chapter 1, the structures of the fashion industry and the mechanisms of the sustainable fashion product development process is firstly introduced. In Chapter 2, an extensive literature review towards fashion industrial structures and product development process is performed. Based on the findings in Chapter 2, we further study the operation management theories which are used to explain the phenomenon of a sustainable fashion business strategy development in Chapter 3. Then, through establishment of a three-stage methodological approach, a novel framework for sustainable business development strategy is developed. To explore the applicability of the developed framework, a case study towards sportswear brand Nike is conducted in Chapter 4.

Fashion industry is very complicated which involves different processes and participants. The cognitions of the participants towards sustainable fashion

development influence the strategic decision-making and resultant business performances. Therefore, In Chapter 5, a gap analysis on the attitudes between the suppliers (retailers, designers, and manufacturers) and consumers towards the sustainable fashion product development is conducted, especially for sportswear products. Through analysis of the gathered data from the questionnaire survey, the attitude gap between the suppliers and consumers is identified. The managerial insights are provided to facilitate the suppliers' cognitions and development strategies towards sustainable fashion to fulfill consumers' expectations.

Through analyzing the structures and mechanism of the fashion industry, it is found that there are no prior assessment indicators for sustainability based on the triple bottom line (environment, economic, social) that are able to provide practical solutions for suppliers to estimate the implementation of the sustainable business development strategy. To deal with this problem, in Chapter 6, we further explore the assessment approaches on sustainable fashion product development. Unlike the existing assessment indicators, this newly proposed indicators' system aims to balance all three dimensions of sustainability with consideration of their correlative performances. Through conducting statistical analyses, we examine the applicability of the proposed indicator system based on a real case of fashion sportswear development (leggings).

With the increase of awareness on sustainability in the fashion industry, the studies on sustainable fashion business and product development research are growing remarkably. In Chapter 7, a knowledge network analysis (KNA) and main path analysis (MPA) are conducted from a global scale to further build up an academic knowledge network to define the four key knowledge clusters of sustainable fashion product development with

explorations of their evolution, thus determining the research directions and providing the guidance for future industrial practice.

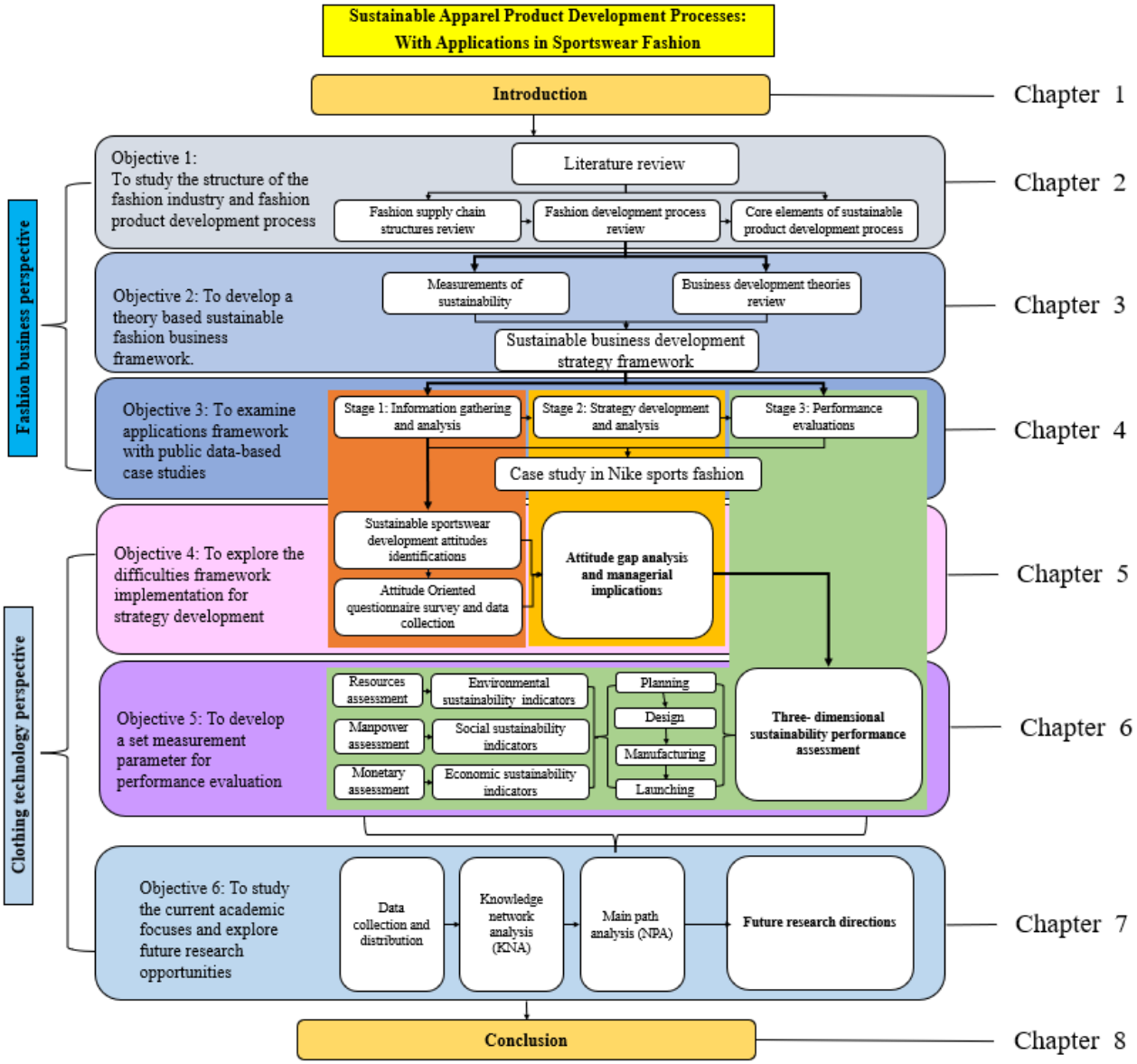


Figure 1.Research flow of this thesis study

CHAPTER 2

Literature Review

The main purpose of the Chapter 2 is to examine the structure of the fashion industry and the product development process. In this chapter, we first conduct an in-depth study of the supply chain structures of the fashion industry. Then, we further study the fashion product development process and identify the critical steps and evolutions of the fashion product development process. Finally, the core elements of each critical fashion product development step are studied.

2.1 Structures of fashion industry

In real-world practices, it is observed that fashion brands adopt different business operations strategies, including centralized operations, decentralized operations, and original equipment manufacturers (OEM), based on their available assets and resources. This leads to different supply chain structures. The fashion supply chain structures can be classified into three main types, as shown in Figure 2 and Table 1. Structure A (the vertically integrated structure) indicates a vertically integrated product development process within one fashion company. For example, a fashion retail brand called "PYE" belongs to a company called Esquel. Starting from raw material production (farming), product design, manufacturing, and launching, the Esquel group owns and has full control of every single step of the process. This kind of company can be regarded as the original brand manufacturer (OBM), as it conducts the design and development, product manufacturing, and brand marketing tasks by itself (Azadegan & Wagner, 2011).

Meanwhile, many designer labels such as Ralph Lauren adopts business Structure B (production outsourcing structure). This structure is characterized by its outsourcing property. Instead of owning the manufacturing facilities, the company sets up a merchandising team to outsource the production and material sourcing activities. However, the product design is still centralized by the fashion retail brand's in-house design team. Once the brand's in-house product designs are finished, the in-house merchandising team will work directly with the nominated manufacturers, where the manufacturers will work with the nominated material suppliers to develop the requested materials and produce the products. It should be noted that Structure B can be expanded through globalization. For example, a globalized fashion retail brand, Levi Strauss & Co is selling its products to 110 countries with over 50,000 retail locations.

Thus, a more complicated outsourcing structure is needed to manage this intricate retail network. To have a better understanding of the market demand, Levis used to set up local buying hubs in countries where the sales are relatively high. Meanwhile, the regional offices are used to serve countries that are geographically close together. They will first gather the sales information from the local buying hub to plan for the new season's product line plan (product categories, number of products per category, and corresponding SKU). Then, the in-house design team and the merchandising team will work with the nominated manufactures and material suppliers to develop the product samples for buying meetings. During the buying meetings, local offices will place orders to the regional offices for production and delivery, and the cross-region orders will occur. Finally, Structure C (decentralized structure) is widely used by brands or companies which offered diversified products to the market. For example, companies such as Target and Walmart, provide different kinds of products in their stores, including clothing,

footwear, accessories, and lingerie. Instead of having separate design and manufacturing teams for each type of product category, they "decentralize" (i.e., outsource) the design and manufacturing functions to either third-party trading companies or original design manufacturers (ODM). Trading companies such as Li and Fung usually provide fashion product design and merchandising services. The trading companies' in-house design team could provide design services for the brands they serve. At the same time, their in-house manufacturing team will identify suppliers for materials sourcing and original equipment manufacturers (OEM) for manufacturing. Once the fashion retail brand adopts the design, the trading companies will order the materials from the suppliers and ship to the OEM for product manufacturing. The trading companies will also arrange the shipment for product distribution. As a service provider, these trading companies earn commission in return, where it captures part of the OEM's earning. Thus, some OEMs start to establish their own in-house design team and become original design manufacturers (ODM). Then, they can provide product design services to the fashion retail brands and capture the commission earning of the trading company.

Table 1. Decision approaches adopted in different supply chain structures for fashion industry

Supply chain structures		Material Supply	Manufacturing	Design	Retailing
A	Vertically integrated structure	Centralized	Centralized	Centralized	Centralized
B	Production outsourcing structure	**Decentralized**	**Decentralized**	Centralized	Centralized
C	Decentralized structure	**Decentralized**	**Decentralized**	**Decentralized**	Centralized

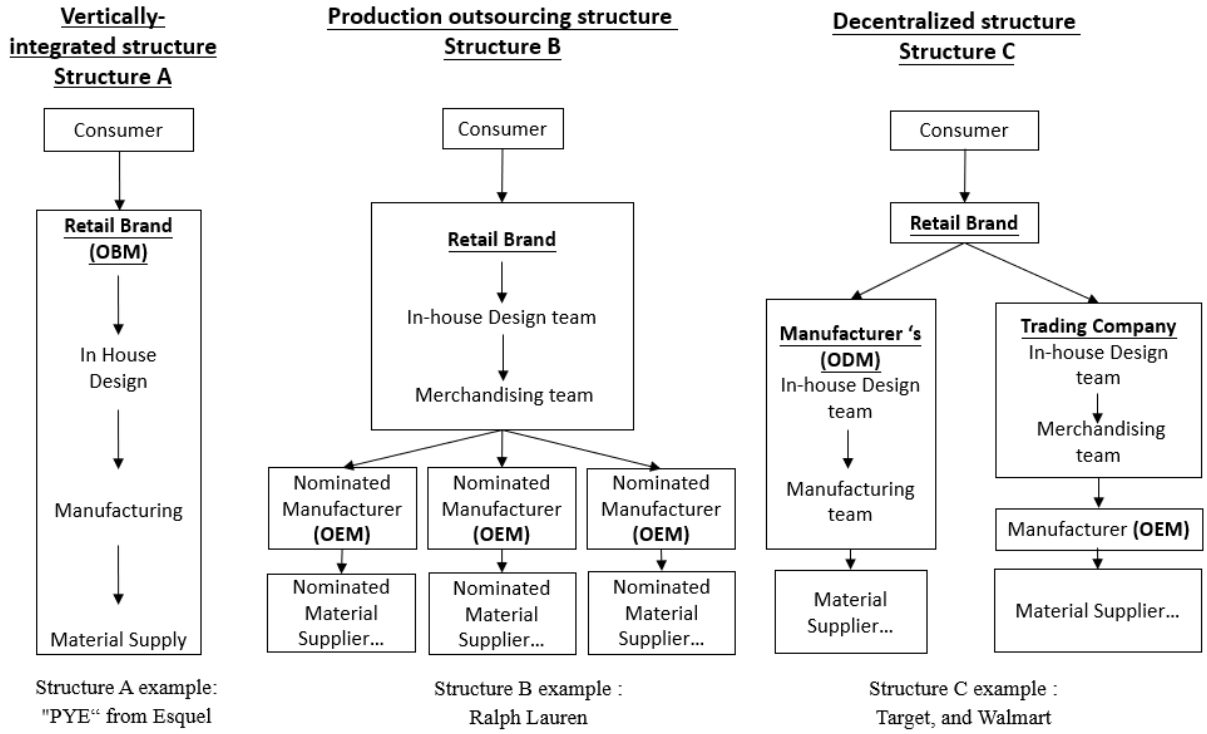


Figure 2. Supply chain structure for the fashion industry [1]

Note: The structures for the fashion industry are based on the fashion supply chain allocation, with material suppliers as the upstream members while the retail brands as the downstream members

Figure 2 summarizes the supply chain structures for the fashion industry. The key characteristics of the fashion industry include the vast product varieties with a short life cycle (Wen et al., 2019). According to Inditex's 2008 business report, the Inditex group launches over 7,5000 SKU in 2018 (Inditex, 2018a), where one of its fashion retail brands, Zara, contributes around 12,000 SKU per year (Klammer, 2009). Comparing with the traditional fashion product development process which takes months for products to be launched, the fast-fashion brand Zara demonstrates a quick response nature in which it can introduce the new products in two weeks (Inditex, 2018b), from design to the sales floor. Also, to support quick response, firms adopt technologies in

[1] This is based on our experience and discussions with the industrialists.

green supply chain management (Chan et al.,2018; Li et al.,2020; Zhang et al., 2020). According to the best Global Brand (Interbrand, 2019), within the 100 best global brands, 12 fashion brands are included in the list. By which, two of the fast fashion brands (Zara and H&M) rank higher than some of the giant sportswear brands like Adidas and luxury brands like Burberry. The massive growth of fast fashion companies drives other fashion brands to simulate their business strategy. For example, Burberry launched a "See now buy now" strategy in 2017, which was a revolution in the luxury fashion industry at that time (Salonga, 2017). This shows that the growth of fast fashion exerts pressure on the whole fashion industry upon a speedy product development process. However, as the fashion industry is characterized by its vast product varieties with short product life cycles, it enhances the difficulties of managing the product development process throughout different fashion supply chain structures. Thus, it is worth studying the mechanism of the fashion product development process and exploring how to streamline the process to make it more effective and efficient.

2.2 Fashion product development process

To develop a sustainable fashion business, it is crucial for the fashion retail brand to cooperate with the fashion supply chain members throughout the whole fashion product development process (PDP). Thus, it is worth studying the mechanism and the key participants in the fashion PDP. Based on the reviewed literature, we can classify the PDP into three categories, namely the traditional product development process (TPDP), the new product development process (NPDP) and the sustainable product development process (SPDP).

2.2.1 Traditional product development process (TPDP)

Fashion product development involves a series of processes, where the participants within the process are responsible for various functions. Both Johnson and Moore (2001) and Gloria et al. (2014) present a linear process of fashion product development. Johnson and Moore (2001) focus on identifying business operation functions within the whole fashion supply chain. They propose that the fashion supply chain is formed by having various functions, namely: product research, fashion triangle of balance, establishing the first design ideas, proper planning and costing, product line building, and optimal production PDP. Unlike Johnson and Moore (2001), Gloria et al. (2014) focus on the production function and the corresponding operations. They suggest that the apparel PDP starts from fiber production, spinning, dyeing, weaving/knitting, fabric/garment treatment, cut & sew, finishing, sundried application, packing, distribution retail, use (garment care), and final disposition.

Combining the ideas of Johnson and Moore (2001) and Gloria et al. (2014), Carr and Pomeroy (1992) study the critical functions of the whole fashion supply chain together with detailed operations within each function. They first classify the PDP into 4 main steps: (1) the origin of the style, (2) the development of samples, (3) the refine mint of business objectives, and (4) the attainment of commercial products whereas each foremost step has its corresponding operations. Goworek (2010) proposes the fashion PDP is a process of cooperation than coordination; several operations can overlap temporally. From the above literature review, we find that the TPDP is linear operations, with one step followed by the other. To be specific, the traditional PDP consists of 4 major steps, which are

planning, product design, manufacturing, and product launching, respectively.

2.2.2 New product development process (NPDP)

According to Caniato et al., (2014), "new product development (NPD), is a process that facilitates the transformation of a market opportunity and a set of assumptions about a product's technology into a product that is available for sale." Due to globalization, the participants in the fashion supply chain are geographically dispersed, which leads to a transformation of the fashion apparel market and generates new opportunities. Based on this concept, it is essential to translate the new globalized market trend into market opportunities by exploring how the strategic management of the global fashion supply chain can affect every single step of the TPDP and transform it into NPDP. Barnes et al. (2006) identify the influence of product design within the new seasonal PDP. Starting from customers, social-cultural trends, directional trends, trade fairs, legislation, palettes & ranges to advertising, a concept of seasonal new product development schedule is proposed, including planning, design, sampling, manufacturing, and retailing. Through scheduling the activities within the NPDP, all participants are being pulled together with a common goal to fulfill the market demand within the scheduled time frame.

To cope with the ever-changing demands and generate sales, Cooper (2009) suggests a flexible approach of NPDP. The author proposes a "Stage-Gate" concept. Within the NPDP, managers should act as a "Gate" in each step of the NPDP. They should review the NPDP and evaluate if it is on the right track. If anything goes wrong, the manager should revise or terminate the NPDP. Taking a step further, Carr and Pomeroy (1992) suggest that each foremost step has backward and forward relations, which allows

participants to reconsider the decision by relooking the previous steps. Meanwhile, each step can be undertaken at the same time without following a certain sequence, which makes the processes more flexible and efficient.

Taking this scheduling and flexible approach as an NPD strategy, Zara pushes the NPD lead time into a new limit. Barnes et al. (2006) studies the 3 main cycles of Zara's NPDP, namely: development cycle, fabric sourcing cycle, and manufacturing cycle. Within each cycle, the corresponding activities are listed and planned carefully with built-in flexibility. Each cycle of Zara's NPDP provides a certain level of flexibility, which allows its management team to postpone the decision to the later stage. For example, instead of dying the fabrics in the early stage, the management team can postpone the dying process and dye the finished garment in the manufacturing cycle. Besides, through the application of postponement strategies in different countries (low to high cost), high-cost countries can largely shorten the time need in all three cycles (from 28 weeks in total to 4.5 weeks in total) (Barnes et al., 2006). Reducing the lead time of PDP changes the whole fashion retail market, as it makes market demand forecasting more accurate. NPDP aims to capture fashion market opportunities by applying different management strategies and adopting global supply chain management by considering the issues such as import and export rules and regulations (Birtwistle et al.,2003; Bruce & Daly, 2006), currency exchanges (Chmura, 1987), testing standards (Muthu, 2014), as well as global transportation and logistics (Shen, Xu, & Guo, 2019). By utilizing different strategies like scheduling and postponement, TPDP can be facilitated and transformed into NPDP and adapts to the ever-changing fashion industry.

2.2.3 Sustainable product development process (SPDP)

Over the past decade, consumers are environmentally conscious, and they demand sustainable fashion products. This draws the fashion and apparel brands' attention for sustainable product development. Several critical concepts are discussed below.

i) Triple bottom line (TBL): The domination of human in the ecological system directly raises the sustainability concept (Caradonna, 2014). According to Johnston et al. (2007), over 300 definitions of sustainability can be found in the literature, where Geissdoerfer et al. (2017) indicates that the definition of the Brundtland Commission (Cassen, 1987) is mostly adopted. The Brundtland Commission defines that sustainability is the long-term wellbeing of the planet and human society. It is a concept of balancing the limited planet resources with the long-term development of human society (Cassen, 1987). It concerns how to protect the natural resources from being manipulated by the manufacturing and service organization upon productivity and competitiveness (Armstrong & LeHew, 2011; Shaker, 2015b). The goal of sustainability is to seek a way to achieve human-ecosystem equilibrium (homeostasis), and this goal can be facilitated by a holistic approach and temporal processes known as "sustainable development" (Shaker, 2015b). To attain the goal of sustainability, sustainable development is needed. It consists of balancing local and global efforts to meet basic human needs without destroying or degrading the natural environment (Robert et al., 2005). Based on the TBL model, sustainability can be divided into three areas: environment, social, and economic. In terms of economic, it refers to how business organizations' practices affect the economic system. According to Elkington (1998), the economic growth of organizations is highly related to the economic system which

provides support for future generations. Meanwhile, as the ultimate goal of sustainability is to balance the limited planet resources with the long-term development of human society. Thus, environmental, and social considerations cannot be neglected. Therefore, to achieve sustainable fashion, companies need to take severe considerations of these three main areas throughout the whole fashion PDP.

ii) Circular economy (CE): Moorhouse and Moorhouse (2017) present the product development process as a "take, make, and dispose system" or an open-ended system. Within the open-ended system, the natural resources are being taken, reproduced, and disposed after used, which will ultimately become wastage. As sustainability is defined as the long-term wellbeing of the planet and human society (Gallopín & Raskin, 2003), where the waste of resources will exploit the planet's long-term wellbeing and violate the sustainability concept. To bring the wastes back to the planet's eco-system, the resources are reused and recycled. This helps to establish a new closed-loop system: the circular economy. The concept of the closed-loop system is proposed by Stahel and Reday-Mulvey (1981) and Bounding (1966). Pearce and Turner (1990) suggest to include the recycling concept to the open-ended system. Through recycling, the open-ended system will be transformed into a closed-loop system.

Although Jay and Ottman (1998) conclude that SPDPs should not be significantly different from the TPDP and NPDP. However, Curwen et al. (2013) suggest that to achieve sustainable product development, modification of the linear TPDP is needed. To restore the fashion waste to the supply chain system, the SPDP needs to recycle the unused resources back to the supply chain for future circulation and regeneration. To achieve the closed-loop SPDP, each step of the TPDP needs to consider sustainability.

Focusing on sustainable product development planning, Driessen et al. (2013) propose an integrated framework which takes market orientation–innovation–performance perspective as a fundamental guide for the fashion brands to evaluate their competitive advantage in sustainability.

Based on the brand's competitive advantage (e.g., sustainable product design innovation, sustainable materials source varieties, sustainable manufacturing, and logistic partners, etc.), the brand can select business partners who are able to support the CE (e.g., ability to recycle materials and re-manufacturing) in the fashion supply chain. Meanwhile, Curwen et al. (2013) suggest that the interaction between the participants in the supply chain with the design team is essential to achieve the company's sustainable product development projects. It is because the design of the fashion product will affect the selection of sustainable material, costing, performance, and quality (Bhamra & Lofthouse, 2007). For example, the designers should select sustainable and reusable materials from those unsustainable and non-reusable materials. Nevertheless, manufacturing is one of the key component which affects the level of sustainability within the SPDP. Subic, Shabani, Hedayati, and Crossin (2012) develop a sustainable manufacturing framework that includes eight "clusters" capabilities and eighteen "applied outcomes" capabilities that are used to develop a Capability Assessment Tool (CAT) to scale the capability of the manufacturing during the SPDP.

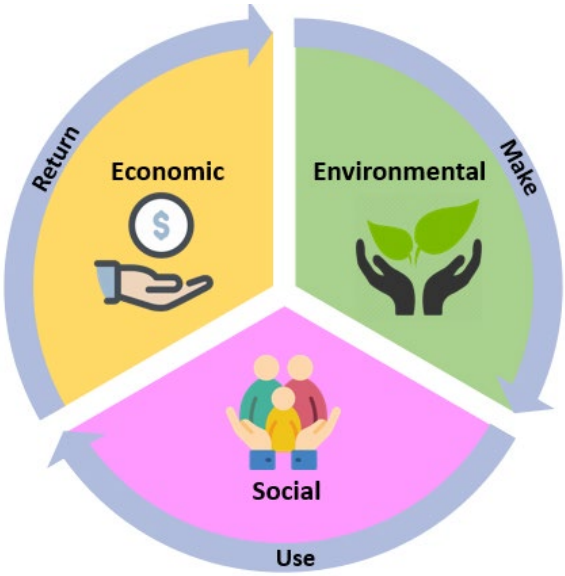


Figure 3. Critical features of sustainability

Based on the above findings, the evolutions of fashion product development process are identified. From Figure 4, before globalization, the TPDP is simpler and exhibits a linear form with one step followed by another, where the linkage between each pair of participants is minimal. Then, after globalization, as the fashion supply chain members are geographically dispersed, the PDP becomes more complicated. Compared with linear TPDP, the NPDP needs to pay high attention to the global supply chain management. Besides, to increase the flexibility, "back and forward checking for relations" and revisiting of previous steps are commonly seen. For the SPDP, one of the most critical evolutions is that, to achieve sustainable fashion, every single step of the SPDP needs to take the TBL model (economic, social, and environment) into consideration. Also, while adopting different sustainable strategies, participants within the SPDP (designers, manufactures, and fashion retail brands, etc.) need to cooperate and share the same sustainable goal. Nevertheless, the SPDP should be treated as a closed-loop circular economy.

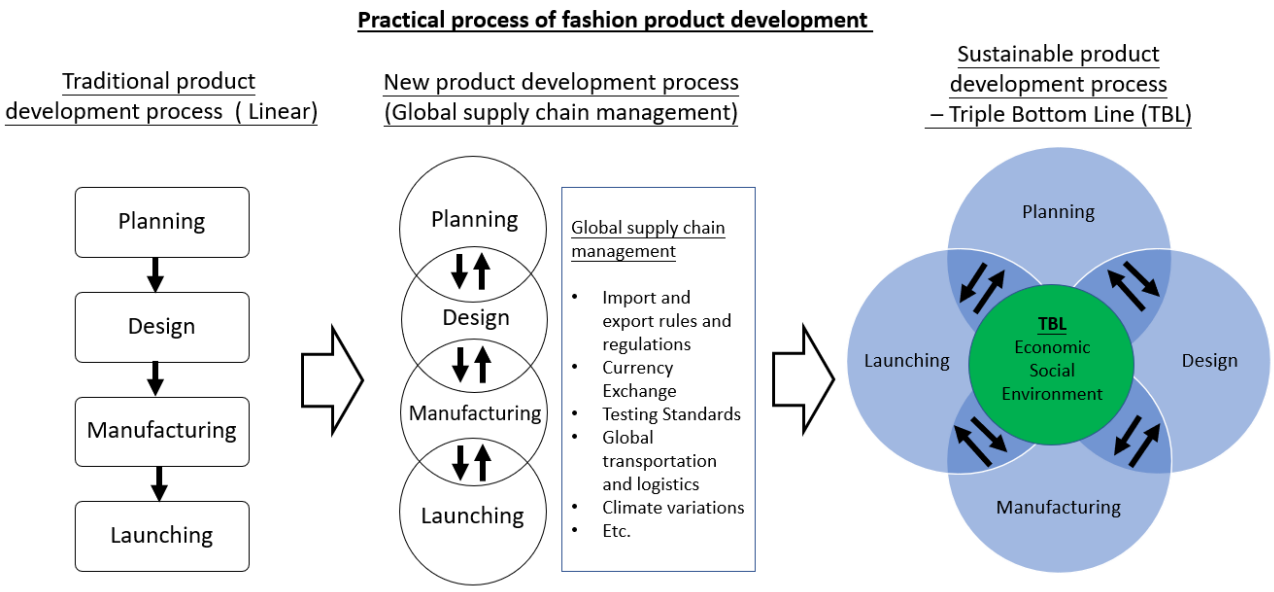


Figure 4. The evolution of sustainable fashion product development process

In Section 2.1, we present three different types of fashion supply chain structures. Through studying the evolution of the fashion product development process, we can further apply the product development processes in various supply chain structures as shown in Table 2. To be specific, the OBM companies (e.g., Haute Couture fashion houses) that adopt the vertically integrated structure (i.e., Structure A), mainly use TPDP. As all the processes are centralized and controlled by the fashion retail brand, the connections between different parties are rather one-way and direct. Meanwhile, the globalized fashion retail brands and multi-products retail brands who adopt Structure B and Structure C, respectively, to mainly support new product development. It is because both Structures B and C are decentralized on some levels. Structure B outsources the manufacturing process while Structure C outsources both design and manufacturing processes. The decentralization of processes implies the need of communication and flexibility, where the new product development process is characterized by its "flexible nature". NPDP allows the revisiting of previous steps with back and forward checking. Also, to enhance efficiency, each step can be undertaken at the same time.

As the growing awareness in sustainable fashion draws the fashion retail brands' attention upon developing sustainable business fashion, companies with different natures or structures should also adopt the SPDP approach. It is because one of the key characteristics of the SPDP is that it considers the TBL model in every single step of the product development process. Rather than being an open-end "take, make and dispose system", it is in fact a closed-loop circular system. Companies with different structures (structures A, B and C) should consider how to contribute to social and environmental sustainability and balance with economic growth throughout the whole fashion supply chain management. The upstream and downstream members should reuse and recycle the resources and bring the "waste resources" back to the supply chain systems.

Table 2.The application of PDPs in different fashion supply chain structures

Supply chain structures	Structure A Vertically integrated	Structure B Production outsourcing	Structure C Decentralized
Traditional product development process	√		
New product development process		√	√
Sustainable product development process	√	√	√

2.3 The core elements of sustainable development process

In this sub-section, we consider the applications of the product development process in different fashion supply chain structures (Structures A, B and C) and discuss how to achieve sustainable fashion by considering TBL model throughout the SPDP. In addition, we also explore the key elements in each step of the PDP for a sustainable commitment. The core elements of the sustainable development process are (1) planning, (2) design, (3) manufacturing, and (4) launching (Figure 5).

Figure 5. Core elements of sustainable development process

2.3.1 Planning

In the planning stage, participants in the whole PDP (fashion retail brands, manufacturers, designers, etc.) need to work together and plan for the product development strategies, management functions, and corresponding actions. Planning is an especially important step of the PDP. Within this scope, three prior studies (Brun & Castelli, 2008; Laura et al., 2015; Moore & Fernie, 1998) investigate the strategies used in product development planning. With some cases, explore the supply chain (Brun & Castelli, 2008), growth (Moore & Fernie, 1998), production, and supply network strategies (Laura Macchion et al., 2015). There are also studies which related to the supply chain management planning (Barnes et al., 2006; De Brito, Carbone, & Blanquart, 2008; Köksal, Strähle, Müller, & Freise, 2017; Martínez, Errasti, & Rudberg, 2015; Shen, 2014; Shen, Li, Dong, & Perry, 2017), modeling dispersed product development activities (To et al., 2009), consultancies and information flows (Heusinkveld et al., 2009), risks and iterations (Unger & Eppinger, 2011) within the PDP.

Within the whole PDP, there is a high intercorrelation between the steps, and the action

of a participant may cause a serious impact to the whole PDP. For example, if a shortage of raw materials arises, it will affect fabric manufacturing, garment making, and finally retailing schedule. As a result, “detail-minded planning of business networks and collaboration” at the beginning is especially important. Thus, studies like business networks and retail internationalization (Unger & Eppinger, 2011), collaborative business network (Shamsuzzoha et al.,2016) supply chain collaboration and innovation (Macchion et al., 2017), internationalization, outsourcing operations, and product development (Caniato et al.,2015) are relevant and being explored. Moreover, forecasting (Hagdorn et al.,1994), data sharing (Kuo et al.,2014), measurement (Gloria et al., 2014), and process control (Pearson et al.,2010) are essentially important to achieve successful PDP planning.

To achieve sustainable fashion, operations managers of the fashion companies need to identify all possible challenges within the SPDP in the planning stage (Boström & Micheletti, 2016). Among the PDP planning related studies, more than 50% are related to sustainability. We then further categorize the journal papers based on the TBL model-based sustainability (economic, environmental, and social). It is found that that most of the studies are related to business development strategies. To conduct a holistic study, researchers try to introduce a concept of life cycle sustainability assessment (Hannouf & Assefa, 2017) with the applications of the supply chain operations management theories (De Brito et al., 2008; Karaosman et al., 2017; Shen, 2014; Shen et al., 2017). Existing studies show how a green collaborative supply chain (Kuo et al., 2014) can facilitate innovative sustainable performance (Macchion et al., 2017). Then, companies can move on to develop business strategies that best-fit the company. Stål and Corvellec (2018) investigate the sustainable circular business model by applying the decoupling concepts

and provide insights about the development and implementations of sustainable business strategies. Maria et al. (2011) study how the innovative company evaluates the impact of the eco-design strategies when integrating the strategic plans and applications in the supply chain in an innovative manner.

Nevertheless, Fornasiero et al. (2017) attempt to investigate how to implement a customization strategy with respect to sustainable supply chain management and lifecycle assessment. During the business planning for strategic sustainable product development, fashion companies cannot ignore the market information and its implications of business opportunities. Fornasiero et al. (2017) analyze the environmental impacts on clothing consumption. The authors examine whether it is worth the investment for companies to produce sustainable products when shaping their business strategies. Similarly, Moon et al (2015) also conduct a survey upon consumers' attitudes towards sustainable products and how companies can break the barriers between supply and demand upon sustainable fashion to support sustainable business.

Taking the environmental aspect as an individual consideration in planning, Moon et al. (2013) develop guidelines for sustainable energy-saving fashion products during design and production. In this way, companies can refer to the guidelines in the planning stage. While Gloria et al. (2014) focus on the selection of sustainable material. Last but not least, Karaosman et al. (2017) emphasize the social aspect of the TBL model. They explore the human factors and the corresponding social benefit derived from sustainable production projects. This acts as a useful reference for sustainable product planning. To explore an in-depth discussion on the social aspect of sustainability, Köksal et al. (2017) study the related literature and conclude that companies are mainly internal-oriented on

social sustainability. Thus, in the planning stage, fashion companies can consider supplier collaboration as a social assessment in the later stage.

2.4.2 Design

Product design is a very paramount step in fashion product development processes. It affects the use of materials, methods of manufacturing, marketing, product launching, and even the whole fashion supply chain. Among all the selected literature, more than 15% are product design related. During the planning stage, the management of companies shall figure out a strategic business plan for sustainable products to achieve a successful business. After finalizing the business plan, the management team needs to review how sustainable design can generate economic benefits. Niinimäki and Hassi (2011) find that current company sustainable strategies mainly focus on volume. By using a large volume of selected sustainable materials, companies can enjoy the economy of scale and produce a large number of sustainable products at a lower cost. With a lower cost, fashion companies can sell products at a lower price, which can facilitate the sales volume. Meanwhile, understanding the interests of the customers and designers can create alternative eco-designs which provide new sustainable business values. Moreover, through eco-labeling (Gunilla Clancy, Fröling, & Peters, 2015), it is easier for consumers to understand the design background, especially whether it is related to sustainability.

During the product design process, designers need to determine the sustainable product details (e.g., the selection of materials). They may also need to follow the international guidelines (e.g., ISO 14001 standards) and choose the materials which are certified as

sustainable (Ljungberg, 2007), such as nanomaterials (Hutchison, 2016). To facilitate the selection of the materials so that the requirements are met, designers can select technologies that can enhance their material selection processes. For example, the RFID sample management system (Choy et al., 2009), optimization for prediction of fabric specimens (Lau et al.,2006) and fuzzy association rule mining systems (Lee et al.,2015) can all help.

All the above technologies can assist designers to select suitable materials for their design. Apart from the material selection task, designers are responsible for the product innovation (Bagchi-Sen, 2001) and product design. They can design products with sustainable features. For example, Kasarda et al. (2007) explore a new sustainable design concept to extend product lives. The study shows that through sustainable design, apparel products can adapt to changes to fulfil the market demands and extend the product life. Moreover, through the application of computer-aided-design technology, designers can make the design process more sustainable. By using "3D to 2D textiles pattern design" (Lu et al.,2017), 3D modeling, and CAD/CAM (Lu et al., 2017), the need for actual trial samples can be minimized. All these can make the apparel design process more sustainable efficiently.

2.4.3 Manufacturing

Manufacturing is the process that turns a design concept into an actual product. To execute the plans in the planning stage, secure collaboration and coordination among the designers, suppliers, manufacturers, and fashion retail brands, are required. To cope with the ever-changing requirements, manufacturers need to flexibly build a good relationship

with the suppliers (Shih et al.,2014). They should select suppliers carefully for apparel production. Previous studies show that experienced suppliers who are equipped with innovation capabilities and good communication can facilitate manufacturers' business (Delbufalo, 2017). Based on the initial planning in the first stage, production planning and scheduling are essential (Zangiacomi et al.,2004). The manufacturing processes vary between products, which relate to the use of different equipment and facilities. As the market competition is keen, manufacturers keep up with the new technologies and upgrade their production processes. These help to enhance their competitive advantages (Shih et al., 2014). For example, the following technological advances are seen nowadays: (i) using the 3D virtual garment prototyping scheme (Tao & Bruniaux, 2013) to facilitate product design, (ii) applying new plasma technology to control the color fading (Kan et al.,2017), and (iii) integrating polymeric optical fiber (POF) textiles with electronic components to refine the design aesthetics.

Influenced by fast fashion, the fashionable product life cycle becomes shorter, which implies a high disposal rate. Contradictorily, there is an increasing demand from the society and market for sustainable commitment. People have a common belief that there are conflicts between fashion manufacturing and sustainability. To achieve sustainable fashion, manufacturers' participation is crucial. By improving the manufacturing facilities or infrastructure (i.e., water recycling systems), sustainable production can be achieved. However, an extra cost will be incurred, which may drive the manufacturers away from participating in sustainable manufacturing. From the economic point of view, how this can reduce the cost and make sustainable production more cost-effective becomes critical. Alkaya and Demirer (2014) uncover that the widely used sustainable measurements among the textile industry can improve the sustainability level without

devoting a huge investment to new technology or infrastructure. Alkaya and Demirer (2014) show that it not only benefits the economy but also improves the environmental influence of manufacturing. Pinpointing the same issue, Subic et al. (2012) study the sportswear manufacturing industry. The global sporting manufactures with similar capabilities can collaborate with each other and reduce environmental impact. The tier-one suppliers can be the leader and collaborate with tier-two suppliers- to fill the gap of sustainability in the supply chain management which is different from the traditional forward supply chain management.

From the environmental point of view, how we can make the manufacturing of fashion apparel more sustainable becomes crucial. To attain this goal, sustainable manufacturing measurements are needed. Based on the TBL model, a set of sustainable performance indicators could be used to evaluate the green performance of manufacturers (Pineda & Culaba, 2004). Taking a step further, Guo et al. (2017) suggest a set of criteria for manufacturers to assess their suppliers' environmental performances. Manufacturers can benefit from matching the best suppliers and eliminate those who are not up-to-standard. To conduct a holistic study, product life cycle assessment is used to evaluate the impacts of the production processes and alternatives are suggested to reduce the environmental problems in the production process (Parisi et al., 2015).

Due to the demand for a low price as well as being fast and trendy in most markets (especially the western European market), the need for low-cost labors from Russia, India, Brazil, and China (BRIC) is surging. It induces Mair, et al. (2016) to study the sustainable implications upon the social impact in the BRIC. Meanwhile, Kjaerheim (2005) investigates whether clean production can derive a positive impact on the human

factors among developing countries.

2.4.4 Launching

Product launching is the last step of the PDP. It includes all actions which bring the actual product from manufacturing to consumers. The key participants in this step are the fashion retail brands. According to Caniato et al. (2014), among the NPDP related studies, the core focus is on the coordination with the upstream suppliers. The authors indicate that there are only a few prior studies that focus on the downstream fashion retail brands. As a front-line member, fashion retail brands have the highest chance to communicate with customers. They propose that NPDP can be integrated with fashion retail brands. Furthermore, Wigley (2011) examines the nature of diversification and illustrates the competitive advantages by studying the successful UK fashion retail brands. The author discusses different aspects of retail diversifications such as "brand diversification and service diversification, format diversification, foreign market diversification, and business support diversification".

All the above retail activities/diversification strategies will affect how the products are delivered to the customers, which ultimately affect the related business operations. Apart from the retail strategy, fashion product inventory is sensitive to time, and it will become dead stock once the product is out of date. To select the best product launching time, Chiu et al., (2017) use the real options approach to study the discount price and the optimal launch time for a fashion product. As mentioned above, fashion retail brands are the key participant in the product launching stage. Considering one step further, it is essential to address the key roles and responsibility of the fashion retail brands on the

human resources within the retailing system. In a conventional retailing system, buyers of the fashion retail brands play the key roles in product selection. However, Goworek (2014) conducts a study towards the buying roles and responsibilities in UK own-label clothing market. The study shows that, instead of retail buyers, that merchandisers take the main buying role in the UK own-label clothing retail brands.

From the economic perspective, fashion retail brands should have a good understanding of the consumers' value and attitudes towards sustainable fashion products and look for new retail opportunities. As discussed above, retailer is the key participant in product launching. Yang et al. (2017) conducted a systematic review in sustainable retailing to explore the current focus in sustainable retailing. They discover that sustainable retailing literature mainly focuses on "green branding and eco-labeling, disposable fashion, fast vs. slow fashion, secondhand clothing, reverse logistics in fashion retailing, and emerging retailing opportunities in e-commerce". Targeting the sustainable market opportunity, fashion retail brands can utilize the corresponding-customized promotion strategies (Na & Na, 2015) and establish the product service system (Armstrong et al.,2015). Furthermore, companies can reflect/report (Garcia et al.,2017) their sustainable contribution using actual data during product launching to the public. This can draw consumers' attention, generate sales, and reflect findings to the upstream members. This can ultimately improve fashion products in the upcoming NPDP.

From the environmental perspective, product launching strategies like slow fashion (Jung & Jin, 2016; Na & Na, 2015) would help enable the consumers to extend the life spend of the fashion apparel products. This can slow down the disposal rate and reduce the environmental burden. From the social perspective, fashion retail brands can educate

their targeted customers on the sustainable concept behind their products versus product labeling during product launching (Žurga & Forte, 2014). Furthermore, fashion brands can educate the consumers upon sustainable consumption during product launching. Studies conducted by Cox et al. (2013) that consumers tend to have a rapid up-dating and disposal habit due to the low cost of new fashion products. To cope with this consumption habit, Freitas et al. (2004) recommend a set of policies called "polluters pay", emphasizing "cooperating and protecting" the rain forest eco-system via changing the lifestyle of the indigenous people in Amazonas.

2.5 Summary

Sustainable fashion draws massive attention from the public. Related studies have been published over the last two decades. To achieve sustainable fashion, sustainable fashion product development process is one of the key areas that all fashion apparel supply chains should be aware of. In this chapter, we have first identified the supply chain structures of the fashion industry. Then, by reviewing the literatures on the product development process, the essential steps in fashion PDPs are determined. We have further classified the PDPs into three types, namely the traditional product development process (TPDP), new product development process (NPDP), and sustainable product development process (SPDP). We further explored the key factors of achieving sustainable fashion based on the TBL model regarding the PDP.

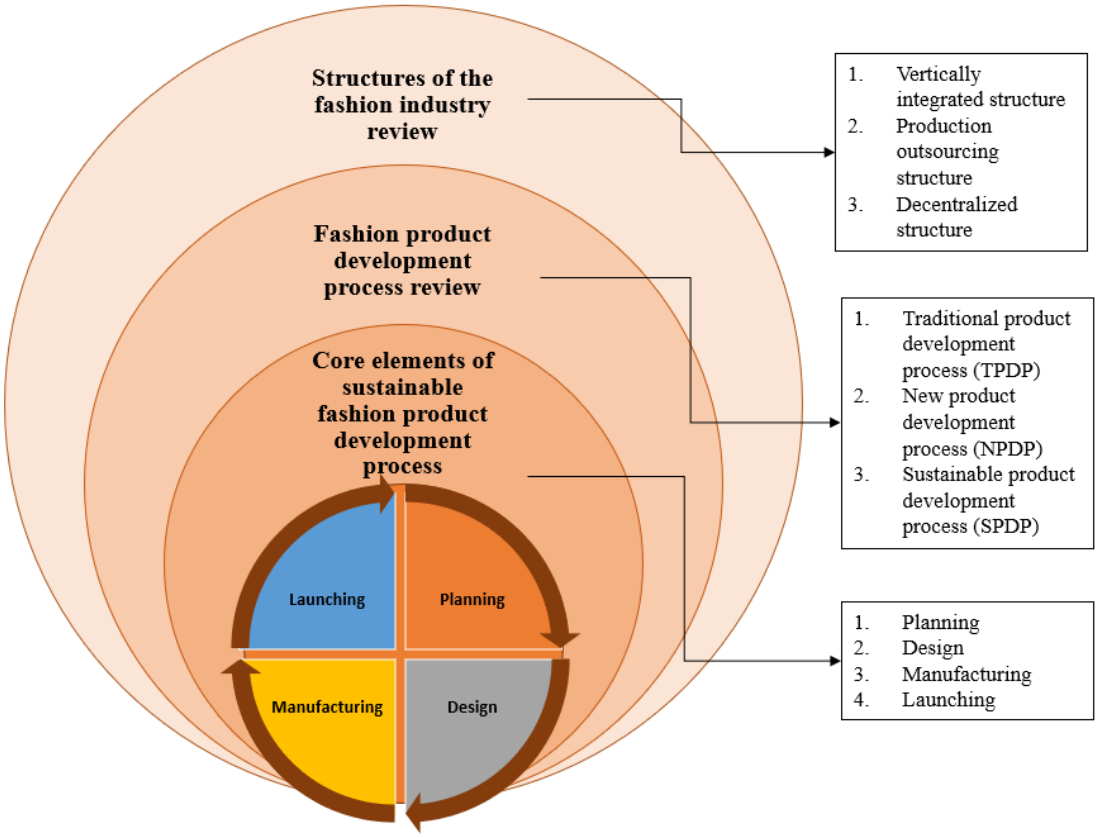


Figure 6. Structure of the reviewed literature in Chapter 2

CHAPTER 3

Development of Strategic Business Framework for Sustainable Fashion

3.1 Introduction

Because of globalization, the core stakeholders in the fashion supply chain are usually geographically dispersed. As a result, how the stakeholders can co-coordinate together to achieve sustainable supply chain becomes critical. To optimize the efficiency of green supply chains, we need to study the supply chain sustainability level and forecast the efficiency of the stakeholders (Dubey et al., 2017; Shabanpour et al.,2017; Zhao et al., 2017). As a virtual organization, the company in the supply chain should connect the stakeholders in the supply chain and improve their competitive advantage via strategic governance. To manage the sustainable fashion supply chain, the company cannot only focus on the company's internal process, but its entire network (Garetti & Taisch, 2012). Any change in the company's sustainable business development strategy requires a substantial effort by its supply chain partners (Macchion et al., 2018).

To make the fashion supply chain sustainable, we first need to understand the fashion supply chain operations and the corresponding stakeholders' activities. Then, the company can develop sustainable strategies and optimal action plans correspondingly. The supply chain of the fashion industry is very complicated which involves the participation of different parties and various interlinking processes. Traditionally, at the beginning of each season, the management team of the company needs to plan

the business strategies and product assortments. Then, based on the company's business strategy, designers' teams need to do research for the upcoming fashion trend about colors, materials, silhouette which would best fit the brand image and target customers' tastes. Then designers design the collection, merchandisers source the desired materials, and factories produce the prototypes. Once the prototypes are finished, the worldwide buyers hold meetings and place orders for bulk production. The production of fashion apparel involves a huge number of workers in the processes of sewing, assembly, finishing, and packaging, etc. Nevertheless, due to the globalization and technology advancement, fashion apparel merchandises will be sold and shipped to global consumers' who are geographically dispersed. A huge amount of distribution and logistics resources (e.g., shipment arrangement, set up of warehouse, international and local delivery) are needed to facilitate the supply chain system and satisfy the global consumers' demands in fashion and apparel products.

As discussed above, the core stakeholders in the fashion supply chain are determined, including retailers, designers, manufactures, distributors, and consumers. To make the fashion supply chain sustainable, inter-cooperation between channel members is crucial. Researchers attempted to investigate how channel members can work together and facilitate fashion supply chain coordination. For example, de Sousa et al. (2015) investigated how the development of a green team within the leading company can facilitate the sustainable supply chain management. Due to internationalization and the advance of information technology, market information is highly visible to fashion consumers. To gain a higher market share, the channel members need to react promptly to the market demand. According to Ailawadi (2001), as the retailers interact directly

with consumers, they can obtain the latest market information which enhances the power of the retailer. Supported by the competitive advantage of the retailers in the fashion industry, Xiao et al. (2007) investigated the effectiveness of retailer-led supply chain via option contract coordination. While Choi et al. (2013) further examined the effectiveness of retailers led fashion supply chain via a systematic comparison. It is studied that the most effective closed-loop fashion supply chain is led by the retailer. To achieve closed-loop circular fashion supply chain, retailers are the key to collect the unwanted fashion apparel products from consumers. Then, the retailer can bring the wasted materials back to the fashion cycle by reuse and re-manufacturing. In this chapter, we set the retailer (the fashion brand) as the focal participant and leader in the fashion product development process for later study and framework development. After identifying the leader and core stakeholders in the sustainable supply chain, the retailer can develop the business strategies for design, manufacturing, and product distribution to consumers.

3.2 Research methodology

Many existing studies investigate sustainable fashion and sustainable supply chain management. However, to the best of our knowledge, there are no prior studies in the literature which identify the external and internal motivations for fashion companies to develop the sustainable business development strategy (SBDS), and how SBDS of fashion companies improve the performance of the stakeholders throughout the whole sustainable fashion supply chain (SFSC). This chapter hence aims to fill this gap and examines how fashion companies can develop successful SBDS to govern the sustainable performance of the stakeholders throughout the sustainable fashion supply chain. A novel theoretical framework, namely sustainable business development strategy

(SBDS) framework, is established for a sustainable fashion supply chain in which the external and internal influencing factors, resources allocation, and decision-making mechanisms of the SBDS are analyzed.

For the specific research approach, this chapter adopts the Noor (2008)'s model for the case study. The model involves three stages, namely the preliminary stage, analysis stage, and conclusion stage. In the preliminary stage, along with theoretical foundation, we first conduct a literature review on sustainability frameworks, sustainable development, and sustainable fashion supply chain management. The sustainable business development strategy (SBDS) framework is then presented.

3.3 Measurements for sustainability

Although the TBL model demonstrate the three dimensions of sustainability, how to make the sustainability measurable for practical operations and decision-making remains to be studied. Researchers have attempted to propose different measurement guide for participants in the supply chain upon decision-making. For example, De Brito et al. (2008), Jørgensen and Jensen (2012) and Shen et al. (2017) investigate the sustainability issues in textiles and apparel supply chains. Gunilla et al. (2015) interview with Sweden garment companies' employees and explore if eco-labeling can help to achieve sustainable fashion supply chain. Köksal et al. (2017) study the supply chain management measures with respect to social sustainability in textile and apparel industries. Meanwhile, an online questionnaire survey is conducted by Žurga and Forte (2014) to examine consumers' knowledge upon eco-labeling. These studies discovered that there lack clear guidelines on how fashion companies develop a sustainable business development strategy which can improve the stakeholder's performance and the

effectiveness of the whole fashion supply chain. As a remark, most prior studies have found that designers and manufactures need a clear vision upon the level of sustainability, while the consumers do not trust the concept of sustainable fashion due to its low-level of visibility. As a consequence, to develop a common vision and transparent guideline for the company and its supply chain members, we have to incorporate consumers into the sustainable fashion supply chain analysis.

In the late 1960s, researchers developed a tool which is now called “Life Cycle Assessment” (LCA) to measure the environmental impacts of manufacturing and production (Chang et al.,2014). According to the International Standards Organization (Hauschild et al.,2005), LCA was divided into four phases, which are: (1) the goal and scope definition; (2) life cycle impact assessment (LCIA); (3) life cycle inventory (LCI), and (4) interpretation. At first, LCA mainly focused on investigating the environmental impacts on manufacturing. In later studies, LCA was extended to cover product design. Furthermore, researchers who study the corporate social responsibility (CSR) reports uncovering how companies disclose its sustainable commitments to the public with law and legislation foundation (Chan et al.,2020). Through the CSR reporting system, companies need to plan carefully in the early stage of strategic planning. It is because that the plans and corresponding movements are governed by the related laws and regulations upon cooperate reporting. Any mismatching between the CSR report and the commitment will affect the corporate image and business performance. Although the LCA and CSR provide measurable guides for sustainable practices, the effects of three pillars of the TBL model on the operations of the whole supply chain remain not be fully considered in the sustainable business development strategies.

According to St Range (2008), the three pillars of sustainability (economic, social and environment) are interrelated intimately and cannot be considered separately. While Folke et al. (2002) and Cobbinah et al. (2011) further enhance the concept of sustainable development. By which, all three pillars are included in the model. This provides a pathway to achieve a symbolic relation between the three pillars. In recent years, more and more countries are dedicated to sustainable development. They aim to build a positive relation between the national civilization and the planet resources (Shaker 2015a). By balancing the sustainable development between local and global, we can meet the basic human needs without degrading or destroying the natural environment (Robert et al.,2005). Based on the above national calls, the United Nations Developments Programme (UNDP) suggested the "Sustainable Development Goals" (SDGs) in 2012. The SDGs are a universal call upon planet protection, which aim at improving the social, economic and environment conditions especially in the least developed countries with measurable guides and suggested actions (Dhahri & Omri, 2018). The SDGs provide universal understandable and measurable guidance which covers all three pillars of TBL model. Decision makers in the supply chain can refer to the SDGs during the SPDP. Thus, the SDGs as a measurement guide is applied to analyze the successfulness of the sustainable business development strategies in Section 4.

3.4 Theories supported sustainable fashion business

As the fashion apparel supply chain involves a huge amount of human and natural resources, companies need to have careful planning upon the sustainable business development strategy and the corresponding movement. Through studying the strategies supported theories, we find that the features of the sustainable fashion industry are well

supported by three core theories namely: intuitional theory, resources-based theory, and decision-making theory. To make the illustration to be specific, in Table 3 we highlight the relevance of these theories towards sustainable fashion supply chain management.

Table 3. Strategic theories supporting sustainable fashion supply chain management

Theory	Description of Theory	Relevance to Sustainable Fashion Supply Chain Management	References
Institutional theory	Companies' business model and practices will be affected by external pressure.	• React to the global demand for sustainable fashion business. • Re-design of business model • Achieve sustainable fashion supply chain.	Hirsch (1975); Hirsch (1975); Song et al. (2017); Wr (2008)
Resources-based theory	Gain competitive advantages by: • Reinforcing the use of precious resources • responding properly to environmental opportunities.	• Fashion companies can reinforce the use of company resources. • Gain competitive advantage • Exploits companies' internal strengths and improve their weaknesses.	Barney (1991); Gardetti and Torres (2017); Sekiguchi (2013); Song, Wang, and Zeng (2018); Song et al. (2018)
Decision making theory	*Normative decision theory:* • Provides suggestions on how to make optimal decisions under uncertainty *Descriptive decision theory:* • Evaluate the real market data • Decision makers make optimal decisions which generate the highest value	• Fashion companies can make optimal decisions on sustainable development. • Gathering the market information on the sustainable demand in fashion. • Fashion companies can react to market demand and make optimal decisions.	Black et al 2017; Peterson (2017); Simon (1957); S.-Y. Lee, Klassen, Furlan, and Vinelli (2014)

3.4.1 Institutional theory

The seriousness of fashion related pollution brings up the global awareness of the fashion sustainability. Any failure in achieving sustainable fashion will hurt the company image and its business. This global norm is supported by the institutional theory, by which the companies' business model and practices are be affected by the external pressure (Hirsch, 1975). According to Shmidt and Khudyakova (2015), the uncertainty implied by the external environment can affect the industrial enterprises' level of sustainability. For example, the local highway transportation system could affect energy consumption and environmental efficiency (Song et al., 2017), while the external environmental

restrictions could affect the water resources utilization efficiency of the sustainable fashion supply chain (Song et al., 2018). Apart from the sustainable economic environment, the interaction between the sustainable fashion industry and the society is crucial for the company's strategic planning upon sustainability. If the sociality is closely engaged to the sustainable fashion, the retailer needs to fulfill the social expectations on the sustainable fashion industry.

According to Wr (2008), the institutional theory classified the external pressures into three different areas, which are: (1) social-knowledge and perceptions which are commonly shared; (2) political-laws and regulations which restrict some behavior and promote the others; (3) economic - resistance/acceptance of shift of common value. By using the institutional theory, Kostova (1997) extended the model to a country level, that is, applied the three pillars of social knowledge (cognitive dimension), governmental policies (regulative dimension) and value systems (normative dimension). Following this stream of literature, we can apply the institutional theory to examine global sustainability with respect to the TBL model (Figure 7). The cognitive dimension focuses on the external pressure upon the social impact of sustainability, while the normative dimension demonstrates pressures on the economic value of sustainability. Finally, the regulative dimension shows the key pressure upon the government legislation on sustainability

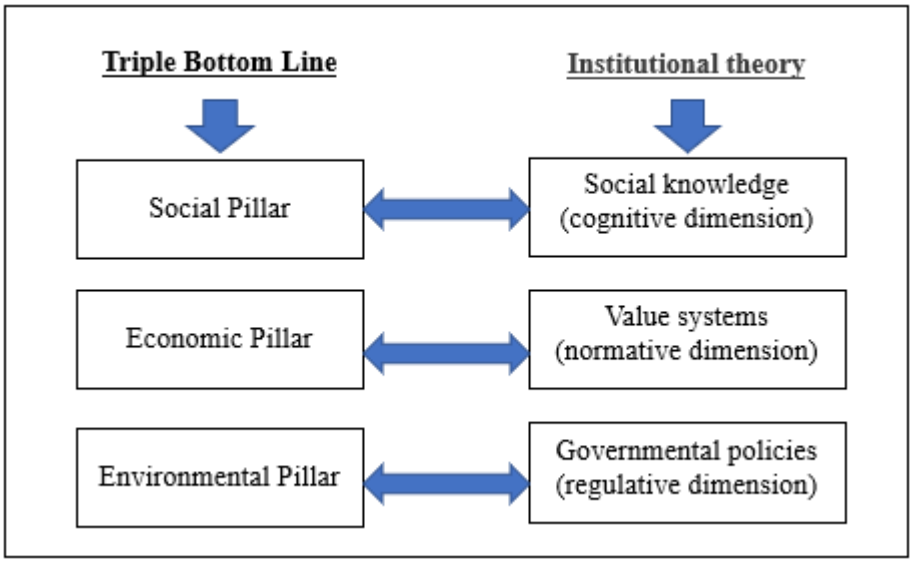


Figure 7. Interrelationships between TBL model and the institutional theory

3.4.2 Resources-based theory

Due to globalization in business operations, fashion apparel companies are facing worldwide competitions nowadays. Competitors are not limited to local organizations but include the ones from the global market. To stand out from the massive competition, companies need to enhance their competitive advantages. According to the resource-based theory, companies can gain competitive advantages by reinforcing the use of precious resources and responding properly to the environmental opportunities (Barney, 1991). A few studies examine the performance of the fashion industry based on the resource-based theory. For example, Gardetti and Torres (2017) explore the social and environmental performance in luxury fashion industry, while Sekiguchi (2013) study the implications of resources-based theory on strategic human resource management in the fashion industry. Expanding the resource-based theory to the sustainable fashion industry, fashion companies can implement sustainable strategies to exploit their internal and external strengths in sustainable development. According to Capon, Farley, and Hoenig

(1990), the key outcome variables of the resources-based theory focus on the performance derived by the effectiveness of resource allocation. Thus, together with the SDGs, companies can develop sustainable strategies by assigning resources and competitive advantages that they have to achieve the desired performance outcomes of SDGs.

3.4.3 Decision-making theory

The decision-making theory can be divided into two parts, namely the normative decision theory and the descriptive decision theory (Peterson, 2017). The normative decision theory indicates how to make optimal decisions under uncertainty (Wang et al.,2017) while the descriptive decision theory concerns how people make decision in the real life. The ever-changing fashion industry is full of risk and uncertainty, any changes in the demands will affect the whole supply chain, especially when it comes to the demands in sustainable fashion. Lee et al. (2014) studied that the consumer demand on sustainable fashion changes in time, when the information transfer along the fashion supply chain, it is distorted in various degree called the “green bullwhip effect”. So how decision makers along the supply chain make the optimal decision in resources allocation becomes critical. Supported by the normative decision theory, companies can evaluate the alternative and select the best decision by comparing the comparative advantages. Furthermore, based on the descriptive decision theory, the decision makers can make optimal decisions by evaluating the real market data to maximize market values (Simon, 1957). Thus, by gathering the market information upon the sustainable demands in fashion, decision makers throughout the fashion supply chain are able to react to the market demand and make the optimal decision.

Based on the institutional theory and resources-based theory (Sections 3.4.1 and 3.4.2), the fashion retail company needs to identify the external demand on fashion sustainability and analyzes the company's internal strengths and weaknesses for resources' allocation. Then, based on the decision-making theory, the retailer can make optimal decisions for strategic planning and generate the highest business values by evaluating the gathered external market information and internal data.

3.5 Framework development of sustainable fashion business

As the fashion industry is well known in generating a huge amount of wastes, the growth in the fashion industry brings the public awareness of fashion sustainability. So how companies can achieve sustainable supply chain management becomes critical. As mentioned in Section 2.2, to manage the sustainable fashion supply chain and implement the sustainable business development strategy, the engagement of related channel members and their counting method is required (Laura et al., 2018). Shen et al. (2017) reported that fashion companies like H&M and North-Face incorporated the business strategies of sustainable investment and management system with the co-related supply chain members. After the implementation of the sustainable strategy, the performance evaluation needed to be evaluated in the final stage for future improvement of the outcomes of the strategy.

Meanwhile, based on the above findings in Section 3.4, we develop the "sustainable business development strategy framework" (Figure 8) which demonstrates how companies can facilitate the sustainable performance of its related stakeholders and achieve sustainable fashion supply chain. The sustainable business development strategy framework is divided into 3 stages, which are: (1) information gathering and analysis;

(2) strategy development and implementation; and (3) performance evaluation.

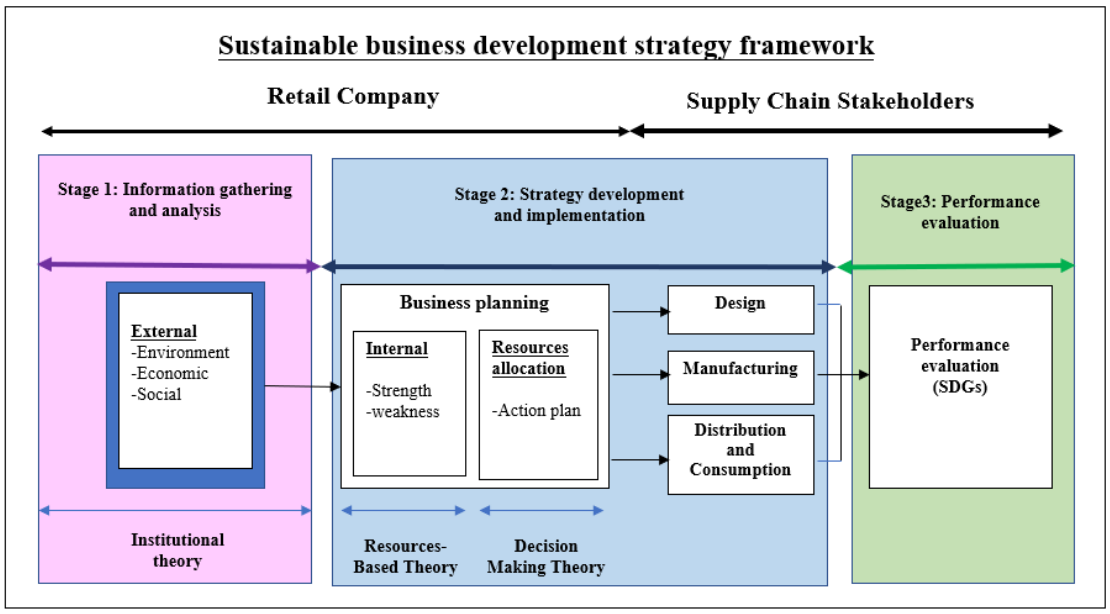


Figure 7. The developed framework of sustainable business development strategy

**Recycle and reuse should be considered in all functions in stage 2, namely "Sustainable business development strategy", "Design", "Manufacturing" and "Distribution and Consumption"

3.5.1 Stage 1: Information gathering and analysis

With the application of the institutional theory (Section 3.4.1), fashion company needs to identify the external demands of fashion sustainability. Combining the findings in Section 2.1, we can identify the 3 core areas of TBL model as the external pressures of sustainable fashion which motivates the fashion retailers to amend its business model to achieve sustainable fashion supply chain. Thus, in Stage 1, the retailer needs to gather external information on the market's demands for sustainable fashion. The information is divided into three areas, namely economic, environmental, and social. According to Song et al. (2017), investigation on social, and environmental sustainability can be facilitated by big data evaluation. Through evaluating the gathered external market information and data, the retailer can make optimal decisions in the later stages.

3.5.2 Stage 2: Strategy development and implementation

After gathering and analyzing the external information, the retailer can move on to Stage 2. Through evaluating fashion retailer's internal strength and weakness for resources allocation, the performance of the retailer and its related supply chain stakeholders can be improved and ultimately achieve optimal sustainable fashion supply chain.

i) ***Analyzing strengths and weaknesses of the retailers:*** Based on the resource-based theory, through analysing company's strengths and weaknesses, companies can allocate resources effectively to the sustainable fashion supply chain. Besides, according to Peterson (2016), through careful resources allocation and integration, companies can develop sustainable strategies which educate channel members and encourage cooperative processes via strategic governance. Thus, in order to react to the market demand upon sustainable fashion, the retailer needs to evaluate internal strengths and weaknesses of company? From the economic point of view, the retailer needs to consider the financial resources of the company itself and its stakeholder because extra financial resources are needed to implement sustainable strategy. For example, for social sustainability strategies, the retailer needs to invest in employment rights protection, public responsibility enhancement and CSR reporting. Meanwhile, in terms of environmental sustainability strategy, the retail needs to invest in green technology and green performance evaluation, etc. Also, it is important for the retailer to estimate the return and the return period on the sustainable investment. Thus, a constant evaluation towards the social sustainability strategies performance and environmental sustainability strategies performance is needed.

Any failure sustainable social performance will harm the business. For example, a recent report from Bloomberg (2017) shows that the growth in total revenue of Zara goes down. This drop-in sale is resulted from the fact that Zara fails to address the complaints in achieving sustainable social responsibility. The using of sweatshop for production and the waste derived by Zara's fast fashion business model draws the market attention which drives the consumers away from consumption.

Through evaluating the retailer's strengths and weaknesses on environmental, economic, and social performance, the retailer can develop different strategies with its stakeholders and react to the market demand (Mike 2011). As mentioned in Section 2.2, we identify the key channel members in the sustainable fashion supply chain (SFSC) which are the design, manufacturing, distribution, and consumption stakeholders. Thus, in this thesis, the sustainable business development strategy of the company will focus on these 3 areas:

i) ***Design strategy:*** The design theory has been widely used in the discussion of product design and design process. According to the definition on the design theory (Walls et al., 1992), the design theory consists of two parts, namely, "design product" and "design process". Simon (1996) suggested that the essential components of design are how organizations shape the design and the corresponding design process. Gregor and Jones (2007) further elaborated the design theory. They focused on the design functions and corresponding action plan throughout the design process. For example, the technological consideration upon the design and its implementation. With the support of design theory, we found that, to produce sustainable products, the retailer needs to work closely with its related stakeholders and design the features carefully with corresponding action plans throughout the whole design process.

To achieve sustainable fashion, retailers need to take all the three pillars of TBL model into considerations during the apparel product design process. The apparel product design will affect the whole fashion supply chain. As mentioned above, the materials, manufacturing processes and garment finishing processes induce a huge negative environmental impact. Thus, selecting sustainable materials and finishing methods can reduce the unfavorable environmental and social impacts throughout the whole fashion supply chain. Kasarda et al. (Kasarda et al., 2007) suggested a new concept of eco-product design, namely Design for Adaptability. Through innovative design, the product can be adapted to the changes and the product life can be elongated. Meanwhile innovative design can add value to the sustainable product which benefits the company and the economy (Maria et al., 2011). Thus, a fashion retailer can integrate its sustainable strategic plans with eco-design to facilitate the sustainable fashion supply chain. Furthermore, Niinimäki and Hassi (2011) presented different design opportunities on eco-design strategies and the corresponding consumers' perceived value towards the sustainable design approaches. Based on their studies, the retailer's management teams, and its design stakeholders can work together to select the ultimate eco-design direction that benefits to the sustainable fashion supply chain and planet at the same time.

ii) ***Manufacturing strategy:*** Fashion manufacturing is notorious for generating environmental pollutants. To achieve sustainable fashion supply chain management, the retailer needs to pay attention to all three pillars of TBL model and evaluate the performance of its related manufacturing stakeholders. Development of sustainable manufacturing strategies for actions and implementation is highly necessary. Many studies investigate the sustainability performance of the fashion manufacturing and production. Cox et al. (2013) and Mair et al. (2016) focused on the social aspects of

sustainable clean production whereas Alkaya and Demirer (2014) studied a manufacturer in Turkey and investigated how to apply different measurements on sustainable fashion production. Furthermore, apart from improving the existing manufacturing and production method, Dissanayake and Sinha (2015) examined a new manufacturing process for fashion re-manufacturing. Unlike traditional forward fashion supply chain, re-manufacturing involves reverse supply chain which requires the support of green production technology (Wang & Song, 2017). Through understanding of the external environment in stage 1 (Figure 8) and evaluating the sustainable performance of the SFSC stakeholders, retailers can design sustainable manufacturing strategies and allocate resources for improvement and enhancement. For example, Agrawal et al. (2015) explored the consumers' perceived value of re-manufacturing and found that they have different perceived value towards re-manufactured products with respect to the re-manufacturing methods (e.g., recycling waste from the production process or the used end products). After knowing the demand for fashion waste minimization and fashion waste recycling, the giant fashion company H&M invests in the new fiber reuse and recycle technology, so that the blended textile materials can be re-cycled and re-produced into new cloths. The above studies demonstrate the benefits of applying sustainable manufacturing strategies towards environment and economy.

iii) ***Distribution and consumption strategy:*** As mentioned in Section 2, the consumption of fashion apparels increased 60% from year 2000. This dramatic surge in consumption is facilitated by the norm of fast fashion. Consumers tend to update and dispose of the fashion apparel in a rapid and constant manner (Cox et al., 2013). However, numerous reports indicate the environmental issues caused by over consumption of fashion apparels. People start to pay attention to the sustainability level of the fashion

companies and are willing to pay more for sustainable fashion apparel products (Choi, 2011). To generate a positive reputation among consumers, retailers are inclined to promote their sustainable acts through different retailing methods. Yang et al. (2017) listed out some of the sustainable retailing methods, namely, slow fashion (Section 2.2.3), reverse logistics (Section 2.2.3), green branding, e-commerce and eco labeling, etc. Both Žurga and Forte (2014) and Gunilla Clancy et al. (2015) found that eco-labeling can enhance consumers' knowledge of retailers' sustainability movement. Žurga and Forte (2014) even discover that consumers are able to pay more if the product has eco-labeling that explains the sustainable features of the product. Goworek (2014) indicates that the retail buyer plays a significant role in fashion industry. They determine what merchandise is being offered to the market. If the retail buyers gather sufficient market information on the consumers' sustainable requirements, they will offer corresponding products with eco-labeling to satisfy the needs. Also, through product assortment planning, retailers can educate the consumers for sustainable consumption which supports further sustainable development. Furthermore, by addressing the customers' demand on sustainability and cooperation with customers, the sustainable performance of the supply chain can be enhanced (Jabbour et al., 2017).

3.5.3 Stage 3: Performance evaluation

In the final stage, the retailer will evaluate the performance of the company itself and the related channel members in the sustainable fashion supply chain. The sustainable business development strategy is a cycle. As the fashion industry is an ever-changing industry, to achieve sustainable business based on the performance report and new

external information, the company needs to work on future improvement plans. As mentioned in Section 2.3, the sustainable development goals provide universal understandable and measurable guides which cover all the three pillars of TBL model. The retailer can refer to the SDGs and evaluate the sustainable performance of its stakeholders and itself.

3.6 Summary

Considering the long-term well-being of both human society and the planet, how we can safeguard the planet resources against exploitation is a critical issue. However, the expansion of the fashion industry has threatened the global environment in the planetary level. With the growing awareness of the fashion sustainability, people start to pay attention to the sustainability level of the whole fashion industry apart from the sustainability level of the fashion apparel itself. Any failure in achieving sustainable fashion throughout the whole supply chain would harm the company image and its business. Supported by the intuitional theory, the external pressure drives fashion companies to engage in fashion sustainability.

Meanwhile, suggested by the resource-based theory, to reinforce the companies' competitive advantages and react to the market demands, careful planning in resources allocation is needed. However, how companies can identify the demands in sustainable fashion and make the right decision in resource allocation throughout the supply chain is a key issue. By studying the related literature upon sustainability and sustainability measurements, we first identify the fundamental model (TBL) which covers most of the market demand upon sustainability and the corresponding measurement goals (SDGs).

Furthermore, based on the decision-making theory, we investigate the critical problems upon the implementation of sustainable business decisions throughout the whole fashion product development process for further study. Finally, a sustainable business development strategy (SBDS) framework is established to help fashion companies to address the key problems for resources allocation and provide a guidance for improving supply chain stakeholders' sustainability performance for achieving sustainable fashion business.

CHAPTER 4

Sustainable Business Development Strategy Framework:

A Case Study on Nike Sports Fashion

4.1 Introduction

According to Siggelkow (2007), to have a better theoretical understanding and implication to an industrial practice, it is suitable to use the case study approach (Yin 2008). The case study in this thesis was carried out by analyzing the secondary data gathered from Nike's annual sustainable business reports (fiscal years 2016 and 2017), news articles, internet public documents, and other published documents. Based on the collected information on sustainable actions of the sustainable fashion company, we conduct a content analysis and examine the application and successfulness of its sustainable business development strategy (SBDS). Content analysis is a research method is being widely used in fashion industry related researches (Mundel 2013; Chan & Astari 2017; Turker & Altuntas 2014; Gulati, 2009), which allows researchers to study documentation texts and analyze the global phenomena (Bauer, 2007).

4.2 Analysis of Nike sustainable business

The target case study company is selected based on its global ranking and the presence of sustainable strategy throughout its entire fashion apparel supply chain. According to the 100 best global brands 2017 (Strijbos, 2018), the top fashion brands in the list include the sportswear brands, luxury brands, and fast fashion brands. With reference to the best global brands 2017 (Interbrand, 2017), Nike has the highest ranking among all other

fashion brands. Its ranking was even higher than the luxury and fast fashion brands (Figure 9). In 2017, Nike generated over US $34 billion revenue with market value over US $100 billion (Strijbos, 2018) and its revenue keeps growing over the 4 years horizon (Figure 10).

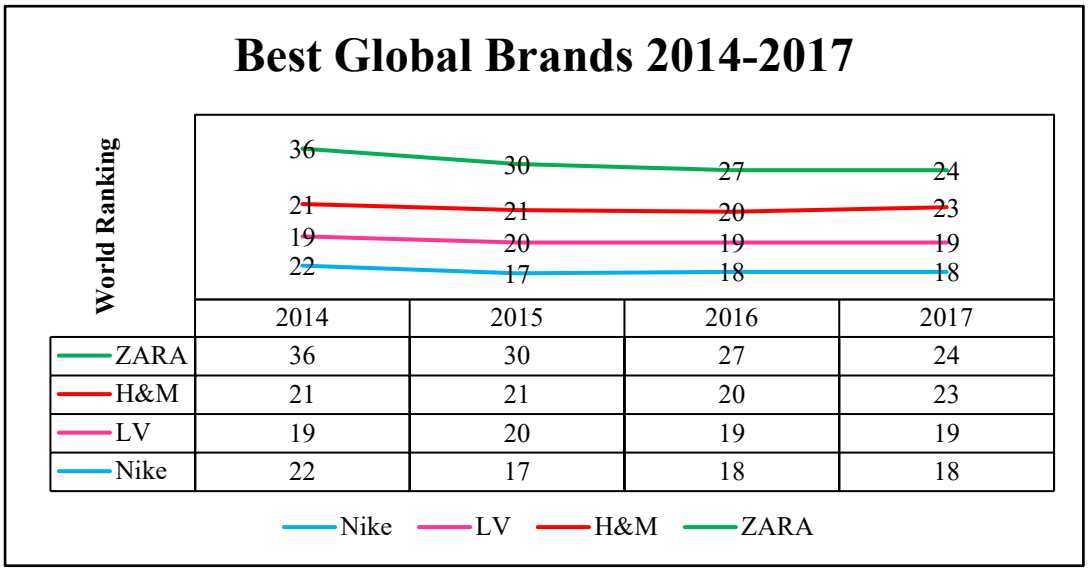


Figure 8. Best global brands 2014-2017

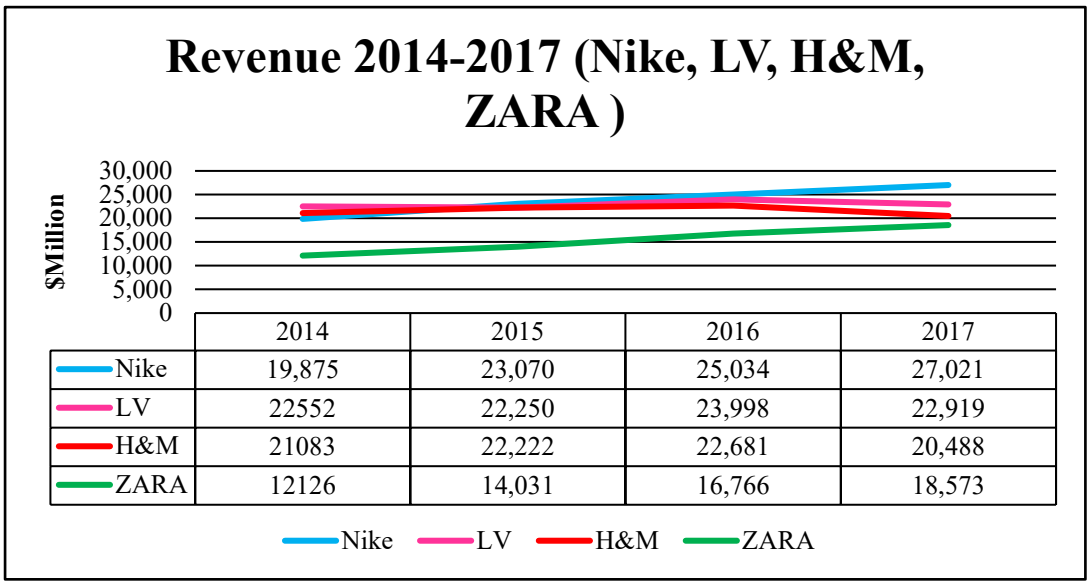


Figure 9. Revenue 2014-2017 (Nike, LV, H&M, ZARA)

Conventional wisdom may indicate that the higher the revenue a company generates, the more merchandise it will sell and the more waste it will generate. However, Nike breaks

the rules. Nike CEO suggested that, through the adoption of sustainable supply chain operations, Nike can make better use of its resources. With the support of sustainable supply chain, the greenhouse emission drops by almost 3% when the revenue increases by 26% (Nike, 2014). As mentioned above, it is important to study Nike's sustainable business strategies and its corresponding movements. This would facilitate fashion retail companies to finding potential solutions for achieving sustainable fashion by implementing sustainable business development strategy.

4.3 Application of the developed SBDS framework in Nike

The implementation of sustainable business development strategy (SBDS) upon design, manufacturing, distribution, and consumption will affect the sustainable performance of the down- stream stakeholders (designers, manufactures, distributors and consumers) in sustainable fashion supply chain. Following the three-stage SBDS methodology (Figure 11).

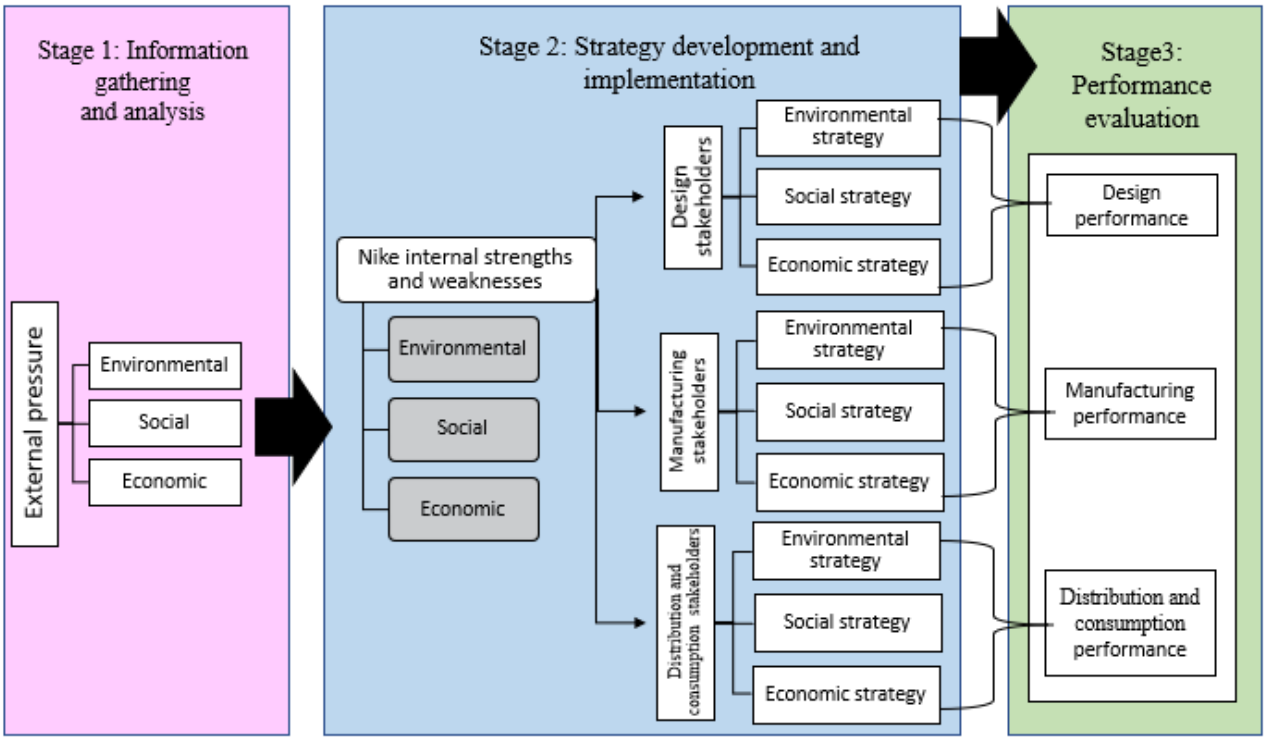


Figure 10**.** Three stages of the sustainable business development strategy framework

4.3.1 Stage 1: Information gathering and analysis - external pressure

In stage 1, Nike first considers the external market pressure upon the demands for sustainable fashion. Thought studying the environmental, social, and economic pressures, Nike would have better understanding upon the market demands for later sustainable strategy development (Figure 12).

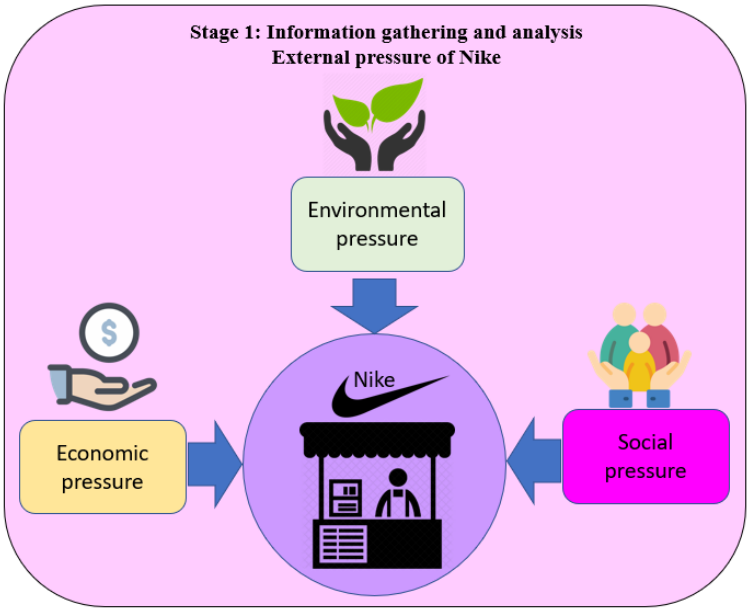


Figure 11. Nike's external pressures towards the development of sustainable business

Environment pressure: Environment consideration is one of the major pillars of TBL model. The natural resources in the planet are limited while the desire of human is unlimited. With the rapid growth of human population, there is a tremendous demand for natural resources. If this situation continues, the problem of scarcity of natural resources will hurt the well-being of our future generation. So, a critical issue is that how we can safeguard the planet resources. Global economy grows rapidly in the past two decades, which supports the expansion of the fashion industry. Together with the rapid growth in the fashion industry, the needs of agricultural productivity increase. According to the International Cotton Advisory Committee (2018), compared with 2016/17, the projected world cotton consumption in 2017/18 increased by 11%, which is about 25.4 million tons. While the International Wool Textile Organization (2015) states that, 1.160 million kg of clean raw wool was produced from 1.163 Billion of sheep to satisfy the world demand. In 2015, this huge demand of nature resources (plant-based fibers and animal fibers) put pressure on the agricultural industry and hint the environment. Over growing and grazing leads to the

loss of organic carbon soil and soil erosion which is harmful to agriculture industry. As agriculture industry is the largest employer in the world which takes up 40% of global livelihood (UNDP, 2018). Corruption in agriculture will increase the undernourished population. So, careful planning on agriculture productivity and its corresponding environmental impact are crucial.

Moreover, the world populations in 2020 is over 7.8 billion. Based on the estimations of the demographers, the project population in 2037 will be 9 billion (Chamie, 2020). With the increase in population and the corresponding activity, the water pollution problem is getting more and more serious. Around 80% of the wastewater generated from human activities is discharged into the waterway without removing the pollutant. Meanwhile, the fashion industry is one of the biggest industries on water consumption and pollution. Cotton consumption for textile and clothing is huge, which induces a high demand for raw cotton material. To ensure the stability of cotton supply, insecticides and prettifies are widely used, which account for 24% and 11% of the world usage, respectively. These toxic chemicals are washed into waterways and cause serious damage in ecosystems. The dyeing and finishing treatment of the fashion apparel manufacturing accounts for 20% of the world industrial water pollution (Bethany 2018).

To cope with these challenges, fashion companies of the fashion apparel supply chain should minimize their ecological footprint which benefits the eco system and protects the planet environment from dissipating. By carefully planning the retailer's business model and its supply chain, natural resources can be saved. This can benefit both environment and sustainable fashion apparel business. To Nike, the competing brand Adidas has tried to contribute in reducing the water

pollution during the manufacturing process. Adidas has invested a new dying technology called “Air-Dye”. Compared with the traditional dying process, Air Dye only uses 5% of water and 14% of energy for production. Meanwhile the greenhouse gases emission is 84% less than before (Hepburn, 2015).

Social pressure: as the well-being of people is one of the core foci of sustainability, the TBL model suggests a set of social responsibility measures for companies to follow. Fashion companies should pay attention to labor equality and conduct a fair business which benefits the community and society. For example, fashion retail companies should trade fairly with their stakeholders. By providing upstream stakeholders sufficient financial support, stakeholders can pay fair wages and provide a proper working environment to their workers. Refer to the global fashion industry statistics (Figure 13; Strijbos 2018), employment in the fashion related industries increased dramatically in the past 30 years. From 1990 to 2014 (Figure 13), the number of people employed in apparel manufacturing, textile, and clothing industries increased by 71%, 68% and 69% respectively. They took up almost 3.5% of the global labor force. Even after the COVID-19 pandemic, the global apparel manufacturing still ranks the fifth among the top 10 biggest global industries by employment in 2021 (IBISWorld, 2021). The above employment statistics and the ranking showed that the ethnical performance of the fashion industry is very important which can affect the global poverty level. However, it is reported that many giant fashion companies had ethical issues in manufacturing and production (Caniato et al 2011). For example, Adidas, Benetton, and Levi Strauss were being blamed for ethnical issues during the production and manufacturing processes (Seuring & Müller, 2008).

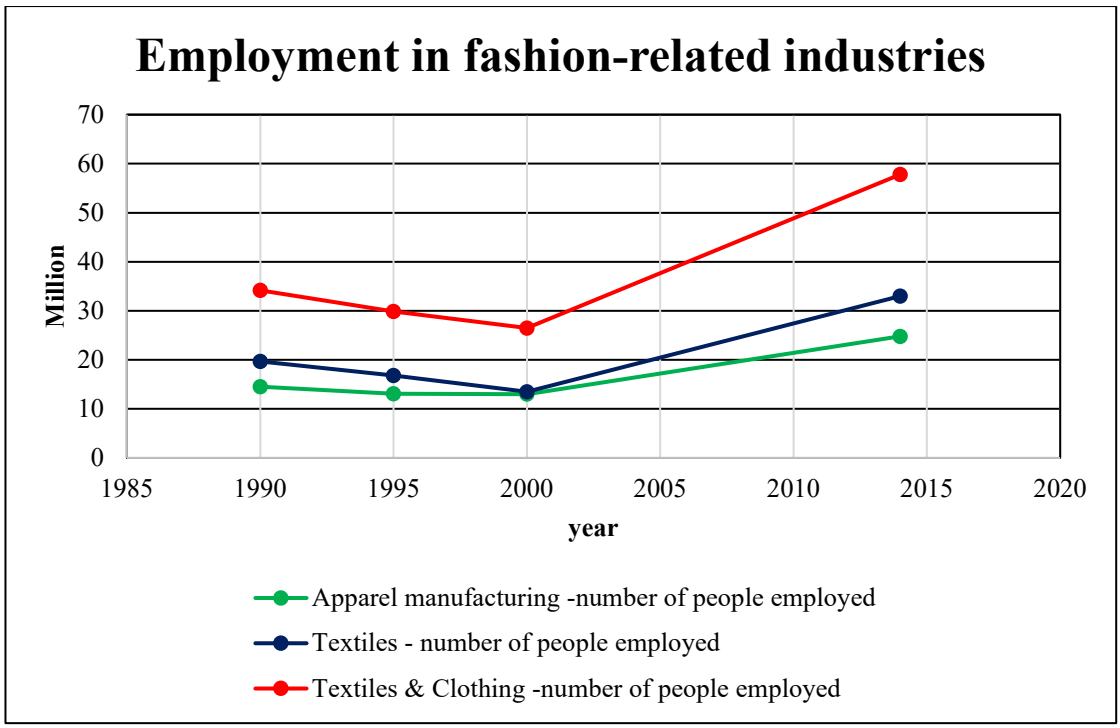


Figure 12. Employment in fashion-related industries

Source: Global fashion industry statistics - International apparel (2018)

In addition, fighting for women and girls' equality and the end of gender discrimination are serious ethics topics which relate to sustainability. Even though empowering women and girls is proved to benefit the economy with multiple effects, women still cannot have full access to jobs fairly in some regions. It is reported that men earn 27% more than women (UNPD 2018). To address this problem, Swedish Cooperation and Development Agency (SIDA) provide the financial support to the coordination among the three parties: (1) fashion brand Argandel, (2) United National Development Programme, and (3) Reginal Development Administration of Southeastern Anatolia Project, towards new apparel manufacturing projects for job creations. These new apparel manufacturing projects bring jobs to 4,300 women in the Southeast Anatolia. Women can participate in the manufacturing and other project supports actives to generate income (Helmore, 2018).

Economic pressure: the economic pillar of the TBL model focuses on the impact of the companies' business development against the global economy (Elkington, 2001). It suggests that companies should set up sustainable profit measures which can benefit the company's business and the economy at the same time. With this win-win situation, future generations can enjoy a healthy economy with continuous growth (Spangenberg 2005). The average clothing purchased per capita in 2018 increased by 60% compared with that in 2000. However, only 60% of the purchased clothing was used while 40% never being worn before dispose. According to the population growth rate, the apparel consumption is expected to increase from 62 million tons to 102 million tons in year 2039, which means more clothing will be purchased and disposed. Moreover, the fashion consumption is further enhanced by the upcoming trend of fast fashion.

The growing fashion apparel business and the corresponding consumption led to the rise of the pollution. Fashion companies should not only focus on their business growth, but also their business model and marketing strategy in considering the business decision. Pookulangara and Shephard (2013), and Jung and Jin (2016) all suggested that fashion retailers should promote the concept of "slow fashion" to make fashion industry sustainable. The concept of slow fashion is composed of three main components, namely (1) the value identification of local resources, (2) the production transparency and (3) extend the product's usable life. Everlane, a U.S fashion brand fully adopts this concept in its business model. They tried to show high product transiency to its consumers. The clear cost break of every single product is shown in its website, including material price, hardware price (sundries), labor cost, duties, and transportation cost (freight). Furthermore, the website also has shown the source of

production of each corresponding product. Such business model is called as “radical transparency”. Through factories selection, Everlane can achieve sustainable supply chain with full transparency. Also, the selection of materials can elongate the life spend of the apparel products. Moreover, Everlane tried to educate its consumers to take responsibility of their consumption. On the one hand, such business model can raise the level of fashion sustainability whereas on the other hand it can promote the sustainable business economy. The factories with high ethnical scores of compliances can be promoted through the Everlane website, attracting other brands to approach them for production.

4.3.2 Stage 2: Strategy development and implementation

4.3.2.1. Nike internal strengths and weaknesses evaluations

After gathering the external pressures towards developing sustainable sportswear business, Nike can start evaluating the companies’ internal strengths and weaknesses (S&W) towards the three dimensions of TBL model and works on the action plans for resources allocations.

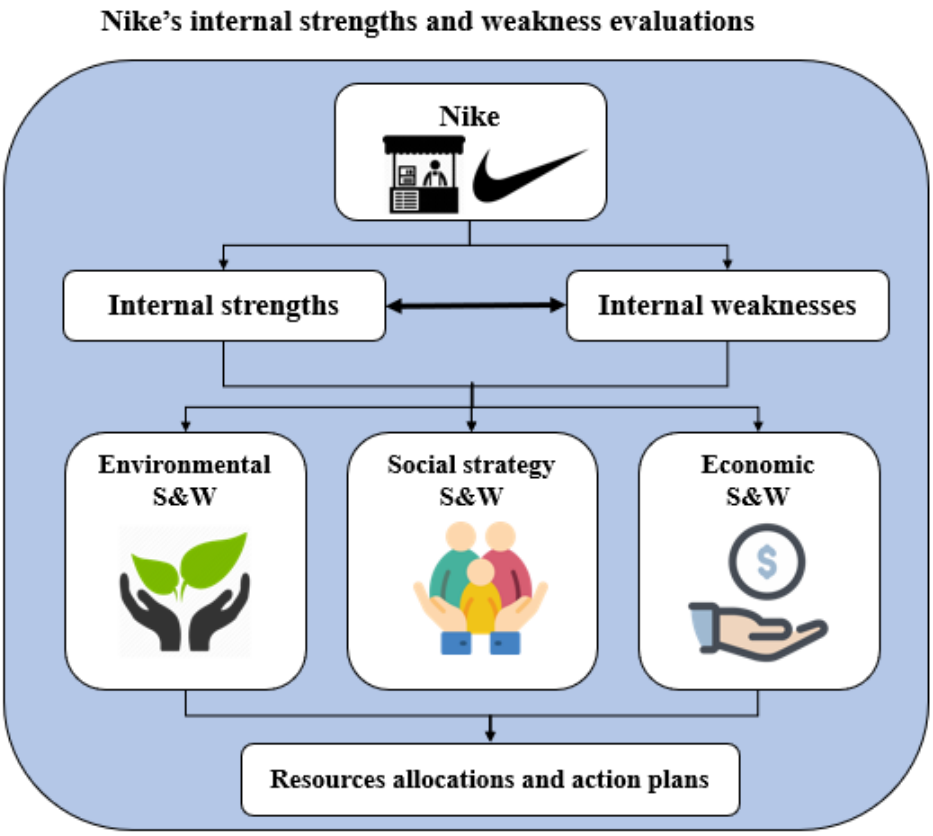


Figure 13. Internal strengths and weaknesses and corresponding action plans

Economic S&W: According to the financial report released by Nike in 2016, Nike's revenue surged 6% and reached to 32.4 billion US in year 2016. Besides, Nike planned to further expand its business in year 2017. With this huge revenue, the company has massive resources for sustainable development. To achieve such business target, the management team foresees that huge energy resources are needed. Due to the oil crisis, the energy cost frustrates and affects the growth of business. Furthermore, it is reported that Nike has over 75 distribution centers around the world. The bigger the growth of the business, the more the energy it needs to consume, and the higher the carbon foot print it will incur (especially for its inbound and outbound logistics). To deal with this potential problem, Nike's management team seeks for cost-effective alternative renewable energy to replace the energy generated by fossil fuel. Together with the onsite wind, solar energy and locally produced biomass and hydro energy, Nike's logistic

campus in Belgium achieved 100% re-renewable energy usage. Meanwhile, 35 percent of Nikes Taicang logistics center energy usage was generated by solar panels. By using the cost-effective and low risk renewable energy, Nike can save the energy cost and generate a lower level of carbon footprint.

Environment S&W: Apparel manufacturing generates a huge amount of pollutants and wastes. This will also be the case for the giant fashion companies like Nike. In year 2016, there are over 500 manufacturers which are business partners with Nike and produce Nike's products. This reported number shows that the production chain of Nike is very complicated which needs high resources on corporate governance. In year 2016, Nike planned to eliminate the impact caused on the environmental impact by half. To achieve this target, Nike set different goals on waste reduction among its related manufactures and suppliers. As lack of fresh water will harm Nike business and also the environment, Nike plans to reduce the water usage by setting up "Nike Water Minimum Program". Nike collects data on its manufacturers' wastewater treatment via this program, manufactures can figure out which part of the production process generate the highest among of wastewater through data evaluation, so that manufacturers can restructure their production and achieve higher water efficiency. Also, they can develop the corresponding water recycling infrastructure and prepare for a closed loop water recycling.

Apart from the wasted water, the common problem of apparel manufacturing is the usage of chemicals and the corresponding chemical pollution issue. As Nike is one of the biggest apparel brands which sell a huge amount of merchandise, chemical usage is also huge. To resolve this problem and improve chemical usage, Nike targets a zero discharge of hazardous chemicals with serious action plans. In early 2017, Nike adopted the

AFIRM Group upon restricted substance list (RSL). Through the AFIRM group, not limited to the compliance requirements, massive types of chemical used in Nike's apparel production process were tested and evaluated. Reports of the environment impacts correspond to each chemical were studied and evaluated by the members of the AFIRM group. A list of restricted chemicals was shown in the RSL. This RSL acts as a guidance for Nike's manufacturers or even the whole fashion industry. It is because RSL not only satisfies the legislation requirements, but also the best industrial practice and facilitates voluntary hazardous chemical reduction.

Social S&W: Over the past few decades, Nike has been arguably reported to run sweatshop operations in producing its products (Laura et al., 2018). To deal with this problem, Nike seeks for the support of Fair Labor Association (FLA), Better Work (a joint program of the International Finance Corporation and United Nations), and other independent third-party organizations to develop its own Sustainable Manufacturing and Sourcing Index (SMSI). Factories which cannot meet Nike's requirements or with rating lower than bronze level cannot manufacture Nike's products. Nike will audit the factories regularly to ensure that they keep up to Nike's and other third parties' organizations' standards upon human rights.

Besides, Nike was recently involved in a lawsuit with its ex-employers (Helmore, 2018). They alleged that male employees received a much higher salary and bonus compared with the female employees. Moreover, the management team of Nike reviewed the company human resource record and admitted that they have failed to promote women in year 2018.With this breaking news, the image of Nike has been spoiled. To win back the trust from worldwide customers, Nike makes dramatically changes in is business and operation. According to Statista (2018), Nike's worldwide employees were over 74000

in year 2017. In year 2016, Nike formally launched "U.S. Family Care Benefit Program". This program aims to provide competitive benefit and promoting equality and healthy family life, which allows employees to enjoy paid time off while taking care of the family (e.g., spouse, dependents or partners, etc.). Apart from its own employees, Nike engaged to create healthy community by building partnership with the Ministry of Education in China in year 2017. Besides, Nike conducts new human resource program for upcoming 2021. In 2021, Nike places high attention in providing diversity, equity, and inclusion (DE&I) education for all Nike's leaders and employees. The DE&I education include unconscious bias awareness training and work to grow awareness training etc. (Nike, 2021). Through these trainings, Nike's management team and employees can fully adapt to the company value and have a clearer understanding of the requirements on human resources evaluation. Thus, the bias and unfair situation can be reduced. Moreover, new monitoring systems and bonus structure are introduced to reinforce the team's cohesiveness and fairness.

4.3.2.2. Nike's sustainable strategies and stakeholders' implementations

After studying the internal strengths and weaknesses of Nike's sportswear business, Nikes is able to allocate the resources and decide sustainable business strategies with corresponding action plans for its design, manufacturing, distribution, and consumption stakeholders for implementations.

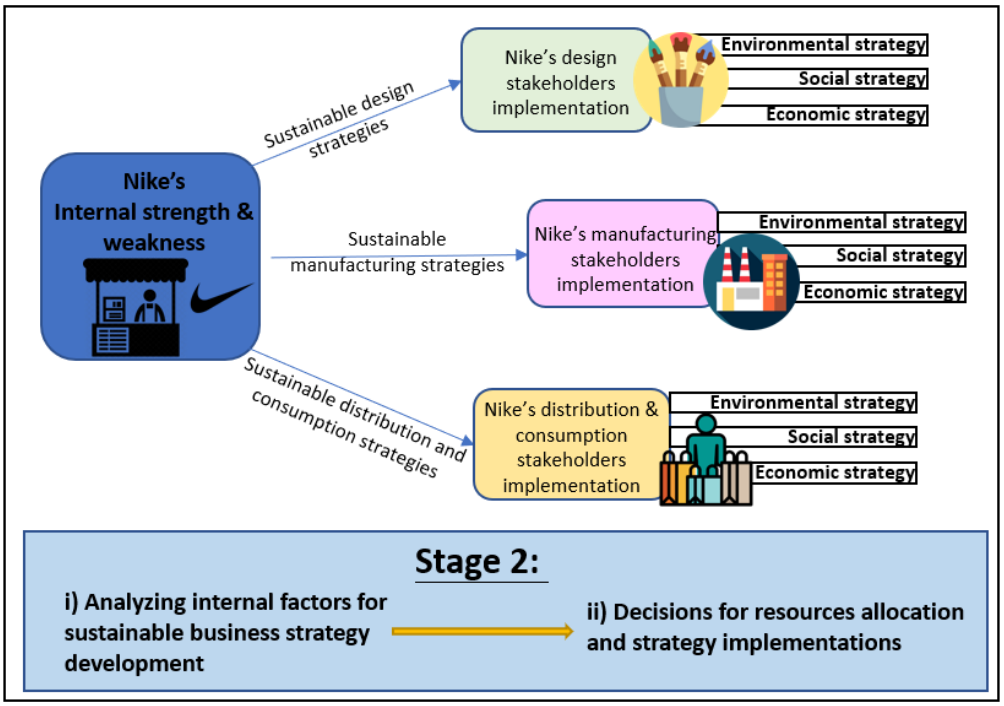


Figure 14. Nike's sustainable strategies and stakeholders' implementations

Sustainable design strategies

i) ***Design strategy towards economic sustainability:*** As a world leading sportswear brand, Nike seeks for innovative design to facilitate its business growth. Traditionally, a pair of Nike racers needs approximately 35 pieces to assembly which requires intensive production procedures and labor. The lead time for production and assembly is very long which makes it difficult to have responsive reaction towards upcoming demands. To deal with this issue, Nike hired a team of engineers and computer programmers to re-engineer a sweater machine which can weave the upper part of racers. They called this "micro-level precision engineering" (Matthew, 2012). In year 2012, Nike launched a new innovative footwear technology called "Flyknit". The Flyknit technology eliminated the complicated footwear construction and helped make the whole upper part of the racers in one piece. This can speed up the whole production process with a huge reduction on

human resources needed in production. This tremendous improvement enables Nike to produce trainers in US and increase the probability of customization. Designers can now react to the fashion trend and market needs promptly by designing racers to fit the trend and demand launched in a short period of time.

ii) ***Design strategy towards environmental sustainability:*** Nike is targeting zero waste for its products. To achieve this goal, Nike tries to select sustainable materials during the design process. Nike developed a sustainable materials index (SMI) which act as a guide to material and design teams upon the more environmental preferable material, as to encourage team members to select materials wisely in design and development. Material teams will first source from suppliers with good sustainable performance. Then based on the index, they work with the suppliers to drive the use of sustainable materials. For example, Nike's apparel moves to use sustainable cottons such as the certified organic cotton, recycle cotton or BCI cotton, instead of using conventional cotton.

iii) ***Design strategy towards social sustainability:*** For the social aspects, Nike aims to design products facilitating healthy and active lifestyle. By integrating the sustainable lifestyle concept into the product design and development process, Nike's product becomes more sustainable. Starting from the initial design concept, materials and product assortment review, designers are supported with a full range of sustainable information.

Sustainable manufacturing strategies

i) ***Manufacturing strategy towards economic sustainability:*** As one of the biggest retailers in the world, Nike's products cover many different apparel categories (for

example, clothing's, racers, sports accessories, functional sportswear, etc.). All these apparel products require different manufacturing processes, facilities, and resources. To make sure all the resources are being used effectively and efficiently, Nike developed a waste management center. The waste management center consolidates the materials used in production. Through evaluation, factories can figure out the causes of wastes generated in production process. Nike even develop a cross-functional team to identify the underlying problems on material waste reduction. The cross functional team can gather information from different Nike departments' expertise and provides solutions upon reducing manufacturing wastes and optimizes the use of resources.

ii) Manufacturing strategy towards environmental sustainability: The key environmental impacts of manufacturing include water pollution, carbon emission, and the manufacturing wastes. To minimize these environmental impacts, Nike adopts different technologies and programs during the manufacturing process. Firstly, Nike developed a "Water Risk Mitigation Guideline" for manufactures to follow during production. Following with these guidelines, Nike can control their water usage and equipment for treatment process in a structured approach during production. To further reduce the water usage, Nike introduced a technology named "ColorDry" in 2012. This technology converts liquid CO_2 to supercritical fluid carbon dioxide via heat and pressure and eliminates the water usage in process of dying (Guardian, 2013). For the energy usage and waste reduction, Nike designs new efficient tooling for production. For example, molding tools for shoe's production. The bottom part of a Flyknit shoe is made by midsole, which is formed by injecting pellets to a mold. On the one hand it can improve the production efficiency, on the other hand it can bring down the energy consumption during manufacturing and production. Moreover, Nike tries to improve

cutting technology to minimize the waste generated during the cutting process. Clothing and apparels usually consist of different panels and parts. Factories need to spread the materials on a cutting table and place the pattern pieces on the fabric plies for cutting. However, as the shapes of panels are irregular, there must be gaps between each panel when it lay fat on the fabric. All those gaps are waste in production. To reduce this waste in materials, Nike improves the cutting technologies and designed more efficient cutting patterns, which allow a smaller gap between each panel so to decrease the waste.

iii) Manufacturing strategy towards social sustainability: As apparel manufacturing is a labor-intensive process, Nike pays high attention to workers' engagement. Engagement of workers is one of the key elements attributed to the business success. According to Nike's annual sustainable business reports (fiscal years 2016 and 2017), apart from the factories' social welfare auditing from year 2014-2017, Nike once conducted social welfare pilot test which involved over 28,000 workers. The pilot workers came from 17 factories located in Vietnam, Indonesia, China, and Thailand. Based on these pilots, Nike designed a protocol standard which helps to measure the workers engagement. With the support of the pilots and survey, the turnover rate and absent rate of workers decrease. Meanwhile, Nike developed an "Engagement and Wellbeing Survey" as a guide for the managers to identify the implications upon the workers working experience. Through this survey, workers can point out the problems upon the working environment and manufacturing processes. Based on the feedback received by factories' management, it showed that the level of workers' well-being and engagement have significantly improved.

Sustainable distribution and consumption strategies

i) Distribution and consumption strategy towards economic sustainability: With the ever-changing retail environment, Nike has found that the traditional bricks and mortar stores are not good enough to serve the customers. Nike realized that the traditional retailing business model which provided customers homogeneous products without much customer interaction cannot support Nike's target growth in business. In order to provide customized service to individual customers at scale, Nike launched a new company alignment operations program called "NIKE Direct" in June 2017. Nike marketed its products around the world which includes, China, North America, Europe Asia Pacific, and Latin America (APLA), and Middle East and Africa (EMEA), etc. Besides, it adopted a variety of retail channels such as community stores, factory stores, company-owned retail stores, mobile applications, and official websites. This "Nike Direct" program allows Nike to coordinate and control the sales channels around the world. By using new technology and data sharing, Nike can serve customer based on individual personality and provide customized service at scale. In early 2018, Nike acquired a leader in data analytics called Zodiac (NIKE, 2018). Such acquisition enabled Nike to have a better understanding of its customers through data analysis. In addition**,** Nike invested huge amount of effort upon the technology improvement, it introduces a new "Nike App at Retail "(Nike 2018) which allows Nike's store to recognize customers who have installed the App. The App can select the favorable items corresponding to the customers' preferences recorded. Once the App recognizes the customer, it will select products which are tailored to the customers. Meanwhile, customers can make a reservation of the products and hold in a personal locker for try on. They can even pay in the App without lining up. This new App function helps to facilitate the economic

sustainability towards product distribution and consumption. On one hand the App helps to enhance the consumers' buying intentions and increases the sales, on the other hand less salesforce is needed for reservation which bring down the cost of the goods sold.

ii) Distribution and consumption strategy towards environmental sustainability: Compared with the traditional full load shipment, shipments for e-commerce generate higher carbon emissions. As Nike is a worldwide sportswear retailer which produces and sells its products around the world, Nike has introduced the Supply Chain Sustainability Index (SCSI) to minimize the carbon footprint generated by the supply chain. Based on SCSI, all Nike's logistic service providers need to follow the requirements of minimum sustainability. Nike's logistic partners can only use inbound air freight and ocean freight providers when necessary. Moreover, Nike identified delivery options to generate less carbon emission like deliver products by bike. Apart from the bulk product shipment and e-commerce delivery, Nike also pays attention to the environment impact upon the retail sales floor. As mentioned in the previous section, Nike has introduced the "NIKE Direct" to control its stores around the world and commits to sustainable retailing. In years 2016 and 2017, Nike employed an Energy Management System (EMS), which centralized the electrical systems and automatized HVAC lighting system. By using EMS, Nike can spot the energy saving opportunities for improvement. For example, it upgrades the lightings in LEED stores to reduce retail locations' energy usage.

iii) Distribution and consumption strategy towards social sustainability: Due to the upcoming trend of share community, Nike has introduced the "BIKETOWN" program and set up 100 bikes stations with 1,000 bikes across the Portland. Finally, to have a worldwide education upon sustainable consumption, Nike has introduced "Reuse-A-

Shoe" to its retail stores. Customers can drop-off any brands' athletic shoes to Nikes Reuse-A-Shoe collection point. Nike transformed the collected shoes to Nike Grind which are used to build tracks, courts, playground, or fields.

4.3.3. Stage 3: Performance evaluation of Nike's sustainable business

After studying how Nike develops different strategies for its supply chain stakeholders, and how its stakeholders implement business strategies in their own industrial domains, We move on to Stage 3 (Figure 16) and study the sustainability performance of Nike itself and its stakeholders (design, manufacturing, distribution, and consumptions).

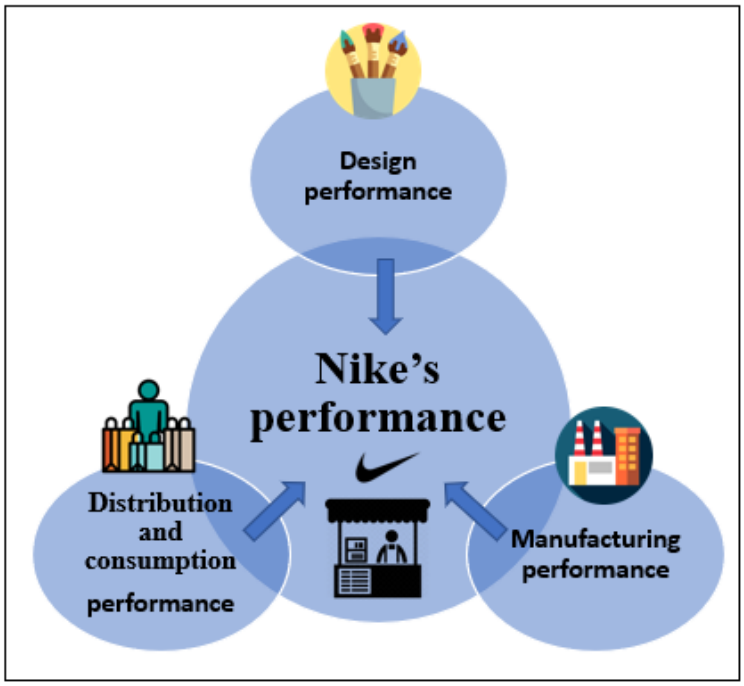


Figure 15**.** Performance evaluation of Nike's sustainable business

i) ***Performance of Nike:*** It is reported that there is an increasing trend of renewable energy used by Nike in 2015, 2016 and 2017, namely 14%, 20%, and 22%, respectively. Besides, Nike is targeting 100% reusable energy in year 2020. Due to the comprehensive planning of the water minimum program, 40% of Nike's suppliers recycle the wastewater to its manufacturing process during the production of primary materials. This

led to a drop of freshwater usage by 7.4 percent compared to year 2016. At the end of the financial year 2017, based on the adoption of AFIRM Group upon restricted substance list (RSL) and corresponding action, 82% and 72% of Nike's manufactures and suppliers were being trained, respectively. Meanwhile, 98% of the used materials is in compliance with the RSL. Based on the adoption of Sustainable Manufacturing and Sourcing Index (SMSI), all factories are regularly audited and passed the Nike requirement with rating higher than Bronze level. For the internal employees, the "U.S. Family Care benefits program" launched in 2016 allows employees to enjoy paid time off while taking care of family (spouse, dependents or. Partners etc.). Also, the partnership program with Ministry of Education, has trained approximately seven thousand teachers to engage and deliver sports lessons. Meanwhile, Nike provides sports related resources to over 300 schools across China and encourage kids to be more active in sports. Nevertheless, based the on the Nike annual sustainability report, Nike has supported US active sports schools and committed to a three-years "Active School and Active Community" which provided over 60,000 kids with positive sports experience (Table 4).

Table 4**.** Performance of Nike under the TBL model

TBL	**Action plan**	**Performance**	**SDGs**
Economic	Cost-effective alternative renewable energy	22% of energy used in Nike are cost effective renewable	7
Environment	Nike water minimum program AFIRM Group Restricted Substance List (RSL)	-40% of Nike's suppliers recycled the wastewater. -Drop in freshwater usage by 7.4 percent compare to year 2016 - 98% of used materials being compliant with the RSL	6 6 12
Social	Sustainable Manufacturing and Sourcing Index Partnership with Ministry of Education (SMSI) Active School and Active Community	- 100% manufacturers rate higher than Bronze -Trained 7,000 teachers -Helped 60,000 kids with positive sports experience	12,17 3 3

Data source: Nike FY16/17 sustainable business report (Nike, 2017)

ii) ***Performance of design stakeholders:*** This new Flyknit design developed through "micro-level precision engineering" Programme was widely accepted by the market. In year 2015, Nike launched 25 models of racers by using fly knit technology and the numbers of Flyknit models still keep growing. This innovative design and production technology bring sustainable footwear production to the next level. Compared with the traditional racers, Flyknit racers generate 60% less of production waste and 100% of the core yarn is made from recycle polyester. Apart from it, it generates remarkable sales. The footwear revenue of Nike increases from 13.5 billion US dollar in year 2012 to over 20 billion US dollar in year 2018 (Statista 2018). 98% of Nike rubber usage are environmental preferred rubber which employs environmental preferred compounds during processing in 2017. Nevertheless, the core yarn used in Nike's Flyknit is 100% recycled polyester. The recycled polyester may come from elite track, football team kits and other classic shoe components. One of the most festinating achievements is that Nike transforms over 4.6 billion plastic bottles to sports apparels. The used of environmentally friendly materials in its product designs facilitate the continuous growth of the planet. Although Nike aims at designing products which encourage a healthy and active lifestyle, there is no information upon the sustainable product proportion towards Nike's total product assortment. Higher visibility is needed in this area (Table 5).

Table 5**.** Performance of Nike design stakeholders

TBL	Action plan	Performance	SDGs
Economic	-micro-level precision engineering -Flyknit technology	-launched 25 models of racers by fly knit -footwear revenue of Nike increases from 13.5 billion US dollar in yearn 2012 to over 20 billion US	7
Environment	Sustainable material index (SMI)	-Nike transformed over 4.6 billion plastic bottles to sports apparels -generated 60% less of production waste -100% of the Flyknit core yarn is made from recycle polyester	6 6 12
Social	Design for environment	-need higher visibility on sustainable product proportion towards Nike's total product assortment	12

Data source: Nike FY16/17 sustainable business report (Nike, 2017)

iii) ***Performance of manufacturing stakeholders:*** Compared with year 2016, the revenue of Nike increased by 8% in 2017. The growth in revenue is not only contributed by the increase of the total sales, but also the optimization of manufacturing process. In 2018, it is reported that the energy used in Nike footwear finished goods has been reduced by 60% compared with that in the previous 10 years. The reduction in energy usage implies saving in cost is beneficial to Nike's business. Through Water Risk Mitigation Guideline and the new "Color dry" dying facilities, Nike saved 20 million liters of water for dying 600,000 yards of fabrics. Furthermore, compared with the traditional running shoes, this free midsole molding process reduced the waste up to 60%. From the social perspective, even though Nike found that the factories participating in the Engagement and Wellbeing Survey performed better than the peers, more detailed data are not available in its sustainability report and hence higher visibility and data support is needed (Table 6).

Table 6**.** Performance of Nike manufacturing stakeholders

TBL	Action plan	Performance	SDGs
Economic	Cross fictional materials efficiency team Waste Management Center	- energy used in Nike footwear finished goods reduce by 60%	7,17
Environment	Water Risk Mitigation Guideline -Colordry New efficient tooling for production	- saved 20million liters of water for dying 600,000 yards of fabric - reduced the waste up to 60%.	9,6 9,6
Social	Engagement and Wellbeing Survey and Pilot test	-factories performed better than the peers in social wellbeing -higher visibility and data support are needed	1,5

Data source: Nike FY16/17 sustainable business report (Nike, 2017)

iv) ***Performance of distribution and consumption stakeholders:*** This new "direct to customer" retailing method of "Nike Direct" promoted the growth in worldwide sales. Compared with the sales of the same quarters of 2016 and 2017, business growth in digital direct sales recorded a growth of 18%. From Figure 17, it demonstrates that the

growth in the "direct to customer" sales outpaced the wholesale in Europe, Middle East, Africa, Asia Pacific, Latin America and Greater China in 2017. From the environmental perspective, Nike introduced SCSI, which guides its distribution partners to use inbound freight only if necessary and motivates them to use bike as a means of delivery. According to Nike's 2017 sustainability business report, the energy consumption in inbound is increased by over 30% compared with that in 2016. This figure indicates that Nike needs to work closer with logistics partners to implement the energy saving scheme. Thus, more resources shall be employed to enhance the effectiveness of the SCSI. In the retailing and consumption perspective, Nike implemented the Energy Management System (EMS). Through this EMS, Nike controls its electricity usage retailing. Regarding 18% increase in sales, the energy usage in 2017 only increased by 0.5%. It shows that the performance of EMS is outstanding. Although the environmental performance in logistic still has room for improvement, the social aspect of consumer's contribution should be highlighted. From Nike's sustainably report 2017, the post-consumer waste collected from distribution centers in 2017 were over 1.3 million pounds through Reuse-A-Shoe program (Table 7).

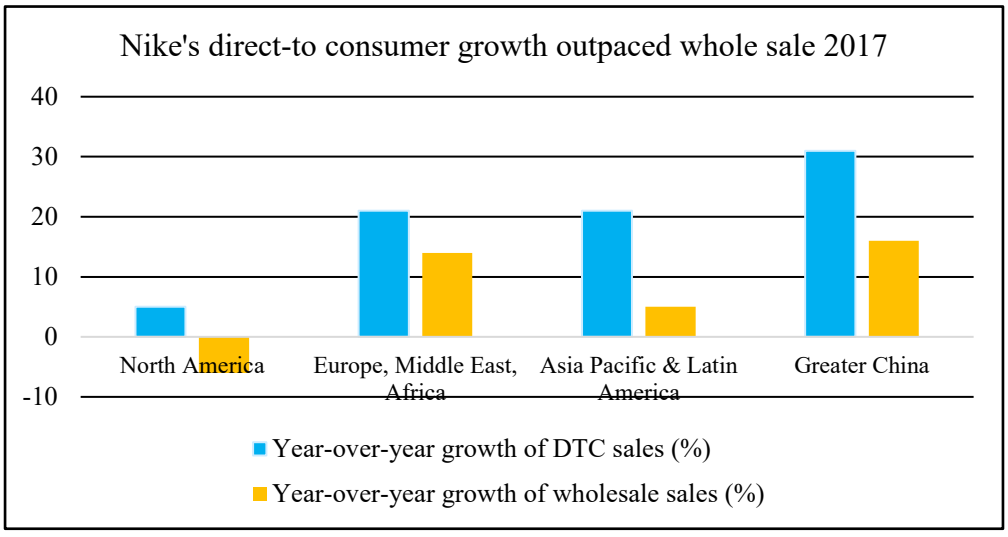


Figure 16. Nike's direct- to consumer growth outpaced wholesale 2017 (Marc, 2018)

Table 7. Performance of Nike distribution and consumption stakeholders

TBL	Action plan	Performance	SDGs
Economic	NIKE Direct	- business growth in the digital direct sales grown by 18%	8
Environment	Supply Chain Sustainability Index (SCSI) Energy Management System (EMS)	- energy consumption in inbound increased by over 30% - electricity usage in retailing increased by 0.5%	7 7
Social	BIKETOWN Reuse- A-Shoe	- introduced 1,00 bikes stations and 1,000 bikes across the city - collected over 1.3 million pounds post-consumer waste	11 11,12

Data source: Nike FY16/17 sustainable business report (Nike, 2017)

Overall performance of Nike's sustainable fashion supply chain: Based on the above findings, we discovered that as the world's largest sportswear company, Nike pays high attention in its level of sustainability. It firstly decides the corporate sustainable targets upon the economic, environmental, and social. Different programs and policies are developed to its' related supply chain stakeholder's towards product design, manufacturing, distribution, and consumption. Table 8 shows the overall performance of Nike's sustainable business development strategy.

Table 8. Performance evaluation of Nike's SPDS in this study

Performance	Economic	Environmental	Social
Nike	√	√	√
Design Stakeholders	√	√	PS
Manufacturing stakeholders	√	PS	√
Distribution and consumption stakeholders	√	PS	√

√ - Successful; PS- Partially successful

4.4 Summary

In this chapter, we examine how the SBDSF can help decision makers in fashion supply chain to make managerial decisions without missing the core demands in sustainable

fashion. Based on the case study on Nike, it is found that the sustainable SBDSF can be applied to the real-world case. Table 9 shows that how the theories of sustainable business development strategy can be applied in the Nike case study.

According to Van der Byl and Slawinski (2015), cooperate sustainability is embraced by different tensions. Through careful tension management, organizations can find a balance between operations and sustainability performance. Referring to Van and Slawinski (2015)'s findings, the tension can be divided into 4 different approaches, namely win-win, trade off, integrative, and paradox. The win-win approach suggests that organizations can avoid tensions by focusing on sustainable goals where alignment exists, while the trade-off approach eliminates the tensions be selecting one goal over another. Contrastingly, an integrative approach aims at aligning all three elements of the TBL model. Through the institutional theory, organizations can explore creative solutions towards the demands of sustainability. Through the studies in Chapter 4, it is concluded that the proposed sustainable business development strategy framework would be able to assist organizations in finding a balance between operational and sustainability performance (Table 10).

Table 9**.** Application and evaluation of the strategic theories based on Nike's case study

Theory	**Description of theory**	**Nike's case study (application and evaluation)**
Institutional Theory	- Companies' business model and practices will be affected by the external pressure	- Nike reacted to the global demand on sustainable fashion. - Developed sustainable business model and achieve sustainable fashion supply chain
Resources-Based Theory	- Reinforcing the use of precious resources - Responding properly to the environmental opportunities. - Companies gain competitive advantages	- Evaluating the internal company strength and weakness of Nike . - Reinforced the use of company's resources. - Implemented sustainable strategies - Nike and its stakeholders gained competitive advantage.
Decision Making Theory	- Evaluating the real market data - Provides suggestions to make optimal decisions under uncertainty - Decision makers make optimal decisions which generate highest value	- Nike made optimal decisions for sustainable business development. - Nike reacted to the market demand by the developed sustainable business strategies and made correlated decisions.

Through the sustainable business development strategy, leading retail companies can respond to the gathered market information and improve the operations performance to enhance economic growth of the respective sustainable supply chain. Meanwhile, following the suggested steps of sustainable business development strategy, the leading company can develop different strategies and programs to improve the environmental and social performance throughout the sustainable supply chain (Jabbour et al., 2015).

Table 10**.** Features of sustainable business development strategy (SBDS) and the satisfaction of these features by Van & Slawinski (2015)' s approach of tension

Approach	**Method of managing tension**	**Applications of sustainable business development strategy framework**	**Satisfied?**
Win-Win	Avoiding tension via optimization/alignment of sustainable elements	By evaluating the strengths of the retailer and its aligned supply chain stakeholders, retailers are able to plan for strategic alignment which enhance the efficiency of sustainable performance.	yes
Trade off	Avoiding tension via choosing one sustainable element over another	By evaluating the weakness of the retailer and its aligned stakeholder, retailers are able to plan for strategic enhancement of weak-links and avoid failure in sustainability	Yes
Integrative	Managing tension via shifting economic focus to environmental focus and/or social focus	Through evaluating the external market demand of sustainability, the retailers are able to address all the three core elements of TBL and react accordingly.	Yes
Paradox	Rather than resolution of tension, acceptance and exploration of tension is applied	By evaluating the internal and external demand for sustainability, the retailer is able to explore creative solutions which can balance the economic growth with the social and environmental contribution	Yes

CHAPTER 5

Attitudes towards Sustainable Sportswear Development: A Gap Analysis between Consumers and Suppliers

5.1 Introduction

Based on the developed SBDS framework in Chapter 3, we find that there are many inter-related participants in the whole sustainable fashion supply chain. The participants' attitudes towards the implementation of sustainable fashion business would affect sustainable business performance and consumers' satisfaction. Meanwhile, consumers' attitudes towards sustainable fashion are also highly related to their consumption behavior. By studying the consumers' attitudes towards sustainable fashion, suppliers (e.g., retailers, designers, developers, and manufacturers) can uncover directions for sustainable product development. However, in the literature, investigations on the sales and market share of sustainable sportswear products remain under-explored. Gaps may exist between consumers' expectations and the developed sustainable sportswear products. As a result, in this chapter, an in-depth study has been conducted to examine the attitude gaps towards sustainable sportswear development between the sustainable sportswear suppliers (SSSs) and the sustainable sportswear consumers (SSCs).

In this chapter, the key attitudes towards sustainable sportswear development are being identified. Then, how attitudes affect the products being developed. The effects of the attitudes' difference between the SSSs and the SSCs towards sportswear product development and consumption are investigated. A gap analysis methodology is adopted

through questionnaire survey and data collection. The results indicate that a significant difference exists between SSSs' and SSCs' attitudes towards sustainable design, manufacture, product features, and branding. Based on the in-depth interviews, the major causes of the difference in attitudes are studied to provide managerial insights for sustainable sportswear product management and business development.

5.2 Research methodology

5.2.1 Research motivation and research questions

The global sportswear market is growing tremendously in the past ten years. According to Grand View Research (2019), the estimated global sportswear market size was USD 239.78 billion in 2018, which took up over 8% of the global fashion industry. According to Business Wire (2020), although the outbreak of COVID-19 led to significant negative sales impacts in the first quarter of 2019, the impact on the annual economic growth was limited. It is reported that the COVID-19 provides new business opportunities, where in the period of 2020-2024, the expected growth in sportswear market will be around USD 630 million.

Table 11. The 2020 ranking of the top 10 apparel brands (Finance, 2020)

Brand	Category	Rank	2020 Sales	2019 Sales	% Change
Nike	**Sportswear**	**1**	**$34,792**	**$32,421**	**7%**
Gucci	Luxury	2	$17,630	$14,662	20%
Adidas	**Sportswear**	**3**	**$16,481**	**$16,669**	**-1%**
LV	Luxury	4	$16,479	$13,576	21%
Cartier	Luxury	5	$15,015	$13,642	10%
Zara	Fast Fashion	6	$14,582	$18,424	-21%
H&M	Fast Fashion	7	$13,860	$15,876	-13%
Chanel	Luxury	8	$13,705	N/A	N/A
Uniqo	Fast Fashion	9	$12,878	$11,991	7%
Hermes	Luxury	10	$11,909	$10,920	9%

With the expanding sportswear market, more newcomers intend to capture the market share and become the next leader in the sportswear market. According to Baier et al. (2020), fashion companies should take sustainability into business considerations as to stand out from the keen sportswear competition. Nowadays, sportswear consumers are paying full attention to the sustainable properties of sportswear products during purchase. According to Nam, Dong, and Lee (2017), consumers' expectation and attitudes on sustainability will affect their purchase intention upon sustainable sportswear. Meanwhile, studies show that consumers' attitudes towards sustainability is one of the key drivers of sustainable sportswear consumption Biswas and Roy (2015). Through studying the consumers attitudes towards sustainable product, managerial insights can be generated for business improvement (Young et al., 2010).

However, the fashion and apparel industry are well known for generating wastes and leading to pollution (GLF 2018), which is harmful to personal and planetary health. Meanwhile, SSSs (e.g., retail planning manager, designer, and manufacturer, etc.) working as different roles in the product development process, may have different understanding and attitudes towards sustainability. The differences in sustainability attitudes will affect the product being produced and may lead to failure in fulfilling consumers' demands. The purpose of this chapter is to identify the attitude gaps that could exist between the SSSSs and SSCs towards the sustainable sportswear. Through determining the attitudes' gaps between the SSSs and SSCs, managerial insights and guidance can be provided for SSSs upon SPDP. The key research questions are presented as follows:

(1) What are the attitudes towards sustainable sportswear development of the sustainable sportswear suppliers (SSSs) and sustainable sportswear consumers (SSCs)?

(2) What are the attitudes' gaps between SSSs and SSCs towards sustainable sportswear development?

(3) How does the attitudes' gaps affect the SPDP, and what are the corresponding managerial implications?

(4) How could SSSs fill in the attitude gap and develop sustainable sportswear products to satisfy the SSCs' wants?

5.2.2 Survey approach on the attitudes between SSSs and SSCs

Through extensive literature review and analysis of related public data, the key attitudes affecting the sustainable sportswear product development process are identified, including three dimensions of the TBL model (i.e., environmental, social and economic). The critical attitudes towards SPDP and sustainable sportswear development are further determined. After that, an empirical case study is conducted through collection and analysis of the primary data collected by face-to-face questionnaire survey towards sustainable sportswear development. To analysis the attitudes' gap towards sustainable sportswear development between SSSs and SSCs, the questionnaire respondents are divided into two groups. One group is from the SSSs (retailers, designers and manufacturers) and the other group is from the SSCs (consumers who purchase sustainable sportswear). 100 participants from these two SSSs and SSCs groups are studied. The two respondents' groups provide real-life information towards sustainable sportswear development attitudes. Finally, the gap analysis was employed (Marra, Di Biccari, Lazoi, & Corallo, 2017; Scott et al., 1993) through a comparative study on sustainable sportswear development attitudes between the SSSs and SSCs, the

differences of the attitudes between SSCs and SSSs can be examined. Then, through exploring the reason for attitudes differences, the managerial implications upon filling in the attitude gap between SSSs and SSCs for business development and decision-making are discussed.

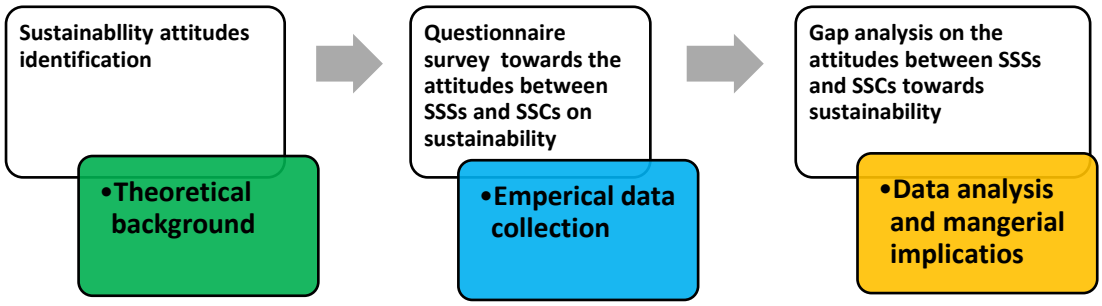


Figure 17. Study flow of the SSSs and SSCs attitudes' gap analysis

5.3 Attitudes identifications of sustainable sportswear development

The main purpose of this section is to identify the attitude gaps that could exist between the SSSs and SSCs towards the sustainable sportswear development. The three major dimensions are investigated to estimate the attitude gaps including i) attitudes towards TBL, ii) attitudes towards sustainable product development, and iii) attitudes towards sustainable sports fashion.

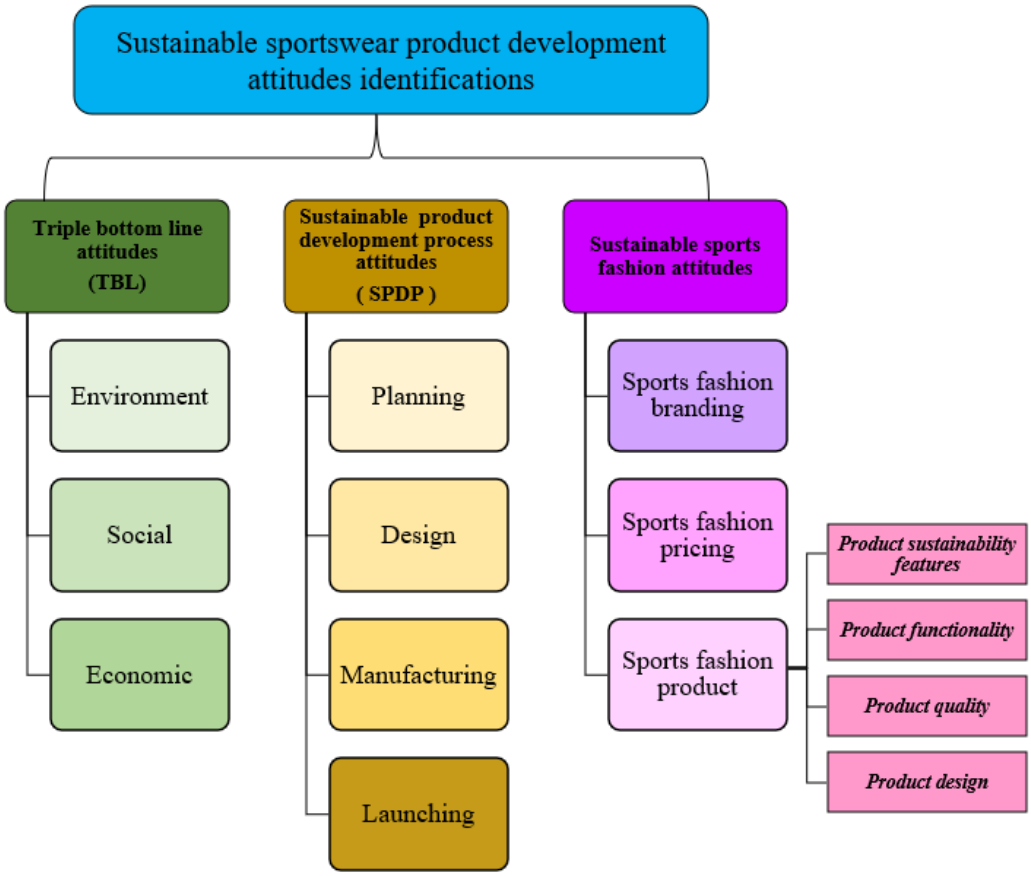


Figure 18. Summary of the three dimensions used to estimate the attitudes gaps towards sustainable sportswear product development

5.3.1 Attitudes towards the triple bottom line (TBL)

Sustainability is not only about the environment, but also about the social and economic development. According to the TBL model, sustainability can be divided into three dimensions, namely: environmental, economic, and social (Elkington, 1998). All the SSSs in the SSSP should contribute to all three dimensions of TBL model. Since the sustainable sportswear development involves many suppliers (product managers, designers, and manufacturers). Each of them may have different attitudes towards sustainability. It increases the difficulties in developing a sustainable product which meets consumers' expectations. Thus, it worth studying the SSSs and SSCs attitudes and their attitudes' gaps towards the three dimensions of TBL.

Table 12. The dimensions and key features of TBL model and the relationship with sportswear industry

Dimensions of TBL model	Key features	Relations to the sportswear industry
Economic	Refers to how the business organizations practices' affects the economic system	• Proper management in business which interoperate with environmental considerations can generate positive economic outcomes (Raza et al 2018). • Consumers' buying behavior is positively related to is attitude towards sustainability
Social	Refers to long-term planetary and human society ecosystem equilibrium, the growth of the human society cannot be neglected	• conduct a fair business practice, such as fair wages, equity, education, health care coverage and family development • Beneficial to labor's capital and the surrounded society or community, and ultimately ensure a healthy growth of the global human living environment
Environmental	Refers to how the business organizations engage in resources planning which safeguard the natural resources without compromising it for the further generations	• Efficient use of resources, such as water and energy as long as minimizing the greenhouse gas emission and ecological footprints • Develop good business reputation

i) Attitudes to environmental dimension: Environment is one of the most important elements in TBL model. It refers to how the business organizations engage in resources planning and safeguard the natural resources without compromising it for further generations (Alhaddi, 2015). It is reported that sportswear apparel and footwear accounts for 8% of the greenhouse gas global emission (Weekendbee, 2020). To deal with this problem, more and more sportswear companies engaged in sustainable business. For example, sportswear brand Puma invested a large sustainability project to reduce environmental impact of the company (Kyle, 2020). Moreover, it is reported that if the business organizations fail to minimize their environmental footprints, they will be suffered from a loss (Blanchard 2012). For example, due to the lack of clear policy upon using sustainable cotton, Ethical Consumers (2020) rated Nike's cotton sourcing policy as the worst among the sportswear market. Thus, it is crucial for business organizations to have an efficient use of resources (e.g., water and energy) and minimize the greenhouse gas emission and ecological footprints (Goel, 2010).

ii) ***Attitudes to social dimension:*** Sustainability seeks for the long-term planetary and human society ecosystem equilibrium; the growth of the human society cannot be neglected. According to the International Labor Organization (2020), the estimated global population ages 15 years old or above in 2019 was around 5.7 billion. Over 50% were included in labor force (3.3 billion) with unemployment rate over 5% (188 million). Meanwhile, it is reported that among the EU countries (excluded UK), over 1.3 million of people were working in the sports related fields in 2019 (Eurostat 2020). One of the largest sportswear brand Nike employed 75,400 employees worldwide in 2020. As an employer, business organization is the key party which affect the employed population. The earnings or profit of business organizations are generated by its workforce. In return, business organizations are responsible for providing its workforce a sustainable working environment. They should conduct fair business practices, such as fair wages, equity, education, health care coverage, and family development, which encourage social responsibility and benefit their labor's capital and the surrounded society or community, and ultimately ensure a healthy growth of the global human living environment.

There is a rise of public awareness towards corporate social responsibility (Pedersen and Gwozdz (2014). If a business organization fails to contribute to social responsivities, there will be a negative effect on corporate reputation, and they will suffer a loss in economic growth (Dhiman,2008). For example, one out of five factories of the sportswear brand puma failed the audits in 2010-2011 (Hickman, 2011). Puma failed to provide reasonable pay and safe working conditions, which harmed its' business reputation and sales. Thus, to ensure the economic growth of the business, sportswear business organizations should pay high attention to corporate social responsibility.

iii) Attitudes to economic dimension: Apart from the environmental and social considerations, the economic dimension is critical for the fashion business. To support the growth of the future generation, Elkington (1998) tied the local business organization growth with the global economic growth, which ultimately support the continuous growth of the economy. So how business organizations can provide positive economic value to the economic system becomes a critical question. It is reported that the global sportswear market in 2018 was around USD 240 billion (Grand view research 2019). Even with the outbreak of COVID-19, the impact of annual economic growth has been limited (Business Wire 2020) and the expected sportswear market growth will be around USD 630 million in 2020-2024. To support the growth of the sportswear market and generate positive economic outcomes, proper management in business which interoperate with environmental considerations is needed (Raza, et al., 2018). According to Laroche et al.(2001), consumers' purchase behavior positively related to their attitudes towards sustainability. The consumers who have positive attitudes towards sustainability intend to buy more if the product include sustainable features (Laroche et al., 2001). This directly increases the business organizations' revenues and becomes the key drivers for fashion companies to enhance their environmental, social, and economic sustainability performance.

5.3.2 Attitudes towards the sustainable sportswear development process (SPDP)

In Chapter 2, we have conducted a comprehensive study of the SPDP, which includes steps such as planning, design, manufacturing and launching. To examine the SSSs' attitudes towards SPDP, the key SSS participants need to be determined for data collection and evaluation.

Table 13. Key suppliers and functions of the sustainable sportswear product development process

SPDP	Sustainable sportswear suppliers (SSSs)	Functions
Planning	• Sportswear Retailer board of management • Retail buyers • Retail Planning Managers • Retail Sales Managers	• Business planning • Research of product • Product planning and costing • Line building production optimization
Product Design	• Sportswear Designers • Materials Designers • Sundries Designers • Technical Designers	• Development of origin style and design • Materials and sundries development • Refine the business objectives
Manufacturing	• Garment Manufacturers • Material Manufacturers • Sundries Manufactures • Merchandisers	• Apparel assembly, finishing and washing. • Fiber production; yarn spinning and dying; knitting and weaving. • Sundries production (e.g. buttons, zippers, grosgrain etc.)
Launching	• Product Analysis • Consumers	• Products analyze and selection for launching. • Product consumption

i) Attitudes to SPDP planning: The board of management of the sportswear retailer needs to discuss with the retail buyers, planners and sales managers upon the business direction and product assortments. According to Simonson (1999), the sportswear buyers' preference on the sustainable differentiation will affect the sustainable business direction. Through data mining, the sportswear planners can work on the sustainable product assortment (e.g., percentage of sustainable products within the product line) and maintain the brand's comparative advantages in sustainability development (Chen, 2007).To facilitate the sales of sustainable sportswear and meet the sales target, the sportswear sales managers need to provide sales plan and strategies for sustainable sportswear business planning (Dissanayake & Sinha, 2015).

***ii) Attitudes to SPDP design*:** Once the sustainable sportswear business direction and sportswear product assortment are confirmed, the designers can start working on the

sustainable sportswear design. According to Carr and Pomeroy (1992), they emphasized the design features of the product development process through exploring the development of origin style and design for meeting or refining the business objectives using backward and forward design refine process. To develop sustainable sportswear products, the apparel product designers need to work with the materials, sundries, and technical designers. Materials is one of the key elements to achieve sustainability. The use of sustainable materials can promote the long-term well-being of the planet and human health Fletcher (2013). For example, the material designers can substitute regular raw materials (e.g., polyester) with eco-friendly raw materials (recycle polyester) for the apparel designers to use Niinimäki (2013). Meanwhile, sportswear product use different sundries (e.g., zipper, draw string, and eyelet) in one product, the sundries designers can design sundries that can be re-manufactured or recycled (Janigo & Wu, 2015), thus enhancing the recyclability of the sportswear product. Sportswear designers may face many difficulties in designing and developing sustainable sportswear products. For example, compared with normal chemical dye stuff, natural dye stuff takes more time to dye, also the impurities may remain in the machine that may be difficult to remove (Gokhale et al., 2004). Thus, the designers need to work with the technical sportswear designers and work out the most practical sustainable design.

iii) Attitudes to SPDP Manufacturing: Fashion apparel production and manufacturing are the key to successfully achieve sustainable fashion. The manufacturing of the sportswear productions involved the participation of many different manufacturers (Gloria et al., 2014). From material manufacturers (raw material suppliers, production, yarn production, fabric manufacturers), sundries manufacturers (buttons, zippers main labels etc.), garment manufacturers (seamless manufacturers, knit and woven apparel

manufacturers), finishing and washing, to packing. Meanwhile, sportswear merchandiser act as the key person to coordinate all the manufacturers who are involved in the sportswear manufacturing process.

iv) Attitudes to SPDP Launching: During the product development process, the designers may design different versions of the same style for comparison. The manufacturers will produce the sample trails of different versions for the designers and planners for review. Considering the consumers' preferences and the business planning directions, the marketing and retailing managers will select the version which best suit their business model for launching. Once the products are confirmed and finished production, it will be launched and delivered to the market for consumption. It is important for the sportswear retailers to gather SSCs' feedbacks of customers or sale reports, then plan for the next season (De Brito et al., 2008). Based on the above studies, we uncover the key SSSs participants of the sportswear product development process and core elements of sustainability. To achieve sustainable sportswear, each participant in the group of SSSP needs to take three TBL dimensions into account for decision-making.

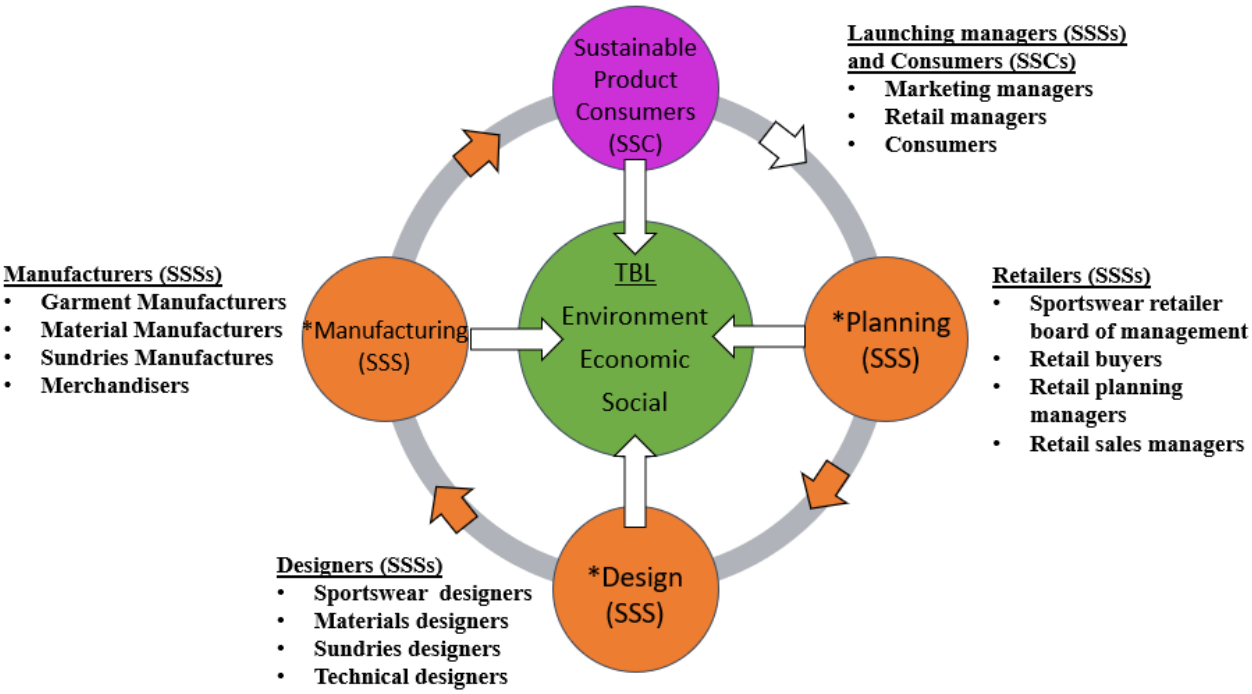


Figure 19. Sustainable sportswear development process and key participants

5.3.3 Attitudes towards the sustainable sports fashion

Apart from the attitude towards sustainability, it is important to identify the critical attitudes towards sustainable sports fashion. It is because, the attitudes towards the sustainable sports fashion will affect SSSs preferences in product development and also consumers' consumption behaviors (Figure 21). The key attitudes towards sustainable sports fashion are: (1) sustainable sports fashion branding attitude, (2) sustainable sports fashion pricing attitude, and (3) sustainable sports fashion product attitude.

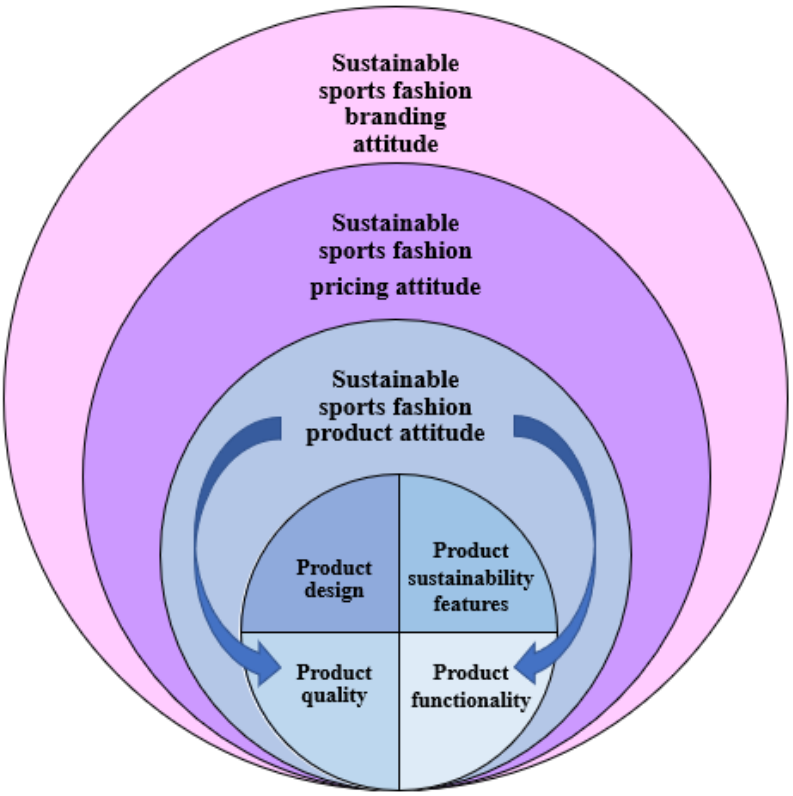


Figure 20. Attitudes towards sustainable sports fashion

i) ***Towards sustainable sports fashion branding:*** Many studies analyze consumers' attitudes towards branding (Chang et al., 2018). The decision-making process of the sustainability-conscious consumers is strongly affected by their attitudes' towards fashion brand (Kim & Hall, 2015). Consumers will process the information gathered from the brands' sustainability schema. If the sportswear brand successfully intercorporate the sustainability management with its businesses, positive consumers' attitudes will be developed which further motivates their buying decisions. Also, sustainable branding and positioning can build a positive corporate social responsibility image and increase consumers' perceived value towards the brand (Chang & Jai, 2015), which will further facilitate the purchase intention of the consumers.

ii) ***Towards Sustainable sports fashion pricing:*** Product pricing strongly affects the buying decision (Chang & Jai, 2015). Consumers have high concerns on the pricing of the sustainable product, as they are usually highly priced Barge, More, and Bhola (2014). Although the sustainability features of the sportswear generate consumers' positive buying intensions, consumers are not willing to pay higher price for the sustainability features. For example, Gam et al. (2010) find that consumers are not choosing organic cotton products over normal cotton products, as the organic cotton price is 60% higher than that of normal cotton products. In New Zealand, Thailand and China, it is observed that the higher the sustainable product price, the higher the negative effects it has on consumers' purchase decisions (Gan et al., 2014; Sriwaranun et al., 2015).

However, if consumers are not willing to pay higher price for the sustainable products, the revenue gain from developing sustainable product will be reduced. This will affect the intention of the sustainable developers to develop sustainable products and ultimately affect their attitudes towards sustainable products. This tug of war between the sustainable product pricing highly affects the sustainable product development and consumption in general (Gregory et al., 2017). Thus, it is worth studying the sustainable product pricing attitude gap between the SSCs and SSSs, thus developing a better understanding of the factors affecting consumers' willingness to pay for sustainable sport fashion product.

iii) ***Towards sustainable sports fashion product:*** The consumers' awareness and concerns towards sustainability strongly affect their buying and consumption behaviors (McNeill & Moore, 2015). Meanwhile, the demands of product strongly account for the end users. It is crucial to study the SSCs' attitudes towards sustainable products and

explore the ethical purchase of fashion products and the corresponding behaviors (McNeill & Moore, 2015). The sustainable product attitudes of the SSSs are also very important. As they are the key players for the sustainable product development. Their attitudes towards sustainable products will significantly affect key features of the final product. Meanwhile, the SSSs are fully equipped with the industrial knowledge which may affect their perceived value of the sustainable products. Instead of developing the product which fits the consumers sustainable value, they may produce the sustainable products in their perspective which may fail to generate positive consumers' sustainable product attitudes, thus demoting their buying decisions. Therefore, understanding the gaps upon sustainable product attitudes between the SSCs and SSDs are essential (Leiserowitz et al., 2006). The product attitudes include: (1) product sustainability features attitude, (2) product functionality attitude; (3) product quality attitude, and (4) product design attitude.

-Product sustainability features attitude: Many studies try to identify the key sustainable features or attributes which encourage the sustainable product consumptions (de Medeiros & Ribeiro, 2017; Stranieri & Banterle, 2017; Zhang, 2014). The SMART © "Sustainable Textile Standard" helps the SSSs and SSCs to address sustainable textile and apparel product attributes throughout the product life cycle based on the TBL (Muthu, 2017). The six main focuses of sustainable textile standards are: (1) sustainable materials; (2) ethnical production; (3) durable and with longevity, (4) recycling and reuse, (5) minimal environmental impact in product life cycle, and (6) harmless and healthy to environment and people.

-Product functionality attitude: Although studies show that consumers' buying behaviors are positively related to their attitude towards sustainability (Laroche et al., 2001), most consumers will not purchase products only because of the sustainability considerations, as consumers are not willing to trade-off the other desirable product attributes for sustainability (Gan et al.,2008). For example, studies show that compression sportswear have multiple functions (Fung & Liu 2019). It can (1) stimulate blood circulation; (2) reduce recurrence of muscular injury (Berry & McMurray, 1987; Kraemer et al., 1998; Muzikante & Reņģe, 2011); (3) reduce muscle soreness (Kraemer et al., 1998); (4) aid recovery (Berry & McMurray, 1987; Davies et al.,2009; Duffield et al., 2010); and (5) enhance lactic acid removal (Davies et al., 2009). All the above functions provide wearer (including aging population) a delightful wearing experience, which can stimulate the health benefit generated from lifestyle sports routine.

-Product quality attitude: The quality of the product highly affects the product attitudes (DeBono, 2000). According to Tsiotsou (2006), the purchase intentions of the products are highly affected by the perceived product quality and corresponding satisfaction. If the product quality does not match with the consumer expectation, that will result in consumer dissatisfaction and have a negative impact on purchase intention and decision. Many researches indicate that the quality attributes of the products affect consumer behaviours (Jorgensen & Jensen, 2012; Ryding et al.,2015), which include quality materials, product durability, and easy care of product. Also, product design is especially important. The design characteristics of fashion and apparel products strongly affect consumers' buying intention as well as the product and brand attitudes (Kim & Ko, 2010).

-Product design attitude: In addition, the design of the products will affect the level of

product sustainability which further affects consumers' attitudes towards sustainable fashion and apparel products (Moon et al., 2013). For example, to fulfil the consumers' desire on sustainable sports fashion, Adidas collaborated with Oceans environmental initiative Parley (Adidas, 2020) and designed a batch of running shoes and compression sportswear made by recycled plastics from the sea. Even the fast fashion brand H&M designed and launched a collection of sportswear named "Conscious" which aims at using sustainable materials for production (Refinery, 2020). The selection of materials and the product details are usually decided during the product design process. Thus, to develop successful sustainable sport fashion products which meet the consumers' expectation, we need to have a clear understanding on consumers' product attitudes towards sustainability.

5.4 Attitudes-oriented questionnaire survey and data collection

To the best of our understanding, no previous study has conducted attitude-oriented questionnaire survey to gather primary quantitative data from both SSSs and SSCs for a gap analysis. In this Chapter, a survey was conducted to obtain primary quantitative data through adopting a theoretical sampling approach (Miles & Huberman,1994; Eisenhardt, 1989), to assess attitudes towards sustainability between SSCs and SSSs. According to Hair et al. (1998) and, Zailani, Jeyaraman, Vengadasan, and Premkumar (2012), the minimum sample requirement is ten respondents to one variable. Thus, the sample size of 100 respondents is considered to be sufficient for this survey. This survey targeted the SSSs who are involved in the sustainable sportswear product development process and the SSCs who consume sustainable sportswear products. The first-tier sportswear companies are considered as the key drivers of the sustainable sportswear industry

(Carter et al.,1998; Zhu et al.,2007). The SSSs who develop and produce sustainable sportswear products in the first-tier sportswear companies are the target of this study. To obtain real market information from the SSCs, we collaborated with a sports gym focusing on healthy lifestyle and selling sustainable sportswear products. Using convenience sampling method, a survey was conducted from September 2018 to March 2019.

In the first phase, the respondents were requested to respond on pre-interview informative screening questions, including screening question and demographic information from both SSSs and SSCs. The respondents were restricted by the first two screening questions. The SSSs respondents who engaged in sustainable sportswear product development process were asked for response. The SSCs respondents must have purchased sustainable sportswear products in the past 12 months as well as have considered sustainability during consumption (Table 14). This approach helped to sort out the potential respondents for further assessment and investigation. A total of 100 valid samples were collected at the end.

Table 14**.** The profile of the SSSs and SSCs respondents

Nature	**Company**	**Industrial Type**	**Short Description**
SSSs	A	Retailing, Tier 1	Selling sports clothing and apparel products with 3 major divisions which including: men's, women's and Kids
SSSs	B	Design, Tier 1	Design and development department in a global trading company which provides design and development service to company A
SSSs	C	Apparel Manufacturer, Tier 1	Producing sportswear products for Company A. The major products include sports tops and bottoms.
SSCs	D	Sports gym	Consumers who buy and use the sustainable sportswear product in the fitness center

As knowledge of a person will directly affect their attitudes and behaviors (Kemm &

Close, 1995), the concept of the sustainability TBL model and the corresponding relations with sustainable sportswear such as the functions of each process and the key suppliers are provided with explanations (Tables 15 and 16). In order to uncover the SSSs and SSCs attitudes towards the sustainable sportswear development, seven questions (Table 17) with a five-point Liker scale (Likert, 1932) from 1 (low extent) to 5 (high extent) were investigated. The Liker scale was a measurement technique that has been widely used in psychometric and psychological studies to determine respondents' attitudes. Three groups of questions with seven aspects of attitudes were designed to measure the SSSs and SSCs attitudes (Table 18). To have a better understanding of the respondents' attitudes, on-site face to face questionnaire survey and interview were conducted and last for 30 to 45 minutes per respondent. Appendix 1 shows the design of the questionnaire survey.

Table 15. Key features of TBL and the corresponding relationships with sportswear industry

TBL model	Key features	Relations to the sportswear industry
Economic	Refers to how the business organizations practices' affects the economic system	• Proper management in business which interoperate with environmental considerations can generate positive economic outcomes (Raza et al 2018). • Consumers' buying behavior is positively related to is attitude towards sustainability
Social	Refers to long-term planetary and human society ecosystem equilibrium, the growth of the human society cannot be neglected	• Conduct a fair business practice, such as fair wages, equity, education, health care coverage and family development • Beneficial to labor's capital and the surrounded society or community, and ultimately ensure a healthy growth of the global human living environment
Environmental	Refers to how the business organizations engage in resources planning which safeguard the natural resources without compromising it for the further generations	• Efficient use of resources, such as water and energy as long as minimizing the greenhouse gas emission and ecological footprints • Develop good business reputation

Table 16. Key suppliers and functions of the sustainable sportswear product development process

SPDP	Sustainable sportswear suppliers (SSSs)	Functions
Planning	• Sportswear Retailer board of management • Retail buyers • Retail Planning Managers • Retail Sales Managers	• Business planning • Research of product • Product planning and costing • Line building production optimization
Product Design	• Sportswear Designers • Materials Designers • Sundries Designers • Technical Designers	• Development of origin style and design • Materials and sundries development • Refine the business objectives
Manufacturing	• Garment Manufacturers • Material Manufacturers • Sundries Manufactures • Merchandisers	• Apparel assembly, finishing and washing • Fiber production; yarn spinning and dying; knitting and weaving. • Sundries production (e.g. buttons, zippers, grosgrain etc.)
Launching	• Marketing Managers • Logistics Company • Warehouse managers • Retail Shop managers	• Supply chain management • Resources and product shipping and delivery • Product distribution and allocation • Customers service

*SSPD= Sustainable sportswear product development process

Table 17. Questions on sustainable sportswear product development

Knowledge	Question	Focus and Options
Sustainability-TBL	Please advise the level of importance towards the key focus of TBL	• Economic • Environmental • Social
Sportswear SPDP	Please advise the level of importance upon the sustainable sportswear product development process which you consider will affect the product sustainability level most	• Planning • Design • Manufacturing • Consumption

Note: Scale: 1=least important; 5=most important

Table 18. Questions on sustainable sportswear

Sustainable sports fashion attitudes	Question	Focus and Options
Branding Attitude	• Please advise the level of importance and ranking towards the sustainable sportswear branding	•Sustainable branding
Product Pricing Attitude	• Please advise the level of importance and ranking towards the sustainable sportswear pricing	•Sustainable product pricing
Sustainable product Attitude	•Please advise the level of importance and ranking towards the sustainable sportswear product	•Sustainable product features • Sustainable product functionality • Sustainable product product quality • Sustainable product design

Note: Scale: 1= most important; 6= least important

5.5. Gap analysis of attitudes and managerial insights

Likert scales are ordinal scale that is widely used in questionnaire survey for attitude measuring (Göb et al., 2007). To measure the attitudes of the two respondents groups (SSSs and SSCs) towards TBL, SPDP, and sustainable sports fashion, the Likert scale is applied in the questionnaire survey of this study. To analyze the altitude gap between the SSSs and SSCs, the independent sample Mann-Whitney U test, a kind of non-parametric significance test, is applied. It is commonly used to measure ordinal variables which are collected without a precise scale (Nachar 2008) and potential differences between the two groups of respondents (Merschmann & Thonemann, 2011; Özden, 2018). For example, Verbeke & Viaene (1998) used U-test to study the attitude gap between Belgium and Poland towards yoghurt preferences by measuring the mean of a five-point Likert scale ranging from strongly agree to strongly disagree. Ngai et al. (2007) studied the Asians and non-Asians consumer behaviour towards hotel services using the same method.

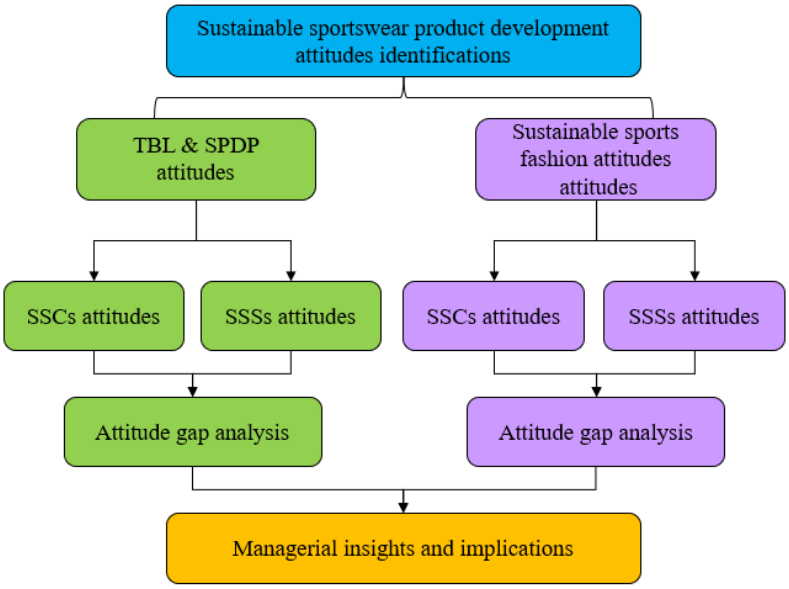


Figure 21. Procedures of the attitude-oriented questionnaire survey on the critical data analysis

5.5.1 Attitude towards the TBL and SPDP

i) SSCs' TBL & SPDP attitudes analysis: According to the questionnaire results (Table 19), among the three core pillars of the TBL, the SSCs respondents paid highest attention to the economic benefit of sustainable fashion with mean score 4.16, which is the highest among all three pillars. Meanwhile, according to Walker (1931) and Wagenmakers et al. (2007), the standard deviation (SD) shows how the group's responds spread out from the mean. The smaller SD implies more response close to the mean. From Table 19, the SD of the attitude towards economic sustainability is the lowest, implying that most of the SSCs (50%) considered the economic considerations to be very or most important compare with that of the environment and social consideration. The SSCs' buying behaviour highly relate to the sustainable economic performance. They highly consider the quality-price ratio. They require the brand and the product be sustainable while the price of the product need to keep in a moderate or acceptable range. Although the mean score of SSCs' attitudes towards social consideration is moderate (mean 3.08), the SD of the response is highest, implying that the response is spread out from and the mean and are relatively extreme. The results indicate that 30% of the respondents consider it is least or not important, with the remaining 14% consider it is a moderate factor for consideration.

However, over 55% of respondents consider social considerations to be very or most important (score 4 and 5). They are extremely sensitive to the corporate social responsibility performance of the brands and companies. In terms of product development process, the SSCs consider the design of the product to be the core factor affecting the level of sustainability. The mean score of SSCs' attitudes towards design is

4.4. where the SD is around 0.6. The group's responds are very close to the mean, that is, the majority of respondents consider that design is the process which highly affect the sustainability level of the product. Meanwhile, SSCs consider that planning is relatively less important towards the level of sustainability. According to the SSCs respondents, they do not fully understand the level of importunacy and difficulties of planning a sustainable business. As launching is the only process where the SSCs and SPSs are being connected, it is interesting to find that the SSCs consider launching is the least important factor which affect the level of sustainability.

ii) ***SSSs' TBL & SPDP attitudes analysis:*** It was found that SSSs respondents paid the highest attention to the economic benefit generated from the sustainable fashion with a mean score of 3.68. To facilitate the sustainable business, it involves high development and investment cost. The SSSs work hard with channel members in committing to the international environmental sustainability standards and passing the compliance. Thus, to make sure they can generate economic benefit, all the SSSs need to balance the cost and revenue. SSSs should place more effort in investigating cost-efficient sustainability projects. However, the SSSs' attitude towards social sustainability is moderate. Based on the survey discussion, the SSSs respondents considered that due to the market demand and international standards, they need to pay attention to social and environmental contribution and balance with the economic benefit.

As mentioned in Section 5.3.1, if the business organizations fail to contribute to social responsivities and fulfil the international requirements, they will suffer a huge loss in business (Dhiman, 2008). Thus, the SSSs cannot neglect the social responsibility towards sustainability. This is consistent with their response towards TBL. In terms of sustainable sportswear product development process, the SSSs considered

manufacturing as the core product development process which affects the level of sustainability with a mean score over 4. Meanwhile, they viewed planning as the second most important process which affects the level of sustainability, where high investigation in long term and short-term planning is needed upon developing a sustainable business. Surprisingly, the SSSs placed least attention to sustainable design. Same case as launching process, they considered design not to be the key factor which affects the sustainability level.

iii) ***Gap analysis on the TBL & SPDP attitudes between SSCs and SSSs****:* As discussed above, we have studied the SSCs and SSSs attitude towards sustainability upon sustainable sportswear. In this Section, we attempted to analyze the attitude gap between the SSSs and the SSC. Independent sample Mann-Whitney U test is used to analyze the potential differences between the two groups of respondents (Merschmann & Thonemann, 2011; Özden, 2018). If the significant value (Sig) is lower than 0.05, we consider that the attitude difference between the two groups is significant. By comparing the mean score between the SSCs and SSSs responses, we can identify the attitude gap between the SSSs and SSCs. Table 19 shows the gap between the SSCs' and SSSs' responses towards sustainable knowledge attitude upon sustainable sportswear. While Table 20 shows the summary of hypotheses testing.

TBL attitude gap: The independent sample Mann-Whitney U test results (Table 20) shows that except the environmental and social attitude of the TBL, the sustainability attitude between the SSSs and SSCs are different in all other aspects. For the TBL, both SSCs and SSSs respondents considered the economic benefit generated by the sustainable sportswear was most important. However, the mean of SSCs is higher than

SSSs, where the significant value (Sig) was smaller than 0.05. This means that, although both SSCs and SSSs had the same attitude towards TBL, there was still a significant difference between their responses. This implies that the SSSs should spend more efforts on generating higher economic value. According to the SSCs advice, sustainability is probably a marketing gimmick instead of actual business. Thus, it is not able to support the SSSs and invest in long-term sustainability business. The SSCs suggested that the SSSs should place more effort in investigating cost-efficient sustainability projects, for example, the energy-saving, reducing water consumption cost, increasing the workforce efficiency, and eliminating the use of child labor. To fulfil the demand the SSCs, SSSs should investigate how to generate economic benefits from sustainability projects and boost the intention of keeping sustainable business in the long run. Meanwhile, more resources are needed to place in improving the economic sustainability of sustainable sportswear.

SPDP attitude gap: In terms of the sustainable sportswear product development process, there is a significant difference between the SSSs and SSCs' attitudes towards sustainable design. The sig value of the independent sample Mann-Whitney U test is 0.00 (Table 19) means there is a significant difference between the two respondent groups (mean score difference 1.24). Compared with the SSSs (mean score 3.16), SSCs consider design as an essential factor (mean score 4.4), which affects product sustainability. To fill in the gap, the SSSs should not only focus on sustainable manufacturing. They should pay higher attention to sustainable sportswear design and more resources should be allocated to sustainable product design and development. SSSs should examine ways to support and facilitate the sustainable design process. More training should be provided to designers upon the sustainability standards and requirements.

Contrastingly, instead of design, the SSSs considered manufacturing the most important process which affects the level of sustainable fashion. SSSs may be over emphasizing the performance of manufacturing. They should pay higher attention to other PDP. Meanwhile, attitude of SSCs and the SSSs towards sustainable product launching are similar. The retailer should educate both SSSs and SSCs upon the sustainability implication of product launching. Also, as the mean difference between the two group towards planning is high, SSSs may interoperate with SSCs upon planning and decision making (e.g., questionnaire survey, focus group, sales data collection and analysis).

5.5.2 Attitudes towards the sustainable sports fashion

i) SSCs' sustainable sports fashion attitudes analysis: The SSCs respondents considered the price most, followed by the functionality and design of the product when making their consumption decisions (Table 19). The SSCs are highly price conscious. Over 54% of SSCs respondents ranked 1 or 2 in the importance of product pricing, with the mean ranking 2.46 which is the highest among all 6 sustainable sportswear product attributes. Based on the survey, the consumers buying intention is mainly based on the pricing of the product. They are willing to spend more on products with desired functionality which fits their sports requirements. Although (Laroche et al., 2001) studied that consumers' buying behavior is positively related to their attitude towards sustainability. However, most of the consumers will not purchase products only because of the sustainability considerations, as consumers are not willing to trade-off the other desired product attributes for sustainability (Gan et al., 2008; Tang & Chan, 1998).

Meanwhile, the SSCs paid high attention to the design features and willing to pay higher

price if the sportswear is good looking or trendy. Thus, the ranking of the product design is relatively high. The selection of materials and the product details are usually decided during the product design process. Thus, to develop successful sustainable sportswear products which meet consumers' expectation, we need to have a clear understanding on consumer's product attitude towards sustainability during the design stage. Furthermore, in terms of sustainability product attitude, the mean ranking of sustainability features is the lowest (mean ranking 5.2). According to the survey discussion, the SSCs co-related sustainability features with the quality. For example, the SSCs respondents considered sustainable features like organic cotton and natural dyes as a premium quality. This is also reflected by the mean ranking with product quality (mean ranking: 3.24). Besides, the SSCs are not highly concerned about the sustainable branding. Consumers will process the information gathered from the brands' sustainability schema. If the fashion brand successfully intercorporate the sustainability management with its businesses, positive consumer attitude will be developed which further motivates their buying decisions. Some of the consumers expected that the giant companies should "build in" sustainable management in their business which is their "duty". They may not buy more from the brand due to its sustainability branding. However, they will buy less if they fail to contribute to sustainability or have ethnical issue in carrying out sustainable management.

ii) SSSs' sustainable sports fashion attitudes analysis: The SSSs industrial respondents pay highest attention to the product quality and the functionality (Table 21). According to the SSSs, they are highly committed to the product quality and functionality. It is because, they need to make sure the product meets the requirements of the retailer's and meet the international standards. Thus, they consider quality and

functionality as the most important factors which affect the sustainable sportswear product development (mean ranking 2.58 for both factors). Meanwhile, the pay high attention to the product pricing. It is observed that the higher the sustainable product price, the higher the negative effects it has on consumers' purchase decisions (Gan et al., 2008; Gan et al., 2014; Sriwaranun et al., 2015). However, if the consumers are not willing to pay higher price for the sustainable product, the revenue gain from developing sustainable product will be reduced. Especially for the sportswear, the requirements from both retailer and consumers upon the functionality is high. To claim the sportswear with "functions", the sportswear need to go through many testing and wear trials which require high technology and specialist's input which imply higher cost. The SSSs pay high attention to price (mean ranking 3.14), whether the increase in wholesale or retail price can cover the investment in technology and manpower.

In terms of sustainable sportswear product attitude, the product design rank relatively low (mean ranking 3.40). The SSSs respondents discussed that the designers need to inter-cooperate with manufacturers and technologist. It is because, due to technical constrains, some design may not be achievable, and designers may need to compromise with some design details. To realize some design features, manufacturers need to work with technologist on the method for implementation. Also, trade-off between product design manufacturing affects the sustainable design attitude. On the other hand, the sustainable product attitude of the SSSs towards sustainability features is also very important. As they are the key players for the sustainable product development, their attitude towards sustainable product will significantly affect the key features of the final product. Meanwhile, the SSSs are fully equipped with the industrial knowledge which may affect their perceived value of the sustainable product. Instead of developing the

product which fits the consumers sustainable value, they may produce the sustainable product in their perspective which may fail to generate positive consumer sustainable product attitude and demote the consumers' buying decision. Thus, understanding the gap between the SSCs and SSSs upon sustainable product attitude are essential. Thus, we can develop products which fill the gap.

In order to create a positive consumer product attitude which encourages buying decisions, the SSSs need to ensure that the sustainable product they developed are equipped with the sustainable product features which are desired by the consumers (Leiserowitz et al., 2006). However, according to the SSSs respondents, they consider the sustainability features is correlated to the branding of the retailer's policy like the social responsibility of fair wages or reduce the carbon emission and is more macro-view instead of product considerations. Thus, the ranking of the sustainability features and branding is relatively low (mean ranking 4.16 and 5.14, respectively).

Table 19**.** Gap analysis towards sustainability product development attitude

Categories	Sustainable product development attitudes	SSSs Mean	SSCs Mean	Mean Diff	SSSs Std D	SSCs Std D
Sustainability attitudes (TBL)	Economic Attitude	**3.680**	**4.160**	**-0.48**	.9781	**.7918**
	Environmental Attitude	3.520	3.420	0.1	.9947	.9278
	Social Attitude	3.400	3.080	0.32	.6389	1.2911
Sustainable sportswear product development process (SSPDP)	Sustainable Planning Attitude	3.360	2.720	0.64	.8020	1.0506
	Sustainable Design Attitude	3.160	**4.400**	**-1.24**	.6809	**.6061**
	Sustainable Manufacturing Attitude	**4.200**	3.660	**0.54**	**.7559**	.8715
	Sustainable Consumption Attitude	3.160	2.660	0.5	.9765	.9817

Note: Likert Scale: 1=low importance; 5= highly importance
Mean Diff: the difference between SSSs Mean and SSCs mean

Table 20. Illustration of Independent sample Mann-Whitney U test hypotheses

Categories e	Hypotheses	Null Hypotheses	Results	Sig
Trible bottom line (TBL)	H1a	The attitude of SSSs and SSCs upon economic consideration is the same	Reject	.007
	H1b	The attitude of SSSs and SSCs upon environmental consideration is the same	Retain	.475
	H1c	The attitude of SSSs and SSCs upon social consideration same	Retain	.971
Sustainable sportswear product development process (SSPDP)	H2a	The attitude of SSSs and SSCs upon sustainable planning is the same	Reject	.007
	H2b	The attitude of SSSs and SSCs upon sustainable design is the same	Reject	**.000**
	H2c	The attitude of SSSs and SSCs upon sustainable manufacturing is the same	Reject	**.001**
	H2d	The attitude of SSSs and SSCs upon sustainable launching is the same	Reject	.011

Sig: Significant value of (Independent Sample Mann-Whitney U test)

iii) Gap analysis of SSCs' and SSSs' sustainable sports fashion attitudes: After identifying the gap towards sustainable product development, we move forward to examine the sustainable sportswear attitude gap between the SSCs and the SSSs. Table 21 shows that in terms of sustainable branding attitude, although the ranking for both SSCs and SSSs are relatively low, we discovered that there is a huge gap between the two respondent groups. According to Table 22, the result of independent sample Mann-Whitney U test is 0.00, which implies that the difference between the two respondents' groups towards branding is significant. Almost 45% of the SSCs respondents consider sustainable branding moderately important (rank 3-4), while over 75% of SSSs respondents consider sustainable branding relatively less or least important (rank 5-6). As discussed in Section 5.2.2, the SSSs consider sustainable branding a macro-management concept which is not highly related to the sustainable product development. The channel members are not highly committed to develop sustainability features. Similarly, the SSCs consider the giant sportswear companies like Nike and Adidas should "build in" sustainable management in their business. However, the significant

attitudes' gap between the two groups implies that the SSCs pay higher attention in sustainable branding. If the retail brand fails to manage its' upstream members (SSSs) in sustainability performance, it will be harmful to the business. Thus, as the lead of the product development process, the retailer should raise the SSSs' attention on their own sustainability contribution and performance throughout the sustainable sportswear product development process.

Meanwhile, the result of Independent sample Mann-Whitney U is 0.00, which implies that the difference between the two respondent groups towards sustainable product attitude is significantly high. Although both SSCs and SSSs respondents pay less attention to product sustainability features, surprisingly the SSSs respondents pay significantly less attention than SSCs. Over 85% or SSSs respondents rank sustainability features as less or least important (rank 5 and 6). Contrastingly, SSCs are more concerned on the sustainable features compared to the SSSs respondents, with over 40% rank 3 and 4. This gap in attitude implies that the SSSs should pay higher attention in developing sustainable features. The SSSs should invest more resources in and contribute more to sustainable product development. Meanwhile, SSSs should provide more sustainability information to the SSCs and distinguish product sustainability feature from product quality, thus additional credits can be generated.

As discussed in Section 5.2.1 and 5.2.2, the responses from both respondent groups towards product functionality are similar (Table 21; mean ranking difference 0.46). Both groups consider functionality is one the key features of the sustainable sportswear products, with 50% of both respondent groups rank 1 or 2. This shows that the SSSs

should be able to meet the SSC's expectation and provide products that meets the SSCs' perceived value upon product functionality and increase the SSCs' consumption satisfaction. For the product quality attitude, the SSSs' pay higher attention to quality than the consumers do (Table 21; mean ranking gap 0.66). As mentioned on Section 2.3 and 2.3, SSCs are lacking industrial knowledge upon product quality standards which may result in the gap between the SSCs and the SSSs towards sustainable product quality. The SSSs pay higher attention to the product quality, which means they are willing to develop good quality products which may exists the SSCs' expectoration and that should be a good sustainable sportswear product development intention and benefit both SSCs and SSSs. Thus, the SSSs should keep up the with the high-quality standards during the sustainable sportswear product development process. From Table 21, it shows that discrepancy upon the design attitude is relatively low (-0.34). SSCs pay higher attention to product design compare with the SSSs. As mentioned in Section 5.2.2, there are trade-off between design and manufacturing. To bridge the gap, the SSSs need to work together and find out the optimal solution to maintain the level of design.

In terms of pricing attitude, Table 21 shows that the attitudes of SSCs and the SSSs towards sustainable product pricing are similar. Almost 55% of SSCs respondents rank 1 or 2 for pricing, similarly, where, over 40% of SSSs consider pricing the most or particularly important (Ranks 1 and 2). Both responding groups consider that pricing of the product is one of the highest concerns towards product consumption and development. It is because, the pricing of the product strongly affects the buying intention and the cost of development and production. Thus, SSSs should pay high attention to costing and pricing controls during the sustainable sportswear product development process.

Table 21. Sustainability sports fashion attitude gap analysis

Sustainable Sportswear Attitude	SSSs' Mean	SSCs' Mean	Mean Difference	SSSs' Std.D	SSC s' Std.D	SSS's Rank 1+2	SSCs' Rank 1+2	SSS's Rank 3+4	SSC's Rank 3+4	SSS's Rank 5+6	SSC's Rank 5+6
Branding Attitude	5.140	4.000	**-1.14**	1.1954	1.3401	4%	18%	20%	**44%**	**76%**	38%
Product Pricing Attitude	3.140	2.460	-0.68	1.5388	1.3734	**42%**	**54%**	34%	38%	24%	8%
Sustainability Features Attitude	4.160	5.200	**1.04**	1.5167	1.2936	16%	8%	**42%**	6%	**42%**	**86%**
Product Functionality Attitude	2.580	3.040	0.46	1.2631	1.9162	**50%**	**50%**	40%	18%	10%	32%
Product Quality Attitude	2.580	3.240	0.66	1.6299	1.4786	**50%**	30%	32%	**50%**	18%	20%
Product Design Attitude	3.400	3.060	-0.34	1.5649	1.3614	**38%**	40%	32%	**44%**	30%	16%

Note: Scale: 1=most important; 6=least important
Note: Ranking according to the mean of the responds.

Table 22. Illustration of Independent sample Mann-Whitney U test hypotheses towards sustainable sports fashion

Sustainable Sportswear Attitude (SSFA)	Hypotheses	Null Hypotheses	Results	Sig
Sustainable Branding Attitude	H3a	The attitude of SSSs and SSCs upon Branding is the same	Reject	**0.000**
Sustainable Product Pricing Attitude	H3b	The attitude of SSSs and SSCs upon Product Pricing is the same	Reject	0.025
Sustainable Features Attitude	H3c	The attitude of SSSs and SSCs upon Sustainability Features is the same	Reject	**0.000**
Sustainable Product Functionality Attitude	H3d	The attitude of SSSs and SSCs upon Product Functionality is the same	Retain	0.463
Sustainable Product Quality Attitude	H3e	The attitude of SSSs and SSCs upon Product Quality is the same	Reject	0.023
Sustainable Product Design Attitude	H3f	The attitude of SSSs and SSCs upon s Product Design is the same	Retain	0.245

Sig: Significant value of (Independent Sample Mann-Whitney U test)

5.6 Summary

According to the empirical research and gap analysis, we uncover the attitudes' gap between the SSSs and SSCs towards sustainable knowledge and sustainable sportswear. Figure 23 shows that the highest discrepancy between the 2 groups is the attitude towards sustainable branding, product design, and product sustainability feature. Based on the gap analysis, it is interesting to find that even the 2 groups have similar attitudes towards

the same sustainable sportswear development feature, the mean attitude discrepancy between them is still high. For example, both SSSs and SSCs consider branding to be least important or not important, with mean ranking towards sustainable branding relatively low. Most of SSSs' (76%) rank branding as the least important (rank 5&6), while most of SSCs (44%) rank branding as not important (rank 3&4). However, compared to SSSs, SSCs pays more attention to branding than SSSs (mean difference -1.14). This shows that SSSs does not pay enough attention to branding, which implies further investigation towards how the SSSs should work to minimize the attitude gap towards branding. Table 23 summarized the behavior implications of both SSSs and SSCs attitude and the corresponding managerial insights and applications.

The demand for sustainable sportswear is growing fast, which draws the SSSs attention and motivates SSSs to find ways to enhance the sustainable sportswear product development process. To develop successful business, it is crucial to have a better understanding of the SSSs and the SSC's preferences. This paper first identifies the key factors of SSSs and examines the inter-relations between each SSS in the sustainable sportswear complex. Then, based on the knowledge-attitude-behavior model, we developed a knowledge-attitude-behavior framework of the sustainable sportswear product development which provides a guidance to SSSs upon how to collect and analysis data to narrow the gap between SSSs and SSCs, managerial insights can be generated facilitating SSSs developing sustainable sportswear to meet consumers' expectations.

Figure 22. The attitudes' gaps between SSCs and SSSs towards sustainability sportswear product development

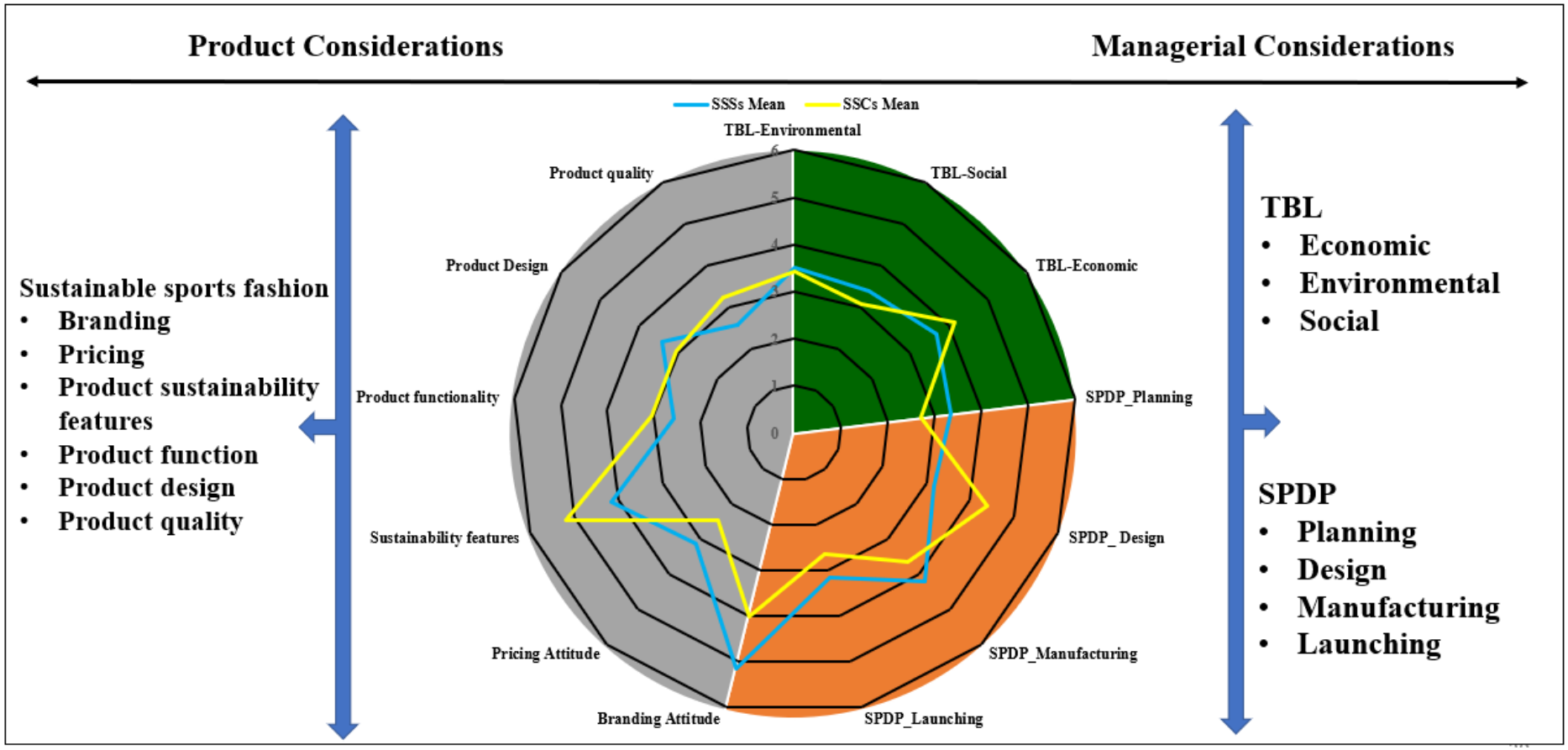


Table 23. Gap analysis and managerial implications of sustainable sportswear product development

Sustainable Sportswear Attitudes	SSSs Mean	SSCs Mean	Mean Difference	Sig	SSSs' Behavior	SSCs' Behavior	Managerial Insights and Solutions
TBL-Environmental Attitude	3.52	3.42	0.1	0.475	Pay higher attention to environmental consideration. Work hard with channel members in committing to the international environmental sustainability standards and passing the compliance.	Responds to environmental consideration is comparatively higher Consider the company should build-in the environmental control in their business model.	Lowest discrepancy with SSCs Investigate in cost-efficient sustainability projects, the energy-saving, reducing water consumption Interco-operate with channel members to achieve sustainable business
TBL-Social Attitude	3.4	3.08	0.32	0.971	Responds to Social consideration is moderate. Mainly bound by the international social warfare standards and compliance check	Responses are relatively extreme Over 55% of respondents consider social considerations very/most important Sensitive to the SSSs corporate social performance	SSSs pay attention to the corporate social responsibility. Increasing the workforce efficiency and eliminating the use of child labor.
TBL-Economic Attitude	3.68	4.16	-0.48	0.007	Pay the highest attention on the economic benefit generates from the sustainable fashion Cost- revenue balance is critical for SSSs to keep the sustainable business	Pay highest attention to the quality price- ratio Product should equip with sustainability feature without high increase in price	Balance the sustainable development cost and the revenue Provide high quality- price ratio product to the SSCs SSSs should place more effort in investigating cost-efficient sustainability projects
SSSS-Sustainable Planning Attitude	3.36	2.72	0.64	0.007	Consider planning as the second most important process which affects the level of sustainability High investigation in long term and short-term planning upon develop a sustainable business	Consider planning is relatively less important towards level of sustainability SSCs may not fully understand the difficulties of planning a sustainable business	Mean difference between the two group is high SSSs may interoperate with SSCs upon planning and decision making (e.g. questionnaire survey, focus group, sales data collection and analysis)
SSSS-Sustainable Design Attitude	3.16	4.4	**-1.24**	**0**	Design is the least important towards sustainability level	Design of the product is the core factor which affects the level of sustainability	Significant difference between the SSSs and SSCs' attitudes towards sustainable design SSSs should investigate how to support and facilitate the sustainable design process. Provide trainings to designers upon the sustainability standards and requirements
SSSS-Sustainable Manufacturing Attitude	4.2	3.66	**0.54**	**0.001**	Consider manufacturing as the core product development process which affects the level of sustainability	Consider manufacturing as the second most important process which affects the level of sustainability	Significant difference between the SSSs and SSCs' attitudes towards sustainable manufacturing SSSs may be over emphasize in the performance of manufacturing. They should pay higher attention in other PDP
SSSS-Sustainable Launching Attitude	3.16	2.66	0.5	0.011	Consider launching is the least important towards sustainability level	SSCs consider launching is the least important factor which affect the level of sustainability	Attitude of SSCs and the SSSs towards sustainable product pricing are similar The retailer should educate both SSSs and SSCs upon the sustainability implication of product launching.

SSFA-Sustainable Branding Attitude	5.14	4	**1.14**	**0**	SSSs co-related the retailer's branding with the retailer's and sustainability policy (e.g. the social responsibility of fair wages or reduce the carbon emission)	Not highly concern with the sustainable branding Have high expectation on sustainable branding and business management Will buy less if they fail to contribute to sustainability or have ethnical issue in carrying out sustainable management	SSCs pay higher attention in sustainable branding then the SSSs Retailer should raise the SSSs' attention on their own sustainability contribution and performance throughout the sustainable sportswear product development process
SSFA-Sustainable Product Pricing Attitude	3.14	2.46	0.68	0.025	Pay attention if the increase in wholesale or retail price can cover the investment in technology and manpower	Highly price conscious SSCs' buying intention mainly based on the pricing of the product	Attitude of SSCs and the SSSs towards sustainable product pricing are similar Pricing of the product is one of the highest concerns towards product consumption and development SSSs should pay high attention on costing and pricing control during the sustainable sportswear product development process
SSFA-Sustainable Sustainability Features Attitude	4.16	5.2	**-1.04**	**0**	Ranking of the sustainability features and branding is relatively low SSSs consider sustainability features as a Macro-view SSSs are not highly committed to develop sustainability features	Mean ranking of sustainability features is the lowest Consider sustainability features should be "build in" in the brand's business management Co-relate sustainability features with the quality	Huge gap between SSCs and SSSs towards the product sustainability features attitude SSSs should provide more sustainability information to the SSCs and distinguish sustainability feature from quality SSSs should pay higher attention in developing sustainable features. SSSs should invest more resources and contribute more to sustainable product development
SSFA-Sustainable Product Functionality Attitude	2.58	3.04	-0.46	0.463	Pay highest attention on the product functionality Go through many testing and wear trials Requires high technology and specialist's input	Willing to higher for products functionality which fits their sports requirements	Both groups consider functionality is one the key features of the sustainable sportswear products SSSs can meet SSC's expectation and provide products which meets the SSCs' perceived value upon product functionality and increase the SSCs' consumption satisfaction
SSFA-Sustainable Product Quality Attitude	2.58	3.24	-0.66	0.023	Highly committed to the product quality Make sure the product quality meets the requirements of the retailer's and meet the international standards	Co-relate sustainability features with the quality Lack of industrial knowledge upon product quality standards	SSSs' pay higher attention on quality then the consumers SSSs should provide more sustainability information to the SSCs and distinguish sustainability feature from quality
SSFA-Sustainable Product Design Attitude	3.4	3.06	0.34	0.245	Product design rank relatively low. Designers need to inter-cooperate with manufacturers and technologist Due to technical constrains, some design may not be able to achieve, and designers may need to compromise with some design details	SSCs consider product design is the core factor which affects the level of sustainability Willing to pay higher price if the sportswear is good looking or fit the trend	Discrepancy upon the design attitude is relatively low SSSs need to work together and find out the optimal solution to maintain the level of design

CHAPTER 6

A New Three-dimensional Performance Assessment Approach on Sustainable Development Process of Sportswear

6.1 Introduction

In prior studies, environmental impact, economic performance, and social responsibility, are commonly considered separately. Interrelations between the three-dimensions of sustainability are rarely reported. The development process of sustainable sportswear products is complicated. Changes in the product components (e.g., materials, manufacturing methods, and product design) of sportswear will correspondingly influence supply chain activities and meanwhile affect environmental, economic, and social performances. Through the assessment of the social, environmental, and economic sustainability performance of the fashion industry, sustainable product developers (designers, retailers, and manufacturers) can address the problems associated with the developed products.

In Chapter 6, the interrelations between different sustainability performances and how the interrelations can help product developers strike a balance among the three sustainability dimensions are explored. Based on the findings, a set of three-dimensional (3D) assessment indicators is introduced. To examine the applicability of the developed indicators, six pairs of sportswear legging products were developed. The developed sportswear legging products were assessed in terms of the interrelated dimensions of environmental, economic, and social performances. The results

demonstrate the effects of shifting in design details and product functions on the environmental, social, and economic performances of sportswear products. The outcome of Chapter 6 provides insights on the approach to balance the three dimensions of sustainability and the development of cost-effective and sustainable sportswear products for sportswear developers.

6.2 Research Methodology

6.2.1 Research motivation and research questions

It is reported that the sports fashion market has been growing globally in the past ten years (GVR, 2020b). The sportswear market contributed 8% of the total fashion industry, accounting for almost USD 240 billion in 2018. According to GVR (2020b), the global sportswear market will significantly grow at a 10.4% compound growth rate from 2019 to 2025. Furthermore, in 2023, the global sustainable fashion market is expected to be over USD 8 billion at a compound annual growth rate of over 10% after recovering from COVID-19 in 2019 (Technavio, 2020b). This tremendous growth of sustainable sportswear draws the fashion retailers' attention upon developing sustainable sportswear products.

However, how the retailer can develop sustainable sportswear products that meet the market demand is critical. The sportswear product development process is highly complicated, involving many participants, and their functions and responsibilities may vary over different fashion supply chain structures (Fung et al.,2021). Thus, developing a sustainability performance assessment method for the sustainable sports fashion participants to follow throughout the product development process is critical. To assess the performance of the developed product for business planning and development, an

empirical study with a set of indicators' design is conducted based on below aspects,

1) developing a sustainability performance assessment method for sustainable fashion product development.

2) studying the current sustainable fashion product development indicators and identify the most relevant indicators for sustainable fashion product development assessment.

3) analyzing the interrelation among the indicators, and

4) applying the indicators to real-life examples.

6.2.2 Study flow

Figure 23 shows the study flow of the 3D sustainability performance assessment approach. Existing researchers (Basbagill et al., 2013; Kozlowski et al.,2012; Zamani et al., 2017) attempted to assess the SPDP through SPA; however, these studies mainly focused on environmental and social sustainability without considering economic aspect. To the best of our knowledge, in the sustainable fashion product development performance assessment domain, no previous study covers all three dimensions of the TBL model (environmental, social, and economic). Therefore, the theoretical background of sustainability performance assessment (SPA) with respect to the TBL model is examined first.

Then, a three-dimensional SPA method is proposed to assess the sustainable sports fashion product. To apply the proposed method to real development, six pairs of proof-of-concept sportswear leggings were developed. The assessment data on economic, environmental, and social aspects are collected. The collected data are analyzed by using z-score data normalization (Basbagill et al., 2013; Calandro, 2007; Dibley et al., 1987; Minium et al.,1993). Managerial insights are generated based on the investigation.

This study provides a profile to product developers for decision-making in the product development process.

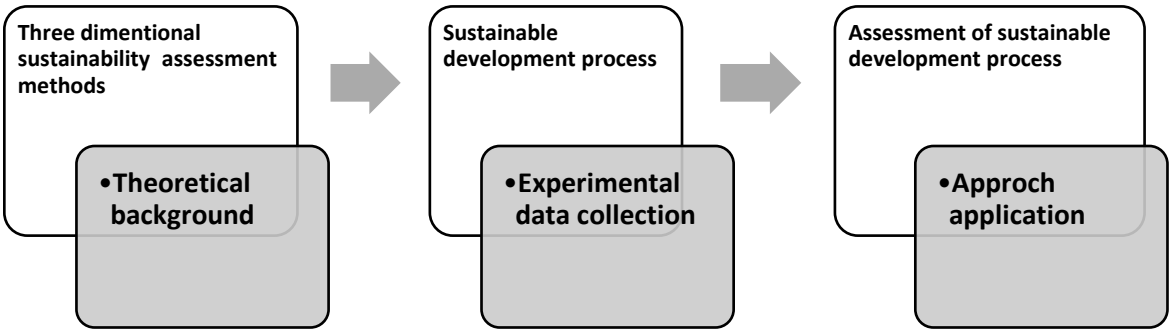


Figure 24.The study flow of the 3D sustainability performance assessment approach

6.3 Development of a 3D performance assessment approach

Performance assessment is a tool to evaluate the impacts of the whole product development process (planning, design, manufacturing and launching), thus helping to select the most relevant indicators to identify the performance aspects for further evaluation (Kozlowski et al., 2012). Massive studies have been conducted to explore the application of performance assessment towards sustainable fashion industry (Basbagill et al., 2013; Kozlowski et al., 2012; Zamani et al., 2017). According to Brundtland et al., (1987), sustainability performance assessment is an excellent tool to assess sustainable product development performance. The sustainability performance assessment can be divided into three modules (Ekvall, 2002), (1) attribute performance assessment, (2) consequential performance assessment, and (3) macro-economic performance assessment (Table 24).

Table 24. Product performance assessment properties and applications in sustainable sportswear

Types performance assessments	Properties	Applications in sustainable sportswear industry
Attribute performance assessment	- Linear method - Input and output analysis - Focuses on the environmental properties of the product performance	• Materials input and output analysis (e.g., fibers, yarn, fabric, water, energy)
Consequential performance assessment	- Nonlinear method - Study and access the effects of the changes in product	• Analysis the social impact (manpower usage), upon the change in product design
Marco-economic performance assessment.	- Record the monetary transactions of different industrial sectors throughout the product development process - Analyze the money flow between different sectors and evaluate the economic value of product and its contribution to the macro-economy	• Record the monetary transaction data of the sustainable product development developers • Analysis their economic contribution for further improvement

Attribute performance assessment (ASPA): It is a linear method that focuses on the product's environmental properties. By studying the input and data upon environmental properties, various product performances (Andrews et al., 2009) can be compared. Then, the problem can be identified for improvements. For example, through analyzing the input and output of materials in the sportswear manufacturing process, the manufacturer can have a clear picture of material usage and material wastage. This can help improve environmental sustainability as manufactures can have better control on material usage and reduce wastage during the production of sportswear.

Furthermore, as consumers are seriously concerned about the environment, they will seek more information and knowledge about sustainable products. Kallgren and Wood (1986) study that one's attitude relies on their knowledge. Based on consumers' purchase experience, they can gain more knowledge about sustainable sportswear products. Ernst and Spada (1993) study that the relationship between environmental knowledge and environmental behavior is positive. Environmentally conscious consumers who possess higher sustainability knowledge tend to have sustainable

consumption attitudes (Weller & Walter, 2013). Providing sufficient information for consumers upon the environmental-related input and output data (e.g., material usage and wastage) is critical for comparison and evaluation of the actual consumption. However, there are drawbacks to ASPA. It cannot capture the effect of changes throughout the product performance (Weidema, 2003). Plevin, Delucchi, and Creutzig (2014) advise that we cannot only rely on the studies from ASPA to make managerial decisions upon the product development process. It is because the real-world impact is unpredictable. Thus, the consequential performance assessment (CSPA) study is increasingly being paid attention to.

Consequential performance assessment (CSPA): The CSPA studies the effects of product performance changes. By using the nonlinear optimization economical methods, the effect of the change of product performances can assessed (Yang 2016). For example, apart from the actual material input and output data, the CSPA accounts for various institutional aspects such as the social sustainability impact of using substitute input and the corresponding factors of constraints (Ciroth et al., 2008). According to Curran et al. (2005), CSPA studies the changes in the relevant flows, responding to a decision. By comparing the effects of different adaptations and decisions, the best choice, leading to the least environmental influence, can be determined.

In this study, the effect of the changes of the product designs and features towards social sustainability is explored. The changes in product features and designs affect also manpower usage. For example, additional sportswear features will increase the consumption of time for designing and manufacturing of product which induces more

manpower and ultimately affects the social sustainability. Through CSPA, the effect of the change product performance with respect to the change in product features can be captured and assessed. Besides, as the consumer's perceived value and impact are difficult to measure, it is hard to show the actual social inference. It is because most of the consumers are not equipped with textile apparel knowledge; they cannot convert their perceived qualities to measurable criteria. Therefore, measurable criteria are crucial and necessary for product developers, as they can serve as a guide for design and manufacturing.

However, CSPA also has some drawbacks, as some of the unrealistic assumptions and restrictions may underestimate the actual effects of the change and decisions (Barker 2004). As such, researchers intercorporate the macro-economic input and output tables with the SPA called macro-economic performance assessment (MSPA).

Marco-economic performance assessment (MSPA): To achieve sustainability and develop sustainable products, more input and resources are needed, implying a higher cost for product development. For example, to develop a sustainable business, the retailer needs to cooperate with its business partners and keep tracking of their activities; this induces higher management and compliance costs. Also, the designers need to source sustainable materials with certifications, whereas the source and supply should be limited, increasing the difficulties in designing a sustainable product. Furthermore, to produce sustainable products, the manufacturers need to invest in costly infrastructure, e.g., the sewage treatment plant and the energy-saving production machines. All the above bring up the cost of producing a sustainable product. To examine the actual effects of the decisions made in the PLC, the macro-economic input

and output tables record the monetary transactions of different industrial sectors throughout the product development process. The money transfer from one sector to another is captured and recorded (Lenzen, 2002). By analyzing the money flow between different sectors, we can ultimately evaluate the product performance's contribution to the macro-economy (Lave et al.,1995).

Based on the monetary transaction assessment, the sustainable sportswear suppliers can implement various sustainable business strategies and cooperate with their business partners for actions. The fashion retailer may lead the SSSs through providing guidance to the SSSs by using the same goal and standards. However, as there are many different SSSs (e.g., designers and manufacturers) along the sustainable fashion supply chain, where each of them may have different attitudes and interpretations towards sustainability. The attitude difference towards sustainability will affect their decision-making during sustainable product development and ultimately affect the macroeconomy. For example, Nike has high commitment to developing a sustainable business. Although they have a high requirements and standards for their business partners to follow (e.g., designers and manufacturers), it has been reported that to save production cost, the manufactures of Nike hired child labor for sportswear production (Guardian, 2021), which affected brand reputation and ultimately the sales and revenue. Thus, it is especially important to explore the monetary transactions of the fashion product development, so that they can be coherent and meet consumers' expectations.

6.4 Determination of the indicators for SPDP assessment

According to Rosen and Kishawy (2012), sustainability indicators are essential tools that help measure and assess sustainability. It is a driving force for sustainability

development (Afgan & Da Graça, 2000). By using sustainability indicators, the status and progress towards the main objective can be identified. Through measuring the product development process, the non-sustainable processes can be revealed, where sustainability developers can address the underlying challenges and potential problems for further improvement.

There is a growth in a multiplicity of indicators and the corresponding used tools (Voinov, 1997). For example, the Higg index developed by the Sustainable Apparel Coalition (SAC), Dow Jones Sustainability Index (DJSI), as well as Environmental, Social Corporate Governance (ESG). The above sustainability measurement tools are equipped with different sets of indicators that allow business managers to assess their business' sustainability levels for further improvement and planning. However, the existing indicators may not be compatible (Mitchell, 1996) and cover all three dimensions of the TBL model. For example, the higg index focusing on measuring the social labor impacts and the environmental impacts throughout the value chain (SAC, 2021); the DJSI focuses on tracking the finical performance of the world leading sustainability companies in the market (DJSI, 2020); while the ESG pays high attention on the social impact generated by the companies' business investment (Chen, 2021).

To develop effective sustainability indicators, the indicators need to be relevant to the business area and be understandable by both professionals and non-professionals (e.g., sustainable product developers and consumers). The indicators' database should be assessable and reliable so that it can provide trustworthy information for further analysis and development. Also, it is important that the indicators should cover the whole system and shows the interaction between them (Afgan & Da Graça, 2000). It is

because that the sustainable development system is complex and involves different parties and many sub-systems.

To achieve sustainability, the three-dimensions of sustainability (environment, social and economic) need to be considered. Through identifying the corresponding sustainability indicators, the key factors which affect each dimension can be determined. By gathering the relevant data and information during the SPDP (Figure.25), the interrelations between the sustainability impact and fashion PDP system can be found.

SPDP assessment approach and indicators

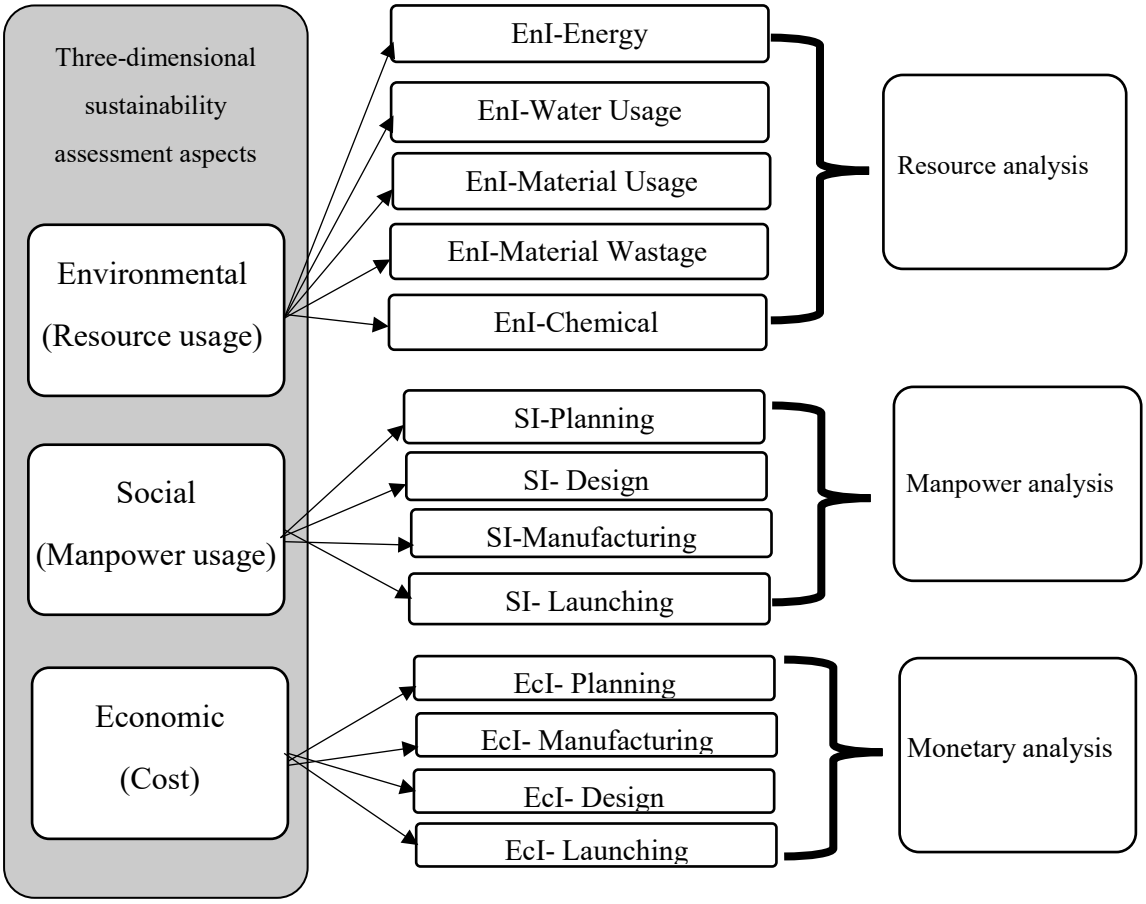


Figure 25. SPDP assessment approach and indicators

Based on the above, an in-depth study on sustainability indicators is conducted and classified into the 3D of TBL. The details for the studied indicators are as below.

6.4.1 Indicators relating to environmental assessment: resources analysis

Energy usage indicator: Textile manufacturing accounts for 80% of the fashion industry's energy usage. The energy used to motivate the textile manufacturing machines are huge (TCC, 2019). Electricity is the main source of energy for garment manufacturing and production (Çay, 2018). To explore the energy consumption and efficiency, Ozurk (2005) conducted a study in the Turkish and apparel industry. The study demonstrated the importance of recording the energy consumption throughout the manufacturing process for future sustainability planning and improvement. Many other researchers also attempt to develop energy usage indicators (EI Energy) for sustainability analysis (Farla & Blok, 2001; Patterson, 1996; Peters et al., 2021).

In this study, seamless sportswear development is assessed. Unlike woven and cut-sew productions, which requires pre-production of textile fabrics. Seamless knitting technology is a knit-to-shape technology where garment panels are knit-to-shape in a seamless circular knitting machine. The main energy consumption is largely generated by the seamless circular knitting machine. To assess the energy usage in seamless production, the knitting time (minute) per legging is recorded. By multiplying the per minute energy usage (kilowatt) for running the seamless circular knitting machine, the energy usage through comparison between different versions of leggings are carried out.

Water usage indicators: Based on the reports of Boston Consulting Group, Pulse of the *Fashion Industry* and the Global Fashion Agenda (Šajn, 2019), the water consumption of the global fashion textile and clothing industry is up to 79 billion cubic meters in 2015. Among all the fashion product development process, washing and dying consume the highest amount of water, which caused serious water pollution. It is crucial

to analyze water usage throughout the sportswear product development process. The water usage will treat as an input for the washing and dyeing process for the seamless sportswear development, which can be calculated for per product (Aivazidou & Tsolakis, 2019; Garcia-Torres et al., 2017; Ren, 2000), while the product will treat as an output.

Material usage and wastage indicators: To improve the environmental sustainability of the fashion industry, material control is a key to success. It is studied that large amount of non-renewable material resources are used to produce fashion and textile products which will send to landfill after consumers' consumption (EAC, 2019). It is reported that 35% of all fashion textile materials become waste before the apparel product can reach the consumers (COD, 2021; EAC, 2019). For this reason, it is crucial to encounter the material usage and wastage as an environmental performance indicator for the sustainable sportswear product development process. In this study, the material usage of seamless sportswear product development is accessed. The yarn cone before knitting the legging is weighed. By comparing the weight of yarn cones after knitting, the exact amount of materials being used can be recorded (total 3 types of yarns are used and recorded). Finally, by measuring the weight of the final products, we can have the materials wastage data for further evaluation.

Chemical usage indicators: It is reported that over 8000 types of chemicals are being used in the textile dyeing process (Scoot, 2015). Over 400 million meters of fabric are dyed. This encounter huge environmental problem, as many of the dying chemical are toxic and environmental persist. To have better control in the chemical usage, it is essential to have a chemical indicator where the amount of chemical used in the product

development process is being recorded and analyzed.

6.4.2 Indicators relating to social assessment

From the social point of view, sportswear companies need to consider how they can benefit the society throughout the whole product development process. For example, company needs to commit to the community and make sure all the labor they hire are well treated. Retailer like Columbia pays high attention on sustainable social responsibility through improving the social and ethical performance and working closely with vendors who share the same ethical value and provide a safe working condition to the workers.

According to Zuo, Jin, and Flynn (2012) study, one of the most important social sustainability performance criteria is that the company should promote work-life balance and measure the appropriateness of working hours for the workers (knitting technician) or professionals (designers). Littig and Griessler (2005) demonstrated how the European employment strategy provided a sensible working hours reduction and facilitated the social sustainability performance. In our study, social indicators are analyzed through studying the consequential effects of the changes in design features towards manpower (working hours) usage. As the product development process are mainly composed by four stages which are planning, design, manufacturing, and launching, the manpower usage in these four stages is recorded and assessed through the consequential performance assessment.

6.4.3 Indicators relating to economic assessment

In the sense of economic sustainability, at the plant level, it has been operationalized as production or manufacturing costs (Littig & Griessler, 2005). Traditionally, companies only focus on the economic growth from their business. To bring down the cost and maximize the profit, they may use materials or production process which are not environmentally friendly and may be harmful to the society. However, to produce sustainable sportswear product, sustainable factors are considered where extra cost may be introduced to raise cost and bring down the revenue. Thus, it is critical to control the cost throughout the whole SPDP and benefit all the participants and achieve economic sustainability. For example, Adidas plan to use ocean recycle plastic from the material supplier Parley (Adidas, 2021). Although the material cost is high, through additional design features and sustainable manufacturing, Adidas is able to promote sustainable consumers' satisfaction and generate extra sales and revenue. Meanwhile, the bulk orders from Adidas provide financial support to material supplier Parley and the sustainable manufactures and can continue its business and develop new sustainable product. This can keep the sustainable business rolling, thus benefiting economy and environment.

As the above, it is critical to analyze the cost induced from the sustainable product development process. A set of sustainable economic indicators is developed. By using the macroeconomic performance assessment, the monetary transaction data throughout the sustainable product development is recorded. Through analyzing their economic contribution (cost), we can plan for future development. As the three dimensions of the TBL are highly related, one of our aims is to study the interrelations of the indicators and the 3D of TBL model. The economic indicators can be divided into two groups, i.e.,

the environmental related cost indicators and social related cost indicators (Table 27). For the environmental related cost indicators, the material usage cost, material wastage cost, energy usage cost, water usage cost and chemical usage cost, are recorded and analyzed, especially how additional product features affect the monetary transection. Meanwhile, to analyze the social sustainability related cost, the manpower usage costs towards planning, design, manufacturing, and launching are recorded and analyzed.

Table 25. Environmental indicators: input and output attributes on sustainable sportswear performance assessment

Code	Indicators	Equation	Data collection	Input	Output	Indicator selection references
EI Material	Material usage indicator	Material input (yarn cone weight before knitting) - material output (yarn cone weight after knitting)	Santoni Top 2; 13", 28 gauge circular seamless knitting	Yarn (gram)	g/product	Bringezu and Moriguchi (2002); Maxime, Marcotte, and Arcand (2006); Maxime et al. (2006)
EI Wastage	Material wastage indicator	Material input (yarn cone) - material output (finished product)	Santoni Top 2; 13", 28 gauge circular seamless knitting	Yarn (gram)	g/product	Maxime et al. (2006); Yano and Sakai (2016)
EI Energy	Energy usage indicator	Knitting time * kW/min	Santoni Top 2; 13", 28 gauge circular seamless knitting	Knitting time	kW/ product	Peters et al. (2021); Patterson (1996); Farla and Blok (2001);
EI Chemical	Chemical usage indicator	Weight of dyeing detergent / number of products	Dye stuff weight	Dye stuff (gram)	g/product	E. Ozturk, Karaboyacı, Yetis, Yigit, and Kitis (2015)
EI Water	Water usage Indicator	Amount of water use for washing & dying / number of products	Whirlpool AWO/O 40440	Liter	Liter/product	Garcia-Torres et al. (2017); Aivazidou and Tsolakis (2019);Ren (2000)

Table 26. Social indicators: consequential manpower effects on sustainable sportswear performance assessment

Code	Indicators	Data collection	Measurement Unit	Indicator selection references
SI PM	Planning manpower usage indicator	The working hours used in research and planning of product	min/ product	N. Carter, Klein, and Day (1995); Rao, la O'Castillo, Intal Jr, and Sajid (2006); Hu, Pan, Cheng, Chang, and Lin (2021)
SI DM	Design manpower usage indicator	The working hours used in design of product	min/ product	Hu et al. (2021); H. Wang, Liu, Kim, and Kim (2019); H. Wang et al. (2019)
SI MM	Manufacturing manpower usage indicator	The working hours used in manufacturing monitoring of product	min/ product	Ahmad, Wong, and Rajoo (2019); Ahmad et al. (2019)
SI LM	Launching manpower usage indicator	The working hours used in delivery of product	min/ product	Ahmad et al. (2019); Ahmad et al. (2019)

Table 27. Economic indicators: macroeconomic monetary transection analysis on sustainable sportswear performance assessment

Code	Indicators	Measurement	Measurement Unit	Indicator selection references
EcI PMC	Planning manpower cost indicator	Questionnaire survey interviewer minute wages * minutes spent in the questionnaire survey	USD / product	Onat and Bayar (2010); Zhong and Wu (2015); Bragança, Vieira, and Andrade (2014)
EcI DMC	Design manpower cost indicator	Designer's minute wages * minutes spent in product design	USD / product	
EcI MMC	Manufacturing manpower cost indicator	Knitting technician's minute wages * minutes spent in machine monitoring	USD / product	
EcI LMC	Launching manpower cost indicator	Cost spent in delivery of product	USD / product	
Ecl MC	Material cost indicator	Material input (yarn cone weight before knitting) - material output (yarn cone weight after knitting)	USD / product	Wallbaum, Ostermeyer, Salzer, and Escamilla (2012)
EcI WC	Material wastage cost indicator	Material input (yarn cone) - material output (finished product)	USD / product	Den Boer, Den Boer, and Jager (2007)
EcI EC	Energy cost indicator	Knitting time * kW/min	USD / product	Afgan and da Graça Carvalho (2000)
EcI CC	Chemical cost indicator	Weight of dyeing detergent / number of products	USD / product	Ruiz-Mercado, Smith, and Gonzalez (2012)
EcI WC	Water cost Indicator	Amount of water used for washing & dying / number of products	USD / product	Molinos-Senante et al. (2016)

6.5 Development of sustainable sportswear and data collection

To achieve sustainability in sportswear product development, we first need to understand the corresponding sustainable development process. According to Section 2.1, the SSSs' responsibility towards SPDP will be affected by the sportswear company's supply chain structures. If a sustainable sportswear company utilizes a decentralized structure, the manufacturers of the sustainable sportswear company may need to work on the product design. In contrast, if the company adopts a production outsourcing structure, the sportswear company's in-house design team is responsible for product design, then manufacturers only focus on prototype development and production. Apart from the supply chain structure, the production method of the sportswear product also affects product development participants and processes. For example, Fung and Liu (2019) demonstrate the difference between cut & sew knit and seamless sportswear product manufacturing (Figure 26). It indicates that fewer production processes are needed in seamless sportswear production.

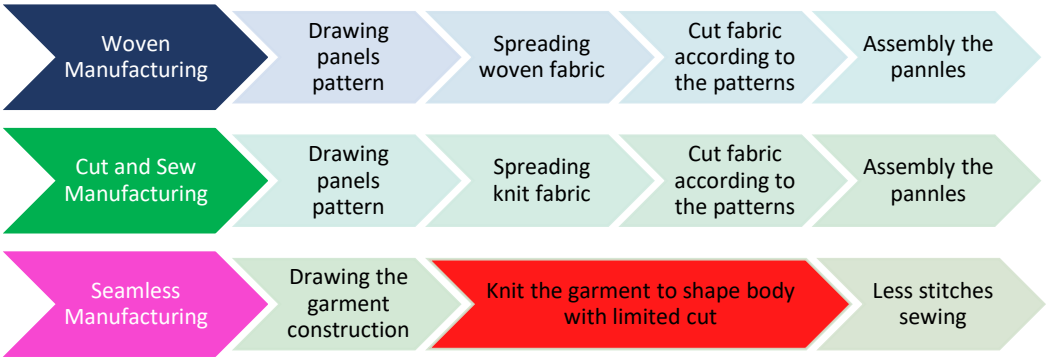


Figure 26. A comparison on woven, cut and sew, and seamless knitting manufacturing

Although different supply chain structures and production methods vary product development process, Fung et al. (2020) studied that, the fashion industry's sustainable product development can be classified into four key steps: planning, design,

manufacturing, and launching. In the planning stage, the product assortment planners need to decide what kind of products to be produced. For example, ten sports leggings will be launched in the new season based on the product line plan. However, what are the key product features they decide to be included? This requires an in-depth market research. The planners need to get previous sales reports or gather consumers' feedbacks on their demands. Fung et al. (2021) conducted a questionnaire survey and studied the consumers' and suppliers' attitudes towards sustainable sportswear requirements. Once the product assortment is confirmed, the designers can start to work on the designs. The sportswear designers need to design products that meet the planners' planning and market demands based on the market information and research. However, among all the requirements, how can the design balance the economic benefit (e.g., cost vs. profit) and the product features (e.g., design features vs. functionality) become critical.

Once the design direction is confirmed, we move on to the manufacturing process. According to Carr and Pomeroy (1992), within the product development process, revisions of the previous steps, and back and forward checking are commonly happened. For example, a seamless knitting machine knit shaped garment panels, its one panel's construction may affect the other structure, especially when the stitch densities are largely different from the stitches next to it, which would increase the leading time for product development due to trials and errors. Any changes in the product features and constructions will affect the environmental, social, and economic performances. The sportswear companies need to balance the design, product construction, and corresponding impact concerning the three-dimensions of the TBL model.

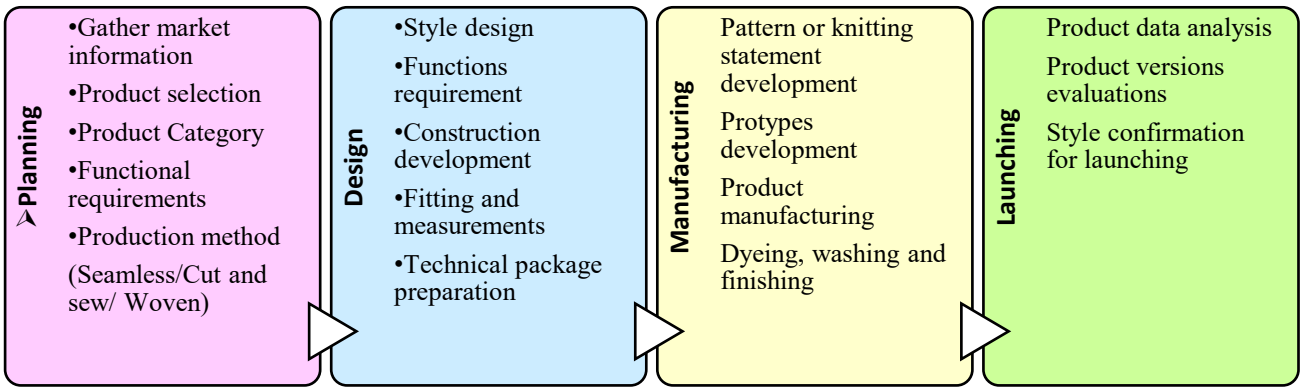


Figure 27. Sustainable sportswear product development process

6.5.1 Product planning

Market research is essential in the first stage of sustainable sportswear development process. Based on the market research, the products to be produced and developed can be determined for sales enhancement. In this stage, the time used in the market research and survey are recorded and become one data source for the social indicator (SI PM) and economic indicator (Ecl PMC).

-Market strategies: Among all the sportswear apparels, compression sportswear is one type of the most emerging sportswear categories. It is reported that by 2022 the expected shape and compression wear global market will be over 5.5 million US dollar with a compound annual growth rate of 5.7% from 2016 to 2022 (AMR, 2019). The compression sportswear have multiple functions (Fung & Liu, 2019). The fundamental function should provide wearers (including aging population) a delightful wearing experience and their benefit healthy lifestyle. Based on the questionnaire survey conducted in this study, one of the most popular sportswear products is seamless sports legging. Based on the above findings, the development of seamless sports legging is being investigated in this thesis study.

-Product features and functionalities: A survey was conducted to explore the

consumers' preferences towards sports legging functions. It is found that the consumers pay high attention to body protection performance (Gerrett et al., 2017). Compression sportswear are widely applied among professional athletes and lifestyle sports players because their benefits to improve blood circulation (Maksudov et al., 2020) and performance (Engel & Sperlich, 2016) in decrease of the injure rate (Rahulan et al.,2015) and speed-up of recovery (Engel & Sperlich, 2016; Liu et al.,2012). Liu and Little (2009) established a 5Ps contextual model to optimize athletes' wearing comfort in sports (Figure 28). They considered that compression sportswear can be examined by the athlete's perceptions of five categories: physical, psychological, physiological, psychophysical, and psychophysiological properties. Multi-relationships exist between the athlete, athletic wear, immediate body space, and sports environment and culture. The 5Ps model explores the mechanisms of action of body-clothing-sports environment system from a comprehensive view to guide and optimize functional design of compression sportswear for enhanced sports achievement and comfort in practice (Liu et al., 2012).

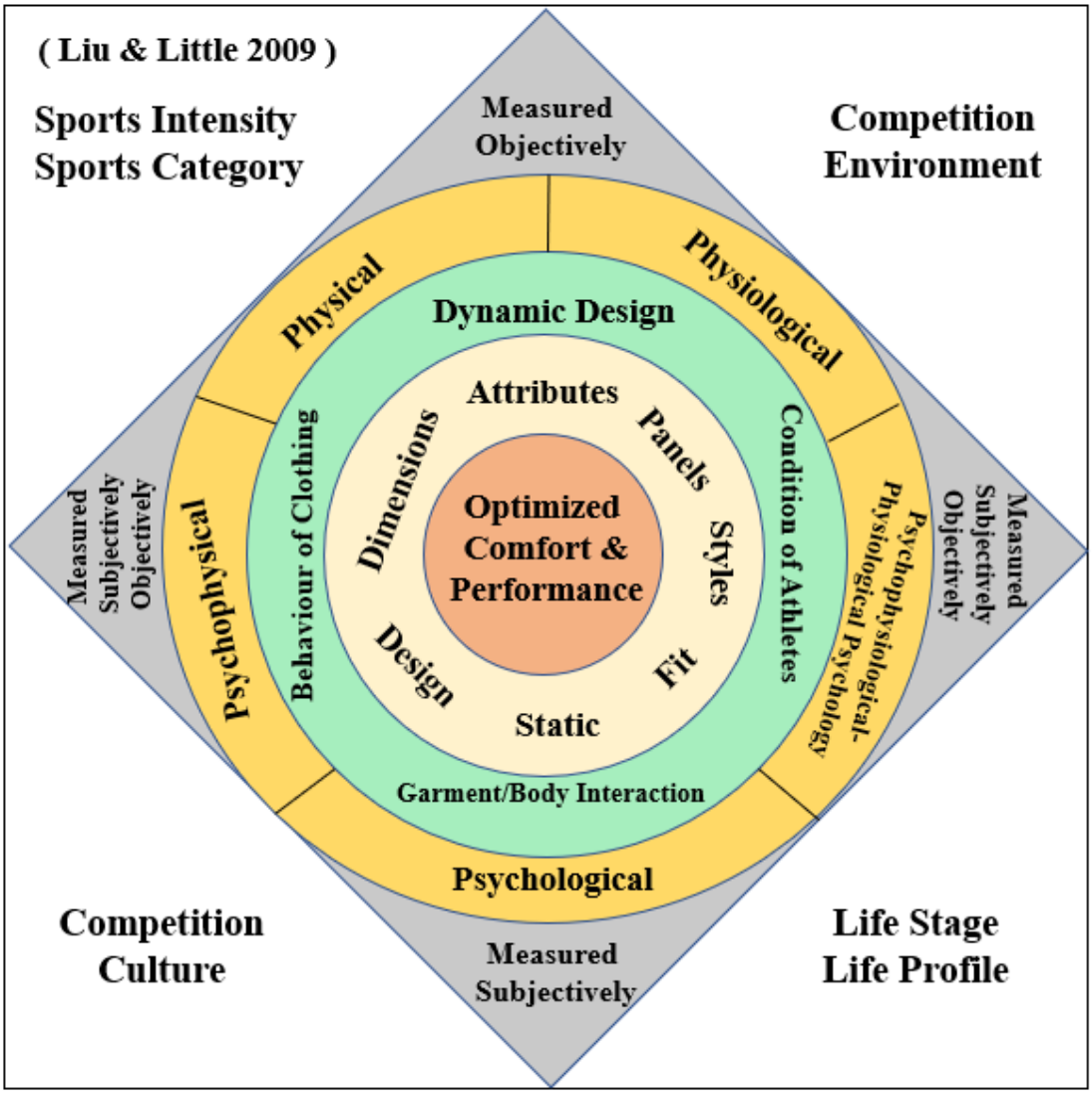


Figure 28. A 5Ps contextual model to optimize athletic wear comfort in sports

(Liu and Little, Journal of Fiber Bioengineering and Informatics, 2009)

Meanwhile, according to the study of Fung and Liu (2019), some functional features of sportswear for enhancing blood circulation, reducing muscle soreness, providing muscle support, reducing the recurrence of injury, aiding recovery, enhancing sports performance and enhancing lactic acid removal have been considered during the development of compressional sportswear. From the questionnaire survey, the respondents show the need of the extra muscular support for reducing the recurrence of muscular injury and muscle soreness incurred during and after exercise. Also,

breathability of the sportswear is another key feature that affects the purchase decision of the consumers, especially for the highly sweating area (Smith & Havenith, 2011). Furthermore, comfortability and ease for movement of the product are also highly important (Zeagler, 2017). All the above market information and consumers' preferences provide the design directions for the designers in the next stage.

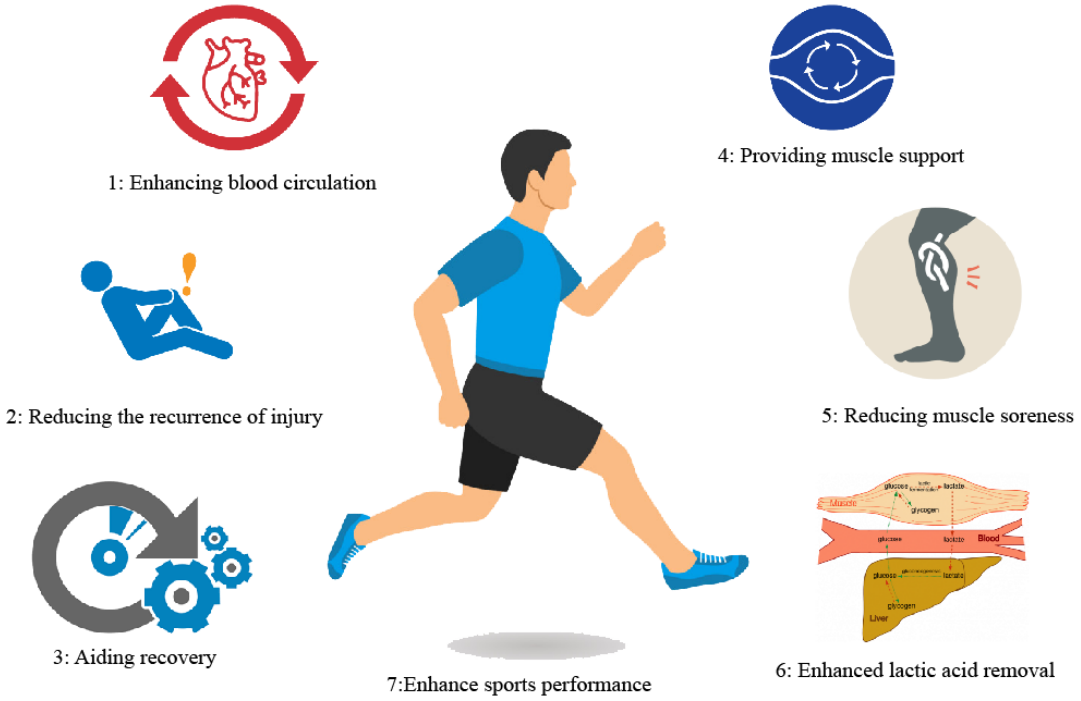


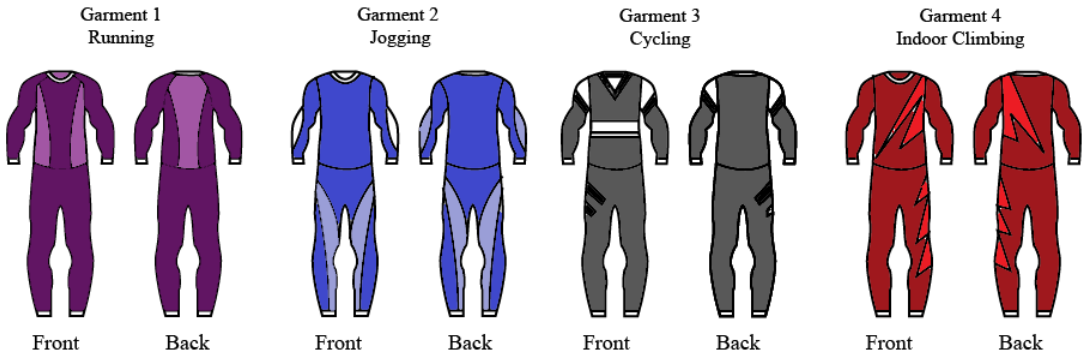
Figure 29. Functional requirements of compression sportswear

6.5.2 Product design

The norm of using compression sportswear among professional athletes influence the lifestyle sportswear market. With the increase of health awareness (Wheaton, 2010), people gradually treat the lifestyle sports as a daily routine and have higher requirements for the functional properties of the sportswear. They are willing to pay more to purchase a set of professional athletes' compression sportswear (Rahulan et al., 2015) providing multiple functional properties like temperature regulation, moisture

management, and reduction of potential injury, and wearing comfortability. The high profit margin of compression sportswear attracts sportswear brands to expand their business correspondingly.

Sportswear retailers tried to balance the aesthetic design and product functionalities to capture more market shares and drive the brand recognition. They place high investment in designing and developing compression sportswear with advance functions to improve comfort and sports performance through optimizing the 5P's properties (Liu et al., 2012). Figure 30 shows the examples of compression sportswear products provided by the sportswear brands in the current market.



No.	Style		Major materials *	Functional properties	Structure
1	Full Body Garment	LST	80% polyester/20% spandex	Raglan sleeves allow natural range of motion Thumbholes help keep the sleeves in place	Plan (warp knits)
		FLB	80% polyester/20% spandex	Tight fit helps you feel confident and supported	Plan (warp knits)
2	Full Body Garment	LST	92% polyester/8% spandex	Follow the shape of shoulders and arms to promote natural movemen	Plan (warp knits)
		FLB	92% polyester/9% spandex	Fast-drying fabric wicks sweat quickly.	Plan (warp knits)
3	Full Body Garment	LST	54% nylon/34% polyester/12% spandex	Stretch fabric delivers natural range of motion Body-skimming design allows for easy layering	Plan (warp knits)
		FLB	54% nylon/34% polyester/12% spandex	Elastic waistband helps keep the tights in place	Plan (warp knits)
4	Full Body Garment	LST	88% recycled polyester/12% spandex	keep you dry and comfortable	Plan (warp knits)
		FLB	88% recycled polyester/12% spandex	keep you dry and comfortable	Plan (warp knits)

Figure 30. Seamless full body sportswear design in the current market

Based on the market and consumers' information gathered from the planning stage, sportswear designers need to consider materials, knitting stitches, and legging constructions, to fulfill functional requirements of the consumers. Table 28 shows the

functional requirements and corresponding stitch selections for the sports legging design for an example. Once the design elements are confirmed, the designers will work on the technical packages (Figure 31) which include all the product details (e.g., leggings measurements, constructions, materials, and stitch details) (Figure 32), and then, the manufacturers will develop actual prototypes for review and approval. To assess the social and environmental effect of the design process, the manpower usage in the design stage is recorded in this study. Computed with the average designers' salaries, the social indicators of the design manpower (SI DM) and the economic indicator of the design manpower cost (EcI DMC) can be analyzed.

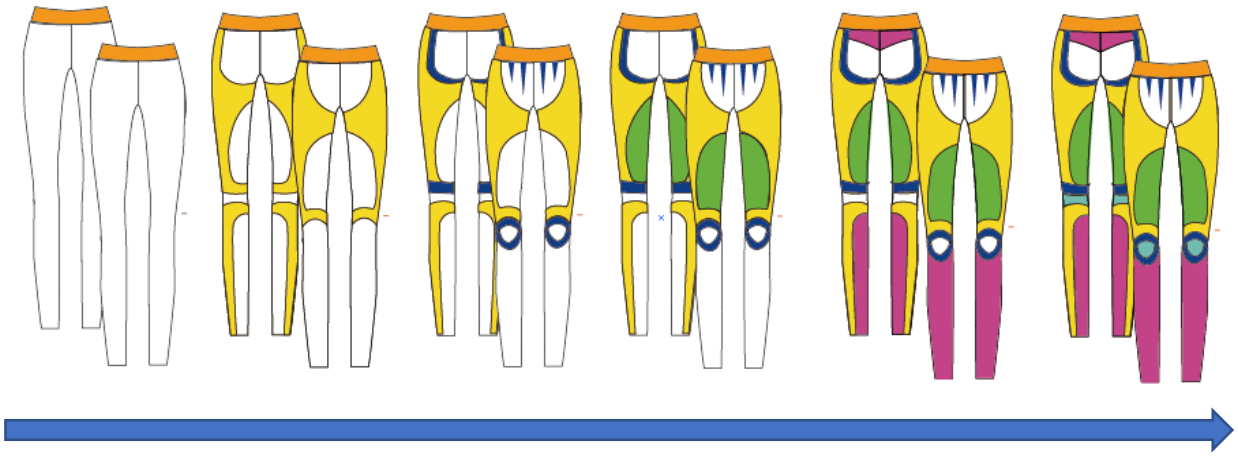
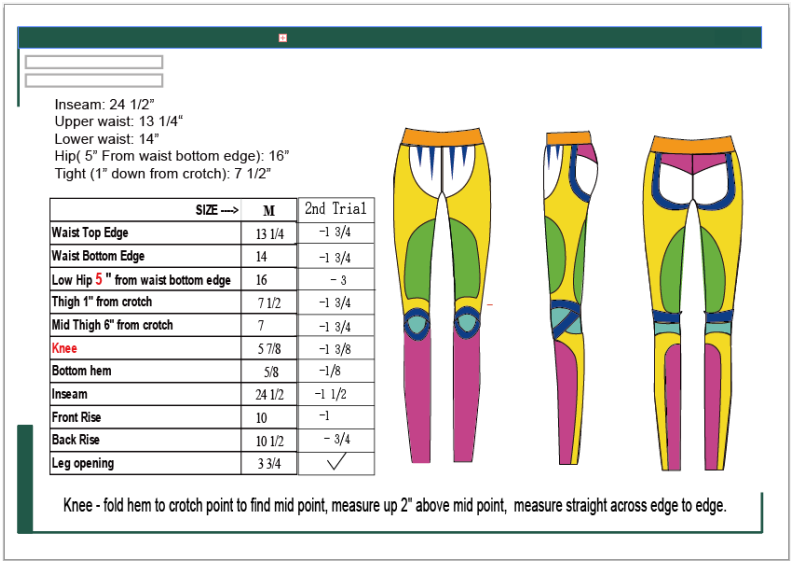
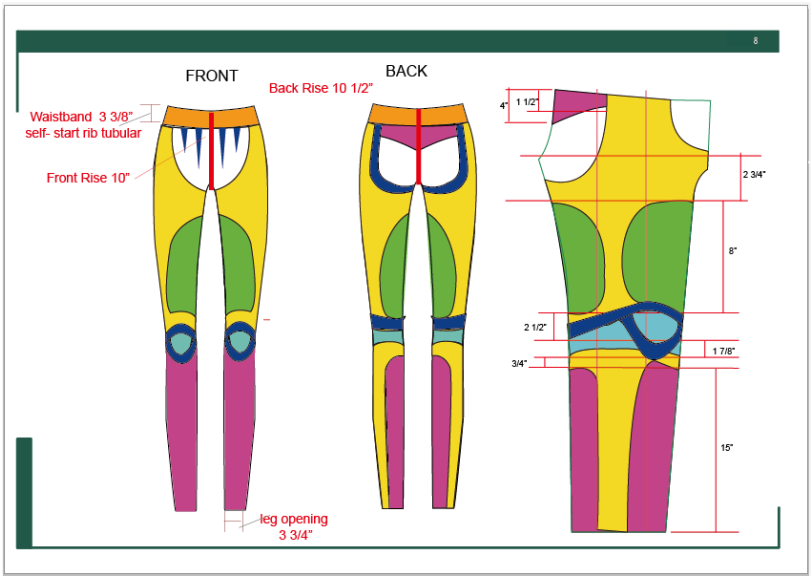


Figure 31. Designing a sportswear according to the requirements of sports and sports environment





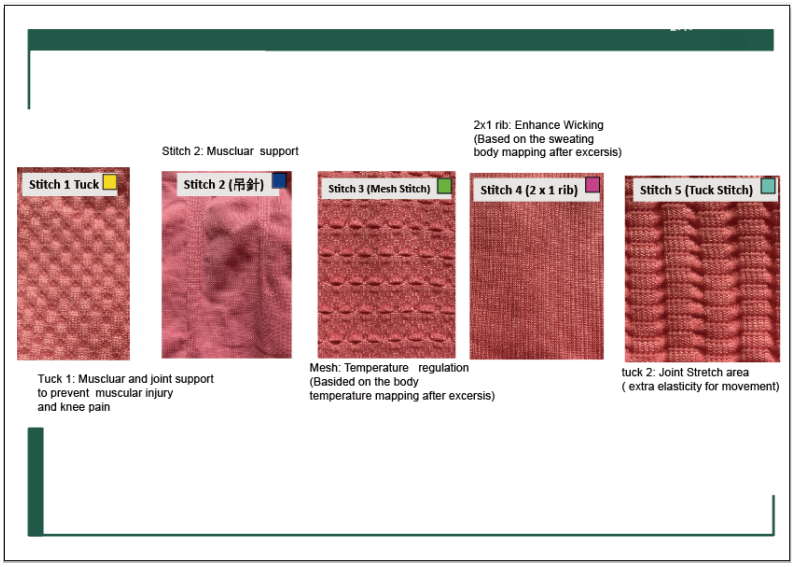
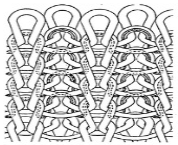
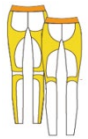
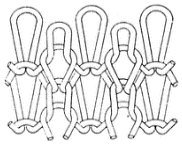
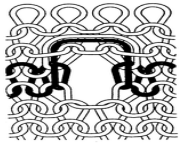
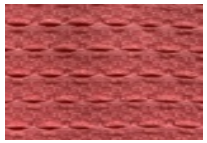
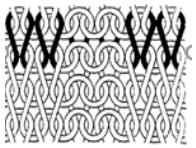
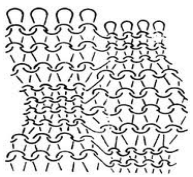


Figure 32 (1-3) Technical package of the sports leggings to be developed

Table 28.User-centered sportswear design

Legging versions	Functional requirements	Key product features affect the buying decision	Solutions	ISO stitch references	Knitting diagrams	Actual stitches	Legging designs
Version 1	Function 1	Soft material and fabric	Control fabric thickness Adjust knitting density Plated with nylon to enhance ease of movement	ISO8338:1998; 3.1.11 plated jersey fabric			
Version 2	Function 2	Reducing muscle soreness	Tuck stitches in area with frequent movement and expansion during sports	ISO8338:1998;3.2.3 grenadine (weft-knitted) USA waffle fabric GBR honeycomb GBR			
Version 3	Function 3	Muscular support	Extra muscular and joint support for belly, buttock and knee	ISO8338:1998:3.3.37 half cardigan rib royal rib semi-cardigan USA			
Version 4	Function 4	Breathability	Eyelets stitches in highly sweat area and enhance wicking of sweat	ISO8338:1998:3.1.41 web eyelet fabrics			
Version 5	Function 5	Comfort Fitting	Enhance fabric recovery 4x2 rib provide extra fabric recovery	ISO8338:1998:3.3.5 2x2 rib (with 2x2 needle set out) two-by-two rib fabric			
Version 6	Function 6	Reducing the recurrence of muscular injury	Tuck stitch at calf and knee and reduce the injuries caused by the long-term exercises	ISO8338:1998;3.1.7 cast-off design fabric press-off design fabric			

6.5.3 Product manufacturing (seamless production)

In this study, seamless compression sportswear is knitted by circular knitting machine. By using different diameters of the machine, sports leggings with different sizes are knitted. “Santoni Top 2” 13-inch 28-gauge circular knitting machine (Figure 33) is used in this study to produce sized-M leggings without side seams. The hems and waistbands are self-started tubular without linking. By using fully fashion function in the seamless circular knitting, the shaped leggings can be knitted with minimized cutting.

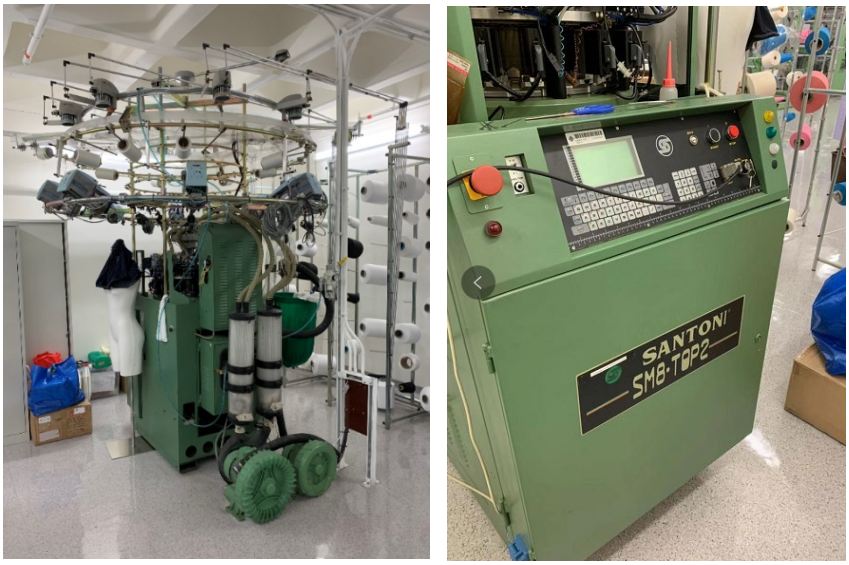


Figure 33. Santoni-Top 2 seamless circular knitting machine
with 13-inch in diameters and 28 machine gauge

As the seamless knitting is a knit-to-shape technology, any changes in the particular stitch constructions and knitting densities would affect the other areas, and untimely affect the sizing, fitness, and outlook of the products. Therefore, manufacturers and designers need to review the styles and constructions before producing the actual products. Figure 34 shows the first and second trial prototypes and the corresponding comments for improvements. Once these constructions and designs are confirmed, manufacturer then start knitting the final products. The seamless knitting technicians

need to work on the knitting statements with the stitch constructions and knitting densities (WPI and CPI) as clearly stated. Then the details are inputted into the "Graph 6" knitting software. With all the details inputted in the software and the machine is ready to knit the products.

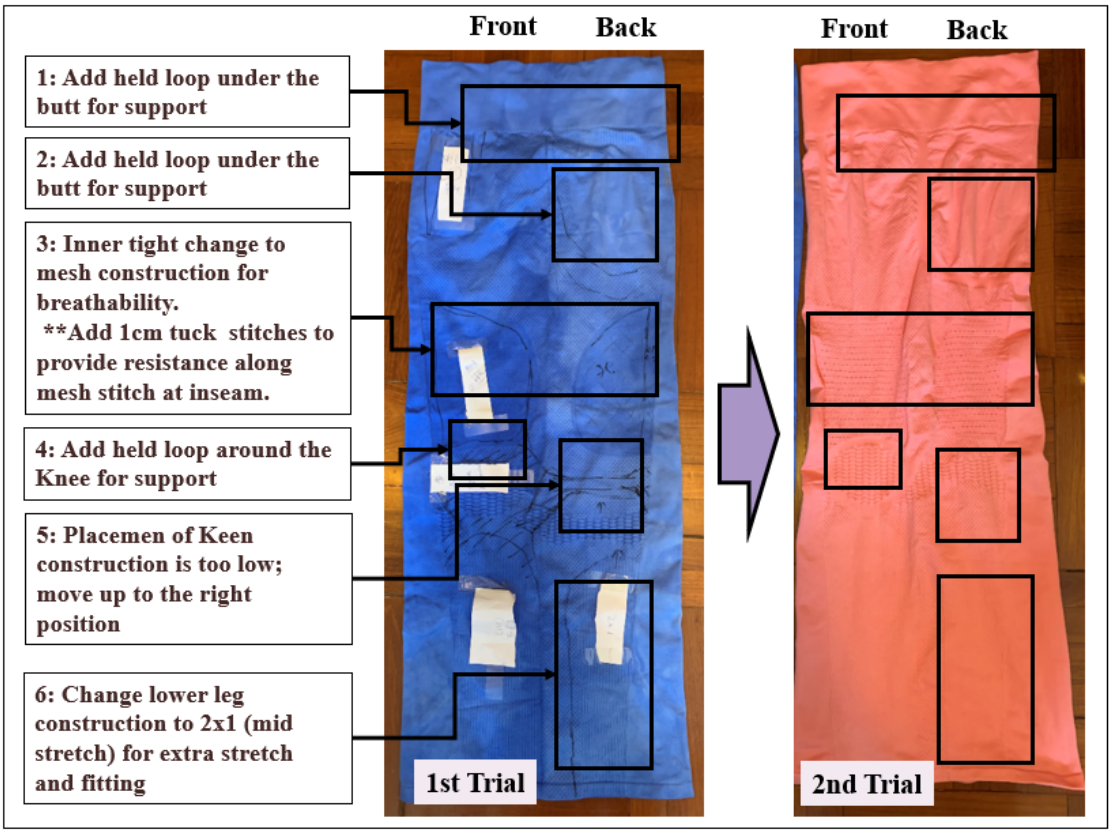


Figure 34. The first and second trial prototypes and the corresponding comments for improvements

To analyze the sustainable performance of the manufacturing process, different sets of data are recorded. In terms of environmental sustainability, the input and output weights of the face yarn (EI_material FY), plated yarn (EI_material PY) and elastane yarn (EI_material EY) are recorded and the material usages are measured. Then, by comparing the weights of materials' usage sand the weights of the finished products, the materials' wastages (EI_Wastage) can be identified. In addition, the usages of the

water (EI_water), chemical (EI_chemical), and energy (EI_Energy) are recorded to indicate the environmental sustainability performance.

Meanwhile, to indicate the social sustainability performance of manufacturing, the manpower usages of the knitting technician towards knitting statement preparation, data input, and knitting machine monitoring, are recorded as the data source of technical manpower indicator (SI MM_T). Meanwhile, as washing, dying, and sewing can be classified as finishing process in industry, they are considered together as one indicator (SI MM_WDF) in this study. As the economic sustainability indicators of manufacturing, the monetary transection relating to the environmental and social indicators are recorded. The cost of material per gram is calculated (EcI_MC, EcI_MWC), and the costs of energy (EcI_EC), water (EcI_WC), and chemicals (EcI_CC) are also recorded. Furthermore, to indicate the economic performance of the manpower usage, the costs of the manpower are calculated (EcI_MMC_T; EcI_MMC_WDF).

6.5.4 Product launching

After a series of product planning, design, and manufacturing processes, we move on to the final step of launching. In this step, the recorded data are being gathered and analyzed (Tables 29-31). Through data analysis, suppliers are able to select the most appropriate version of the legging prototypes that balance all the three-dimensions of TBL.

Table 29. Collected data relating to environmental indicators

				Seamless legging samples					
Environmental				Version 1	Version 2	Version 3	Version 4	Version 5	Version 6
The amount of energy used in the manufacturing process	El Energy	Knitting	1: Energy usage for knitting data input (min)	5	5	5	5	5	5
			2: Energy usage for knitting (min)	10.12	10.12	10.22	12.22	12.22	12.29
		Dyeing and washing	3: Energy usage for dyeing machine (min)	30	30	30	30	30	30
			4: Energy usage for washing machine (min)	60	60	60	60	60	60
		Finishing	5: Energy usage for product sewing (min)	11	7	7	5	4	8
			6: Energy usage for product ironing (min)	5	5	5	5	5	5
			7: Energy usage for size setting (min)	90	90	90	90	90	90
			8: Total energy usage (min)	211.12	207.12	207.22	207.22	206.22	210.29
The amount of material used in the product manufacturing	EL Material	Face yarn (EI Material_FY)	1: Face yarn cone weight before knitting (gram)	33244.5	33436.15	33628.47	33816.79	34001.39	34187.96
			2: Face yarn cone weight after knitting (gram)	33051.17	33244.5	33436.15	33628.47	33816.79	34001.39
			3: Face yarn usage (yarn cone weight before- after knitting) (gram)	193.33	191.65	192.32	188.32	184.6	186.57
		Plated Yarn (EI Material_PY)	4. Plated yarn cone weight before knitting (gram)	10161.91	10220.18	10279.74	10341.28	10401.46	10463.04
			5: Plated yarn cone weight after knitting (gram)	10104.9	10161.91	10220.81	10279.74	10341.28	10401.46
			6: Plated yarn usage (yarn cone weight after knitting) (gram)	57.01	58.27	58.93	61.54	60.18	61.58
		Elastane (EI Material_EY)	7. Elastane yarn cone weight before- after knitting (gram)	603.77	606.35	608.95	611.56	614.17	618.86
			8: Elastane yarn cone weight after knitting (gram)	601.19	603.77	606.35	608.95	611.56	614.17
			9: Elastane yarn usage (yarn cone weight before- after knitting) (gram)	2.58	2.58	2.6	2.61	2.61	4.69
		Total Material usage	10: Total material usage: Face yarn + Plated yarn + Elastane (gram)	252.92	252.5	253.85	252.47	247.39	252.84
		Material Wastage (EI Wastage)	11: Finished product weight (gram)	217.16	214.855	216.142	213.597	209.1	211.207
			12: Material wastage (Total material usage – Finished product weight) (gram)	35.76	37.645	37.708	38.873	38.29	41.633
The amount of water used in manufacturing	EL Water	Dyeing and Washing Water Usage	The amount of water uses in the washing process (Liter)	30	30	30	30	30L	30
The amount of chemical used in manufacturing	EL Chemical	Dyeing chemical Usage	The amount of Dying chemical use in dying process	2	2	2	2	2	2

Table 30. Collected data relating to the social indicators

Social				Seamless legging samples					
				Version 1	Version 2	Version 3	Version 4	Version 5	Version 6
The manpower usage in sports legging product development process	Planning process	SI PM	Manpower usage (min)	1000	1000	1000	1000	1000	1000
	Design process	SI DM	Manpower usage in design and techpack arrangement (min)	20	38	48	55	59	68
	Manufacturing process	SI MM_T	1: Time to prepare the knitting statement (min)	30	30	30	30	30	30
			2: Time for knitting data input (min)	20	20	20	20	20	20
			3: Time for knitting machine monitoring (min)	10.12	10.12	10.22	12.22	12.22	12.29
			Total seamless technical manpower usage (min)	60.12	60.12	60.22	62.22	62.22	62.29
		SI MM_WDF	1: Time for dyeing machine monitoring (min)	30	30	30	30	30	30
			2: Time for washing machine monitoring (min)	60	60	60	60	60	60
			3: Time for product cutting (min)	2	5	9	4	5	5
			4: Time for product sewing (min)	11	11	7	6	4	8
			5: Time for product trimming and ironing (min)	12	11	20	12	9	10
			Total manpower usage (min)	115	117	126	112	108	113
	Launching process	SI LM	Time for data analysis (min)	600	600	600	600	600	600

Table 31. Collected data relating to the economic indicators

Economic				Seamless legging samples					
Description	Development process	Indicators (units)		Version 1	Version 2	Version 3	Version 4	Version 5	Version 6
	Planning process	EcI PMC	Planning cost (1000 mins*0.106/6 products)	17.8	17.8	17.8	17.8	17.8	17.8
	Design process	EcI DMC	Design cost (USD/min)(Design manpower usage*wage)	4.74	9.006	11.376	13.035	13.983	16.116
	Manufacturing process	Ecl MC	1: Face yarn cost (Face yarn price* usage)	0.425326	0.42163	0.423104	0.414304	0.40612	0.410454
			2: Plated yarn cost (Plated yarn price* usage)	0.176731	0.180637	0.182683	0.190774	0.186558	0.190898
			3: Elastane yarn cost (Elastane yarn price* usage)	0.017028	0.017028	0.01716	0.017226	0.017226	0.030954
			4: Total material cost (Face yarn cost + Plated yarn cost + Elastance yarn cost)	0.619085	0.619295	0.622947	0.622304	0.609904	0.632306
		Ecl MWC	Material wastage cost (Material wastage * Material cost)	0.425544	0.4479755	0.4487252	0.4625887	0.455651	0.4954327
		EcI EC	Energy usage cost (Total energy usage * kW/min Energy cost)	0.485576	0.476376	0.476606	0.476606	0.474306	0.483667
		EcI CC	Chemical usage cost (Dyestuff usage*dyestuff price)	0.032	0.032	0.032	0.032	0.032	0.032
		EcI WC	Water usage cost (Water usage*water cost)	0.2906	0.2906	0.2906	0.2906	0.2906	0.2906
		EcL MMC_T	1: Seamless machine technician wage (USD/min)	0.077	0.077	0.077	0.077	0.077	0.077
			2: Total seamless technical manpower cost (Technician manpower usage* wage)	4.62924	4.62924	4.63694	4.79094	4.79094	4.79633
		EcL MMC_WDF	Washing, dyeing, and finishing manpower cost	3.275	3.417	4.056	3.062	2.778	3.133
	Launching process	EcI LC	Launching manpower cost (Data analysis time* wages)	8.057	8.057	8.057	8.057	8.057	8.057

6.6 Results and analysis

6.6.1 Correlation analysis among the indicators

According to Kwatra et al., (2016), correlation analysis is a useful tool to understand the correlations of the selected indicators. In this Section, a correlation analysis was conducted to analyze the correlations of the studied 22 indicators towards the 3D sustainable product development performance analysis (Tables 32-33).

Table 32 uncovers that the environmental indicators relate to the social and economic indicators at different levels. The usage of environmental and social resources (energy, material and manpower) are highly positively related to the economic performance in terms of costing. However, the design manpower usage (SI DM) is significantly related ($r>0.9$) to the material usage of the plated yarn (EI Material_PY), implying that the selection of the materials will highly affect the manpower usage in design.

Moreover, the material wastage (EI Wastage) is positively related to design manpower usage (SI DM). This can be explained by the design complexity of the products. The higher manpower input in design, the higher complexity of the product which may induce higher material wastages, because that the extra materials may be needed to fulfill the complex product structures. Similarly, the design manpower usage (SI DM) is also positively related to the technician manpower usage. It means that the higher complexity of design will lead to an increase in technical support in knitting.

Meanwhile, according to the collected data, face yarn usage took up over 70% of the total material usage. According to the correlation data analysis, the usage of the face yarn materials (EI Material_FY) are significantly negative related to the design manpower usage (SI DM) and manufacturing technician manpower usage (SI MM_T), implying that a decrease in the face yarns usage in sports leggings (i.e., with more functional details) will lead to an increase in design manpower and manufacturing technician manpower (SI MM_T). From the recorded data, the face yarn material usage of versions 1- 3 leggings (simpler versions with less functions) are highest, where less face yarn is needed for versions with more functional stitches (e.g., versions 4-6). It shows that the design of the sports leggings has significant impact on environmental sustainability with respect to the material usage (EI Material_FY), and on social sustainability with respect to the manpower usage in design (SI DM) and manufacturing technician (SI MM_T). In addition, in terms of economic sustainability, the face yarn material usage (EI Material_FY) significantly negative relates to design manpower cost (EcI DMC) and manufacturing technician manpower cost (EcLMMC_T), implying that the leggings with more functional details would lead to an increase in design manpower cost and manufacturing technician manpower cost (SI MM_T). As above, based on TBL model, the design of the leggings will affect the three-dimensional sustainability performance (environmental, social and economic) of the sustainable sportswear development.

Table 32. Correlation matrix of the studied three-dimensional sustainable sportswear development indicators

	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13
1 EI Material_FY	189.5	3.50													
2 EI Material_PY	59.59	1.84	-0.79												
3 EI Material_EY	2.945	0.85	-0.42	0.54											
4 EI Wastage	38.32	1.93	-0.69	0.875*	0.847*										
5 EI Energy	208.2	2.00	0.31	-0.24	0.50	0.02									
6 SI DM	48	17.05	-0.836*	0.926**	0.59	0.900*	-0.34								
7 SI MM_T	61.2	1.15	-0.929**	0.912*	0.48	0.74	-0.15	0.831*							
8 SI MM_WDF	115.2	6.11	0.74	-0.42	-0.18	-0.27	-0.01	-0.30	-0.72						
9 EcI DMC	11.38	4.04	-0.836*	0.926**	0.59	0.900*	-0.34	1.000**	0.831*	-0.30					
10 EcLMMC_T	4.712	0.09	-0.929**	0.912*	0.48	0.74	-0.15	0.831*	1.000**	-0.72	0.831*				
11 EcLMMC_WDF	3.287	0.43	0.74	-0.42	-0.18	-0.27	-0.01	-0.30	-0.72	1.000**	-0.30	-0.72			
12 Ecl MC	0.621	0.01	0.11	0.37	0.76	0.62	0.53	0.30	0.10	0.31	0.30	0.10	0.31		
13 EcI MWC	0.456	0.02	-0.69	0.875*	0.847*	1.000**	0.02	0.900*	0.74	-0.27	0.900*	0.74	-0.27	0.62	
14 EcI EC	0.479	0.00	0.31	-0.24	0.50	0.02	1.000**	-0.34	-0.15	-0.01	-0.34	-0.15	-0.01	0.53	0.02

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 33. Three-dimensional assessment indicators correlation summary

***	(r>0.9)	**	(0.8>r>0.9)	Negatively Correlated	
Social indicator Design manpower **(SI DM)**	Environmental indicator plated yarn material usage **(EI Material_PY)**	Environmental indicator energy **(EI Wastage)**	Environmental indicator plated yarn material usage **(EI Material_PY)**	Social indicator Design manpower **(SI DM)**	Environmental indicator face yarn material usage **(EI Material_FY)**
Economic indicator Design Manpower cost **(EcI DMC)**	Environmental indicator plated yarn material usage **(EI Material_PY)**		Environmental indicator elastane yarn material usage **(EI Material_EY)**	Social indicator manufacturing technician manpower usage **(SI MM_T)**	Environmental indicator face yarn material usage **(EI Material_FY)**
	Social indicator Design manpower **(SI DM)**	Social indicator Design manpower **(SI DM)**	Environmental indicator material wastage **(EI Wastage)**	Economic indicator Design Manpower cost **(EcI DMC)**	Environmental indicator face yarn material usage **(EI Material_FY)**
Economic indicator manufacturing technician manpower usage cost **(EcLMMC_T)**	Social indicator manufacturing technician manpower usage **(SI MM_T)**	Social indicator manufacturing technician manpower usage **(SI MM_T)**	Environmental indicator plated yarn material usage **(EI Material_PY)**	Economic indicator manufacturing technician manpower usage cost **(EcLMMC_T)**	Environmental indicator face yarn material usage **(EI Material_FY)**
Economic indicator manufacturing washing, dyeing and finishing manpower usage cost **(EcLMMC_WDF)**	Social indicator manufacturing washing, dyeing and finishing manpower usage cost **(SI MM_WDF)**		Social indicator Design manpower **(SI DM)**		
Economic indicator material wastage cost **(EcI MWC)**	Environmental indicator material wastage **(EI Wastage)**	Economic indicator Design Manpower cost (**EcI DMC**)	Environmental indicator material wastage **(EI Wastage)**		
Economic indicator energy cost **(EcI EC)**	Environmental indicator energy **(EI Energy)**		Social indicator manufacturing technician manpower usage **(SI MM_T)**		
		Economic indicator manufacturing technician manpower usage cost **(EcLMMC_T)**	Economic indicator Design Manpower cost **(EcI DMC)**		
		Economic indicator material wastage cost **(EcI MWC)**	Environmental indicator plated yarn material usage **(EI Material_PY)**		
			Environmental indicator elastane yarn material usage **(EI Material_EY)**		
			Social indicator Design manpower **(SI DM)**		
			Economic indicator Design Manpower cost **(EcI DMC)**		

6.6.2 Ranking analysis of the determined indicators on the developed sportswear (leggings)

The selected indicators listed in Table 29-31 represent the measurement parameters of the 3D sustainability performance for SPDP (Figure 25). In Section 6.6.1, by using correlation analysis, the relationships between the indicators are being investigated. Then, through Z-score normalization, the measurement parameters of the sustainability performance are being normalized and become the plain Z- score values to evaluate the 3D sustainability performance of the 6 developed leggings. Finally, by comparing the Z-score values of the 6 leggings, managerial insights are generated for product selection.

Z score analysis is commonly used in assessment of indicators parameters (Kwatra et al., 2016). All the gathered data are in different measurement units (e.g., minute and gram) to make the date inter-comparable (Minium et al., 1993) and then by using Z-score normalization, data are converted into plain Z score values without considering the measurement units. Thereafter, the average Z-score values of each dimension's (EI, SI and EcI) indicators are calculated by applying equations (1). Through equal weighting the environmental indicators (EI), social indicators (SI), and economic indicators (EcI), the impact level of SPDP can be assessed (Table 34). The calculation details are as below.

Environmental indicators (Z_EI) = Average Z-EI scores (EI 1, EI 2, . . ., EI n)

Social indicators (Z_SI) = Average Z-SI scores (SI 1, SI 2, SI 3, . . ., Sin)

Economic index (Z EcI) = Average Z-EcI scores (SI 1, SI 2, SI 3, . . ., SI n) …… (1)

The final 3D Z scores (Z_EI, Z_SI and Z_EcI) of each version of sports legging prototypes is calculated by applying equation (2) as below, *Z_TD = Average (Z_EI + Z_SI + Z_EcI)……(2)*

Table 34. Indicators' analysis towards the developed sports legging samples

Z score analysis on the environmental indicators

Legging samples	EI Material_FY	Rank	EI Material_PY	Rank	EI Material_EY	Rank	EI Wastage	Rank	EI Energy	Rank	EI Chemical	Rank	EI Water	Rank	Total scoring
Version 1	193.33	6	57.01	3	2.58	2	35.76	1	211.12	6	2	0	30	0	3.6
Version 2	191.65	4	58.27	1	2.58	2	37.645	2	207.12	2	2	0	30	0	2.2
Version 3	192.32	5	58.93	2	2.6	4	37.708	3	207.22	3	2	0	30	0	3.4
Version 4	188.32	3	61.54	5	2.61	5	38.873	5	207.22	3	2	0	30	0	4.2
Version 5	184.6	1	60.18	4	2.61	5	38.29	4	206.22	1	2	0	30	0	3
Version 6	186.7	2	61.58	6	4.69	1	41.633	6	210.29	5	2	0	30	0	4

** EI Chemical: All six sportswear prototypes are dyed together at the same time, therefore the chemical usage is averaged and shared by all six sportswear trials without ranking.
** EI Water: All six sportswear prototypes are washed together at the same time, therefore the water usage is averaged and shared by all sportswear trials without ranking.

Z score analysis on the social indicators

Legging samples	SI PM	Rank	SI DM	Rank	SI MM_T	Rank	SI MM_W+F	Rank	SI LM	Rank	Total scoring
Version 1	1000	0	20	1	60.12	1	115	4	600	0	2.00
Version 2	1000	0	38	2	60.12	1	117	5	600	0	2.67
Version 3	1000	0	48	3	60.22	3	126	6	600	0	4.00
Version 4	1000	0	55	4	62.22	3	112	2	600	0	3.00
Version 5	1000	0	59	5	62.22	3	108	1	600	0	3.00
Version 6	1000	0	68	6	62.29	6	113	3	600	0	5.00

** SI PM: The questionnaire for product planning is conducted for all six sportswear trials at the same time, therefore the planning manpower usage is averaged and shared by all six sportswear trials without ranking.
** SI LM: The data analysis for product selection and launching is conducted for all six sportswear trials at the same time, therefore the launching manpower usage is averaged and shared by all six sportswear trials without ranking.

Z score analysis on the economic indicators

Legging samples	EcI PMC	Rank	EcI DMC	Rank	EcL MMC_T	Rank	EcL MMC_WDF	Rank	Ecl LMC	Rank	Ecl MC	Rank	EcI MWC	Rank	EcI EC	Rank	EcI CC	Rank	EcI WC	Rank	Total scoring
Version 1	17.8	0	4.74	1	4.62924	1	3.275	4	8.057	0	0.61909	2	0.4255	1	0.485576	6	0.032	0	0.2906	0	2.50
Version 2	17.8	0	9.006	2	4.62924	1	3.417	5	8.057	0	0.6193	3	0.448	2	0.476376	1	0.032	0	0.2906	0	2.33
Version 3	17.8	0	11.376	3	4.63694	3	4.056	6	8.057	0	0.62295	5	0.4487	3	0.476606	3	0.032	0	0.2906	0	3.83
Version 4	17.8	0	13.035	4	4.79094	4	3.062	2	8.057	0	0.6223	4	0.4626	5	0.476606	3	0.032	0	0.2906	0	3.67
Version 5	17.8	0	13.983	5	4.79094	4	2.778	1	8.057	0	0.6099	1	0.4557	4	0.474306	2	0.032	0	0.2906	0	2.83

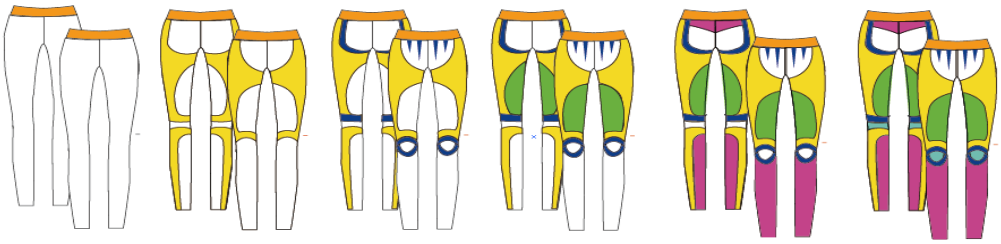
** EcI PMC: The questionnaire for product planning is conducted for all six sportswear trials, therefore the planning manpower cost is averaged and shared by all six sportswear trials without ranking.
** EcI LMC: The data analysis for product selection and launching is conducted for all six sportswear trials at the same time, therefore the launching manpower cost is averaged and shared by all six sportswear trials without ranking.
** EcI CC: All six sportswear trials are dyed together at the same time, therefore the chemical usage cost is averaged and shared by all six sportswear trials without ranking.
** EcI WC: All six sportswear trials are washed together at the same time, therefore the water usage cost is averaged and shared by all sportswear trials without ranking.

6.7 Discussion and recommendation

Based on the indicator analysis in Section 6.6.2 towards the developed sports legging samples, the sustainability performances of the sportswear product development process are analyzed three-dimensionally. Among all these six versions, version 2 performs the best in overall ranking since it balances all three dimensions of TBL and ranks the highest in terms of environmental and economic performances. Thus, version 2 is preferable to the other 5 versions to be selected for launching.

Although version 1 performs well in overall ranking (rank 2^{nd}), but it ranks 4^{th} (unsatisfactory) in terms of environmental performance, and version 1 has no functional properties which may not satisfy the function-conscious SSCs' demands. To fulfill both SSSs' and SSCs' requirements, the supplier can select version 5 for launching. It is because version 5 is the second-best version in terms of environmental performance. Meanwhile, it provides three extra functions for the consumers (i.e., muscular support, breathability, and comfort fitting). Although the ranking of version 3 is moderate in terms of social and economic performances, the additional functions may compensate for its higher selling price.

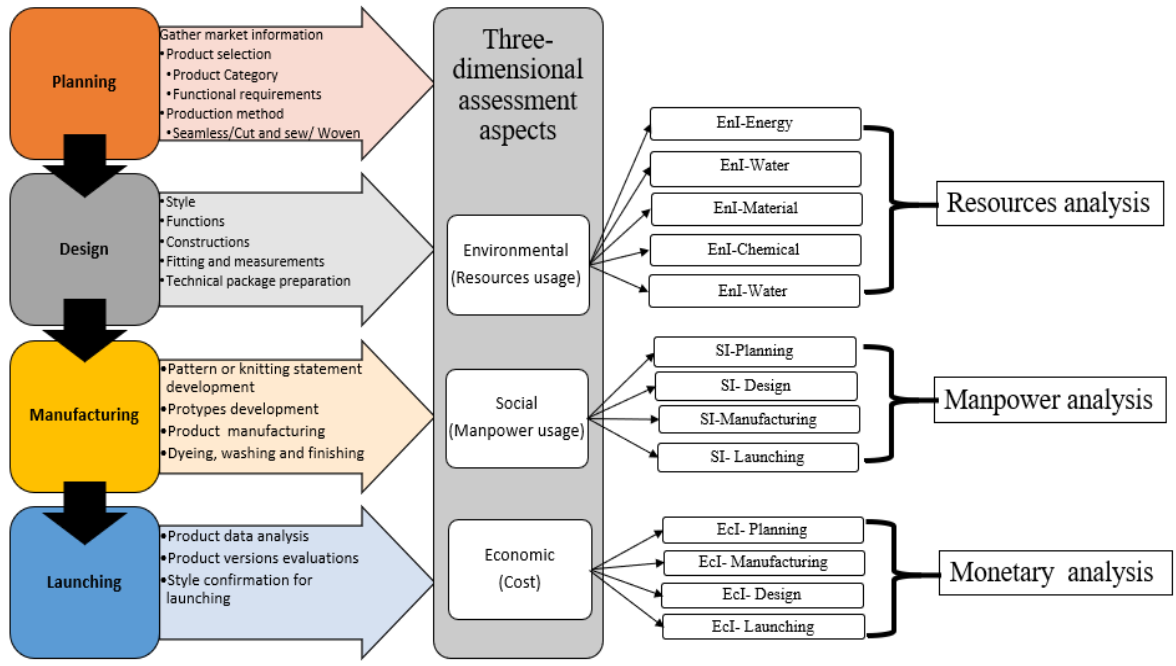
Table 35. Comparison on the results of the developed sustainable seamless legging versions

Sustainable seamless legging samples						
Indicators	**Version 1**	**Version 2**	**Version 3**	**Version 4**	**Version 5**	**Version 6**
Environmental indicators	3.6	2.2	3.4	4.2	3.0	4
Environmental ranking	4	1	3	6	2	5
Social indicators	2	2.67	4	3	3	5
Social ranking	1	2	5	3	3	6
Economic indicators	2.5	2.3	3.8	3.7	2.8	5.3
Economic ranking	2	1	5	4	3	6
Overall Ranking	2	1	4	4	3	6
Prototype						
Production sketch						

6.8 Summary

By using the three-dimensional assessment approaches (Figure 35) of sustainability, a set of measurable indicators is developed to assess the performance of the sustainable sportswear development process. This study shows that the determined indicators provide a useful tool for the sustainable suppliers in product selection for launching. Chapter 6 focuses on the assessment of the product development processes of the six sustainable seamless sports leggings. With the data acumination, a company can set up a database for decision making of business development in a

long run. For example, SSSs can work on the sustainable business development strategy based on the external market research and internal resources evaluation to decide the product line distribution with respect to the three-dimensional sustainability performance assessment.



Indicators	Version 1	Version 2	Version 3	Version 4	Version 5	Version 6
Environmental indicators	3.6	2.2	3.4	4.2	3	4
Social indicators	2	2.67	4	3	3	5
Economic indicators	2.5	2.3	3.8	3.7	2.8	5.3

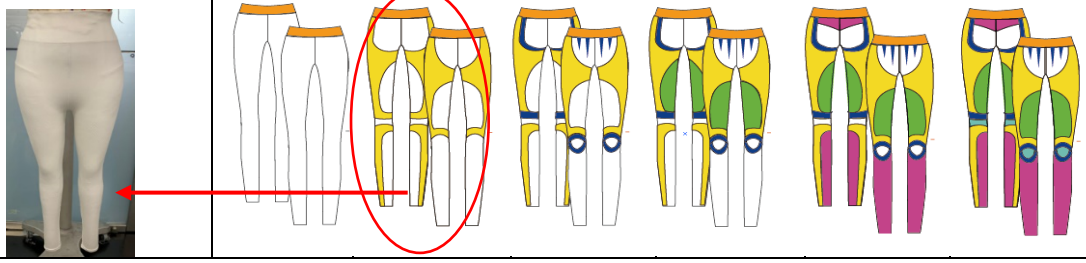


Figure 35. A three-dimensional sustainability performance assessment approach on SPDP of sportswear leggings

CHAPTER 7

Knowledge Network Analysis in a Global Scale on the Sustainable Fashion Product Development

7.1 Introduction

To enhance our understanding of the research and industrial progress relating to sustainable fashion product development in a global scale, a knowledge network analysis (KNA) has been conducted to systematically investigate the related studies carried out by the researchers and teams from different countries and regions. Meanwhile, through the main-path analysis (MPA), the correlations among these existing studies have been established, which shed light on the future research trends/interests and facilitate the strategic planning of industrial activities for sustainable fashion product development.

To now, numerous studies have been conducted to integrate sustainability considerations into the fashion product development process. However, through conducting the KNA and MPA, we found the gaps between the studies and the problems not being addressed. Chapter 7 presents a sustainable product development matrix to depict the whole picture of the current knowledge foundation and the future research direction. The findings provide managerial insights to potentially guide the industrial participators on sustainable fashion product development and management.

7.2 Methodology and data collection

According to Webster and Watson (2002), we should not limit the methodologies, geographical regions, and journals to conduct a comprehensive knowledge analysis. Thus, all relevant literature are considered in this study. To construct a quality review, appropriate database, functions of search, review period, and journals (Wetzstein et al.,2019) should be selected. To ensure the studies that we collect are of high quality, the web of science is used to search articles published in the well-established English journals.

The searching period covers twenty years (from 2001 to 2021) relating to the sustainable fashion product development process. A full-text journal articles are searched by using the keywords: “sustainability,” “product development,” “production,” “design,” “manufacturing,” “garment,” “apparel,” “textile,” “fashion,” and “clothing”. Finally, a total of 212 journal studies are initially selected and analyzed in this study.

By screening the titles, abstracts, and introductions, we sort out the fashion-related studies with the focused sustainable fashion product development. Eventually, 110 studies are determined. Knowledge network analysis (KNA) and main path analysis (MPA) are conducted to examine the critical knowledge interests in the field of sustainable fashion product development, thus orienting the future research (Wetzstein et al., 2019).

7.2.1 Knowledge network analysis (KNA)

KNA aims to examine the knowledge network of the related research fields of sustainable fashion product development. According to Hummon and Dereian (1989), KNA use earlier studies as a foundation to assist researchers to produce new ideas and thoughts in the same or similar research area. This snowball effect will create networks of knowledge. Based on this knowledge network built, the critical expertise that constitutes the main research streams can be determined.

To analyze the network of knowledge in this studied domain, the CitNet Explorer clustering algorithm is adopted. CitNet Explorer focused on the individual publication's citation network (Van & Waltman, 2014). It has two critical advantages in analyzing knowledge network. Firstly, it is forbidden knowledge relations to point forward in time, which means that the publication published early cannot cite studies from the later period. Secondly, it ensures the acyclicity of the knowledge network (Batagelj, 2003). For instance, when we move along the knowledge network, we cannot revisit the same publication which we have been through. Thus, double counting of the publication is not allowed in the CitNet Explorer. CitNet Explorer can visualize the citation network using a citation flow in one direction and construct a precise and visualized network mapping to enhance the efficiency of the analysis.

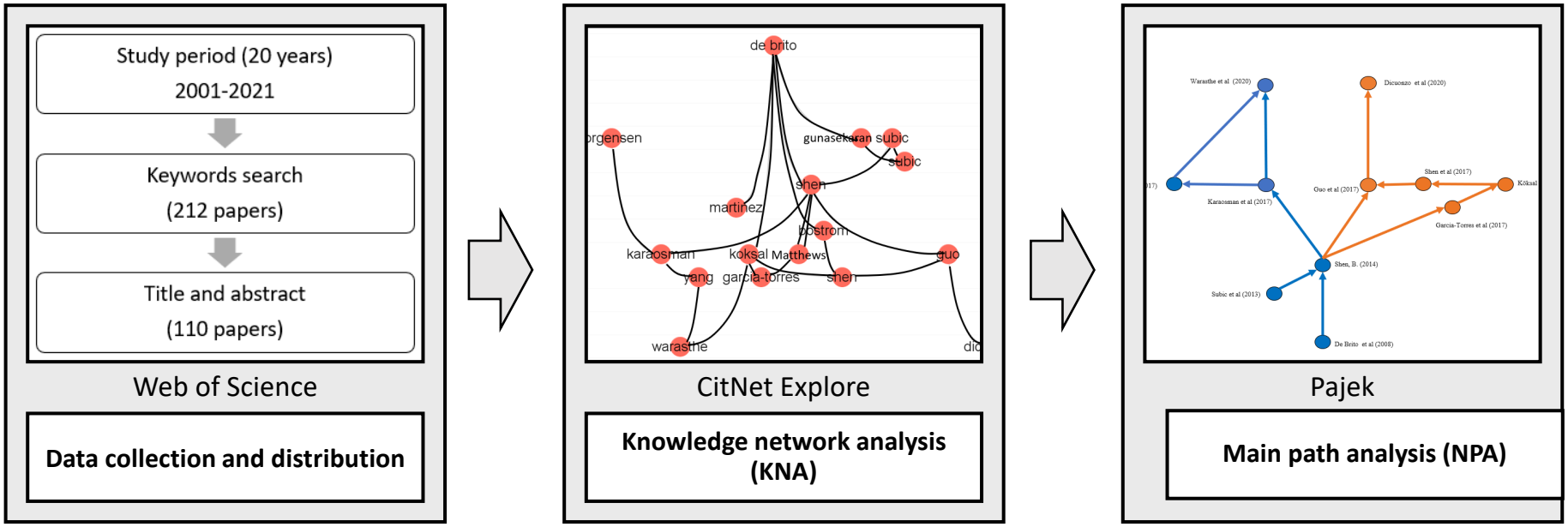


Figure 36. Research methodology on knowledge network analysis

7.2.2 Main path analysis (MPA)

Hummon and Dereian (1989) firstly introduced MPA in 1989 (Xiao et al.,2017). By identifying the maximum connectivity among the collected studies, the MPA can uncover the trends of the development in the studied research domain, and also can visualize the most significant connectivity of the gathered knowledge network (Mrvar & Batagelj, 1998). Using the MPA software "Pajek", the most important studies and knowledge path can be identified (Colicchia & Strozzi, 2012) and can show the linkage and trend of the most significant studies in the studied fields (Dohleman, 2006).

7.2.3 Data collection and data distributions

Knowledge distribution by years: Figure 37 shows the distribution of publications per five years. Obviously, there is a growth of interest within the last twenty years (2001-2021). The number of publications from 2001- 2010 is deficient, where only 16 studies were published. This shows that the attention towards sustainable fashion product developments was still minimal. However, starting from 2011, the numbers of publications increase sharply. Compared to 2001-2010 (10 years), the related domain publications rise almost 220% from 2011 to 2015 (5 years), implying that this 5-year is the turning point in the research domain of sustainable fashion product development. This could relate to the introduction of fast fashion and the sustainability issues derived by the fast fashion industry. During the last five years (2016-2021), sustainable fashion product development attracts more academic attention. Over 53% (59 studies) of the related researches were published in the last five years, implying a sustained academic interests in the related areas.

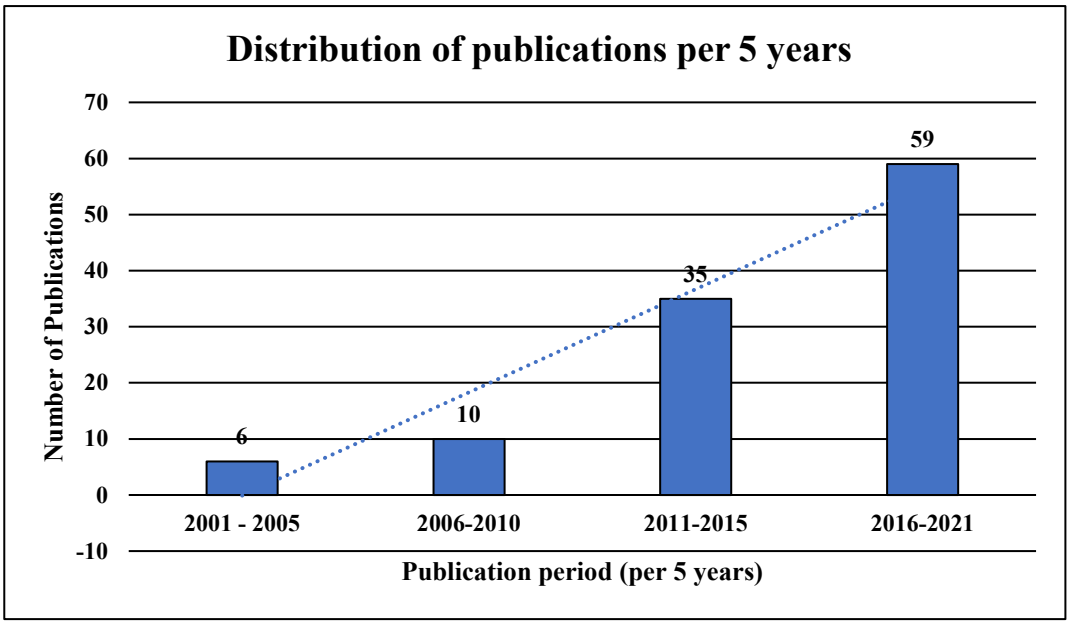


Figure 37. Distribution of the publication per 5 years during 2001-2021

Knowledge distribution by journals: Among the collected studies, over 17% of fashion product development-related journals are from the *Journal of Cleaner Production* (19 studies), where over 15% are from *Sustainability* (18 studies) and 8% from *International Journals of Production Economics* (9 studies). About 5% of the studies are from *Production Planning and Control* (5 studies), and approximately 3.5% from the *Journal of Textile Institute* and *International Journals of Life Cycle Assessments* (4 studies from each journal), respectively.

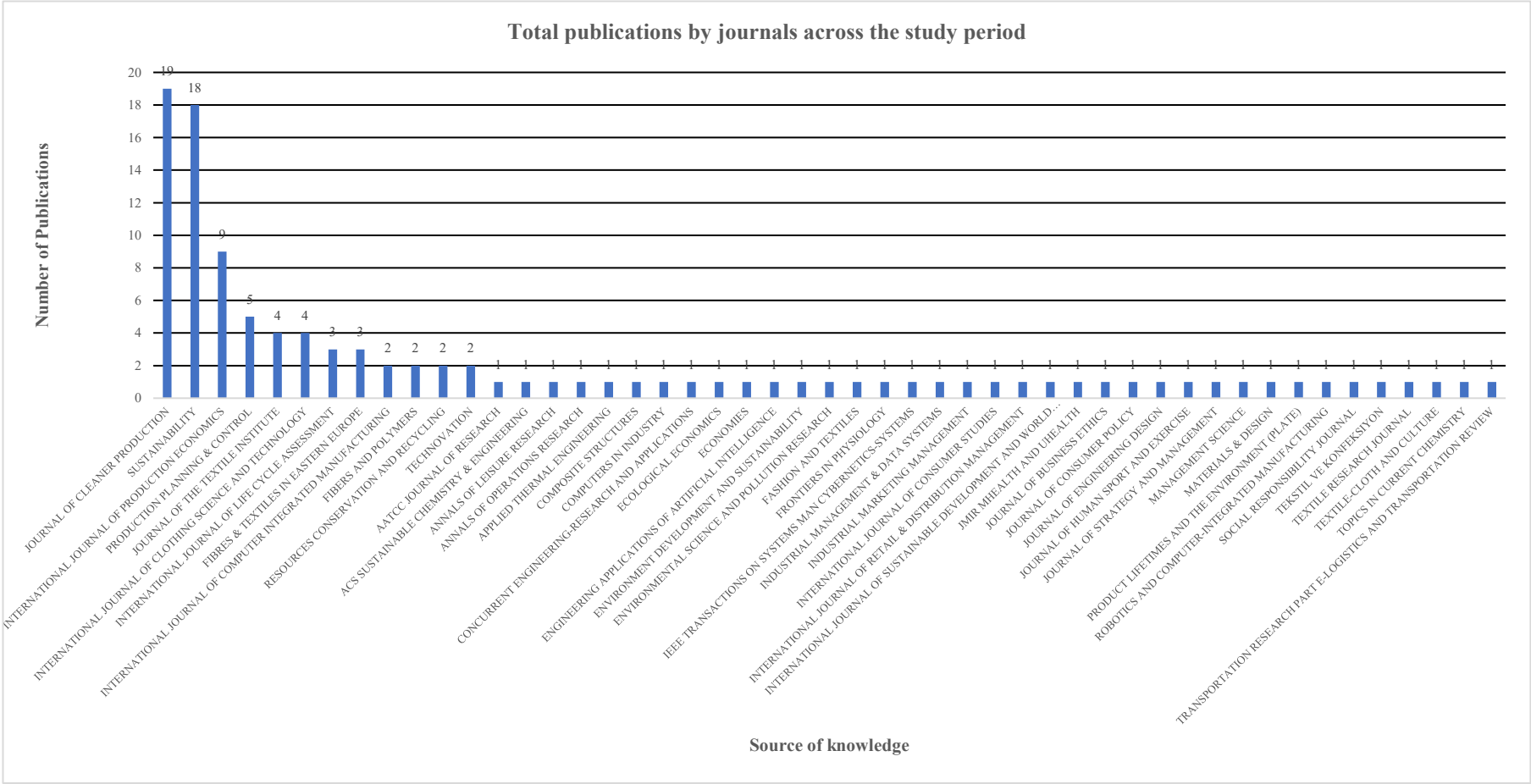


Figure 38. The total publications by journals across the study period (110 articles, 2001-2021)

Table 36. Publication by journals across the study period (110 articles, 2001-2021)

Journals	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
JOURNAL OF CLEANER PRODUCTION	0	0	0	0	1	0	0	0	0	0	2	0	0	2	4	2	0	2	2	2	2
SUSTAINABILITY	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	8	0	2	4	0
INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS	0	0	0	0	0	0	0	2	1	1	0	1	1	2	1	0	0	0	0	0	0
PRODUCTION PLANNING & CONTROL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	0	0	0	0
JOURNAL OF THE TEXTILE INSTITUTE	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	1	0
INTERNATIONAL JOURNAL OF CLOTHING SCIENCE AND TECHNOLOGY	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0
INTERNATIONAL JOURNAL OF LIFE CYCLE ASSESSMENT	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0
FIBERS AND POLYMERS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
FIBRES & TEXTILES IN EASTERN EUROPE	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
INTERNATIONAL JOURNAL OF COMPUTER INTEGRATED MANUFACTURING	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
RESOURCES CONSERVATION AND RECYCLING	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
TECHNOVATION	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
AATCC JOURNAL OF RESEARCH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
ACS SUSTAINABLE CHEMISTRY & ENGINEERING	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
ANNALS OF LEISURE RESEARCH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
ANNALS OF OPERATIONS RESEARCH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
APPLIED THERMAL ENGINEERING	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
COMPOSITE STRUCTURES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
COMPUTERS IN INDUSTRY	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CONCURRENT ENGINEERING-RESEARCH AND APPLICATIONS	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECOLOGICAL ECONOMICS	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
ECONOMIES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
ENGINEERING APPLICATIONS OF ARTIFICIAL INTELLIGENCE	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
ENVIRONMENT DEVELOPMENT AND SUSTAINABILITY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
FASHION AND TEXTILES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
FRONTIERS IN PHYSIOLOGY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
IEEE TRANSACTIONS ON SYSTEMS MAN CYBERNETICS-SYSTEMS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
INDUSTRIAL MANAGEMENT & DATA SYSTEMS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
INDUSTRIAL MARKETING MANAGEMENT	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
INTERNATIONAL JOURNAL OF CONSUMER STUDIES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
INTERNATIONAL JOURNAL OF RETAIL & DISTRIBUTION MANAGEMENT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
INTERNATIONAL JOURNAL OF SUSTAINABLE DEVELOPMENT AND WORLD ECOLOGY	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JMIR MHEALTH AND UHEALTH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
JOURNAL OF BUSINESS ETHICS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
JOURNAL OF CONSUMER POLICY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
JOURNAL OF ENGINEERING DESIGN	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
JOURNAL OF HUMAN SPORT AND EXERCISE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
JOURNAL OF STRATEGY AND MANAGEMENT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
MANAGEMENT SCIENCE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
MATERIALS & DESIGN	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PRODUCT LIFETIMES AND THE ENVIRONMENT (PLATE)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
ROBOTICS AND COMPUTER-INTEGRATED MANUFACTURING	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SOCIAL RESPONSIBILITY JOURNAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
TEKSTIL VE KONFEKSIYON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
TEXTILE RESEARCH JOURNAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
TEXTILE-CLOTH AND CULTURE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
TOPICS IN CURRENT CHEMISTRY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
TRANSPORTATION RESEARCH PART E-LOGISTICS AND TRANSPORTATION REVIEW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

Knowledge distribution by countries: In the research domain of sustainable fashion product development, East Asia (China), North America (USA), Europe (England, Italy, Sweden, Germany, Finland, France, and the Netherlands), and Oceania (Australia) are the top 5 geographical regions/countries with the highest contributions. Researchers from Europe, China, and USA take up 85% of the collected knowledge networks. This is in line with the fashion market sharing. According to the Statista report (Oloruntoba, 2020), upon the apparel market's revenue worldwide by 2019, Europe, USA, and China take up 70% of the total apparel market worldwide.

Meanwhile, Figure 39 shows that India and Japan contribute 4% of the global apparel market revenues, while the academic attention towards the sustainable product development domain is minimal. In contrast, Australia places greater attention to the related studies even the revenue contribution is relatively low.

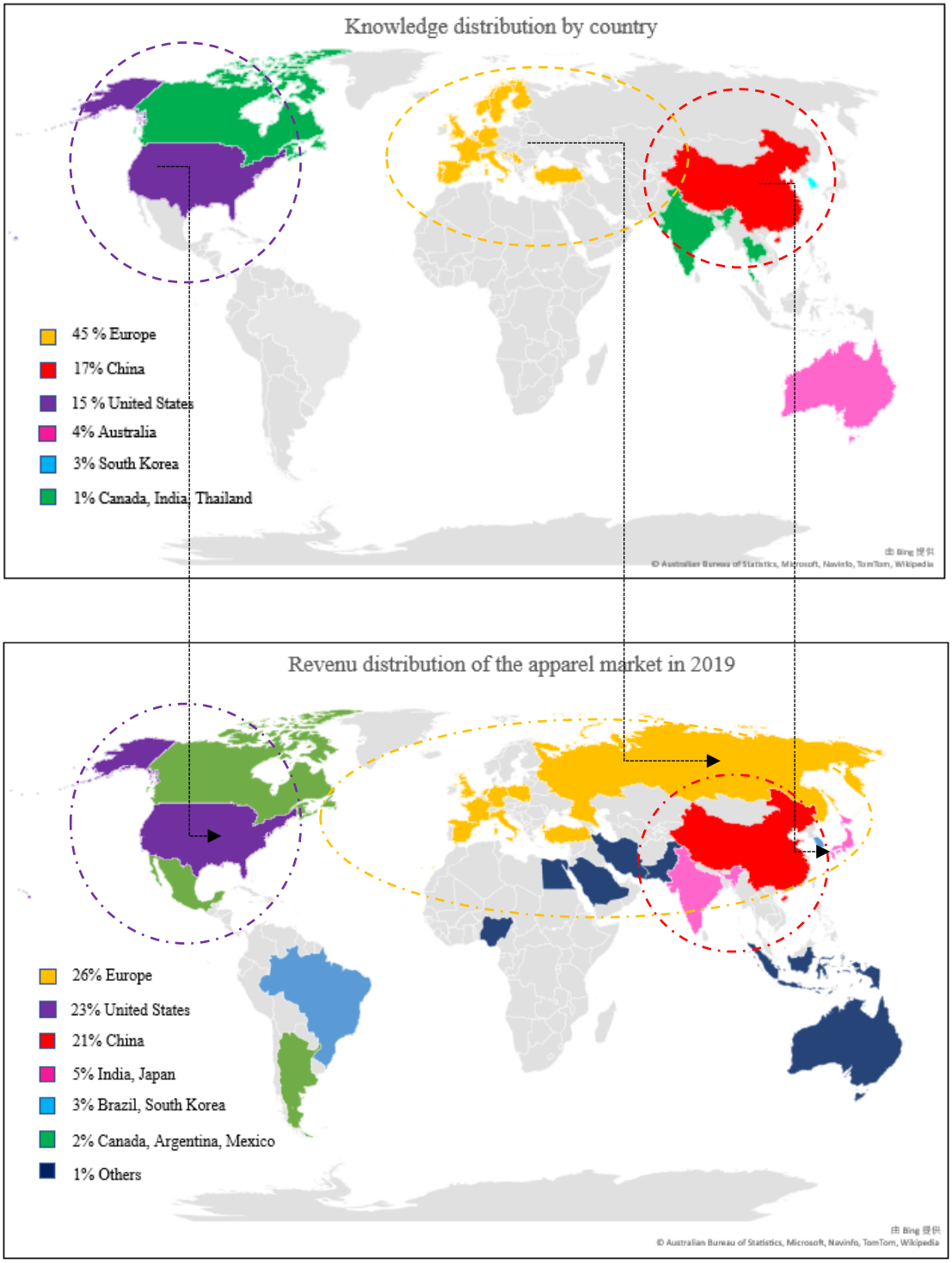


Figure 39. Knowledge distributions by countries vs. revenue distributions of the apparel market in 2019

7.3 Results and analysis

7.3.1 The mapping of knowledge network

To explore the knowledge structures on the sustainable fashion product development, the collected studies were imported to the CitNet Explorer. Four knowledge network clusters are generated (Figure 40), namely: (1) effects of sustainable fashion business strategies, (2) effects of consumers' preferences towards sustainable products on sustainable product development, (3) internationalization of sustainable fashion industry, and (4) sustainable design and manufacturing correlations.

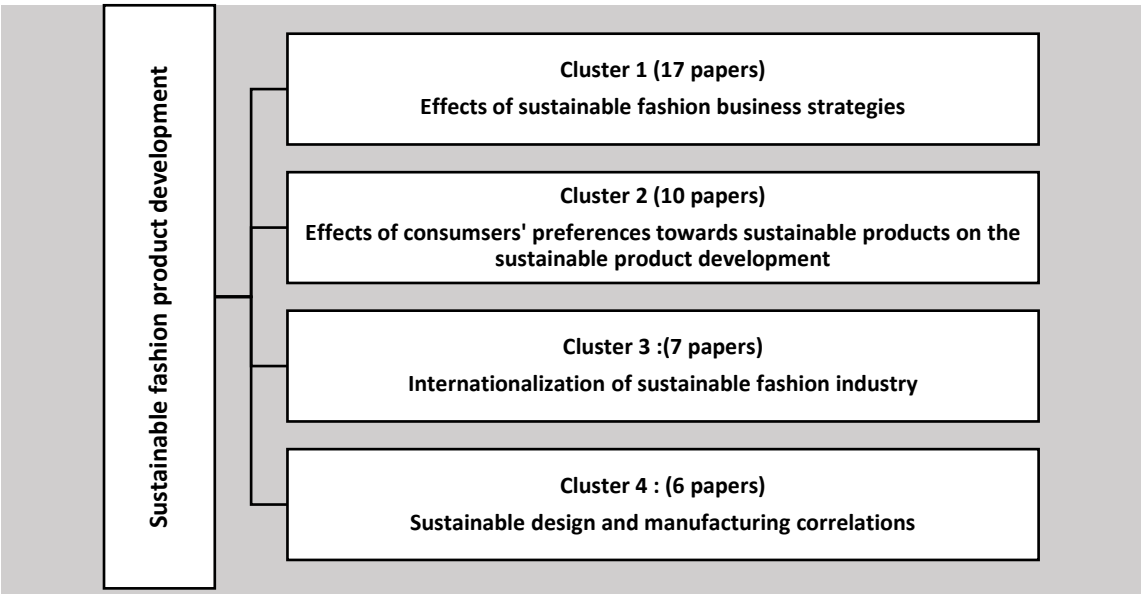


Figure 40**.** Knowledge network clustered by using CitNet Explorer

Cluster 1 KNA: Figure 41 shows the knowledge network of Cluster 1 generated by the CiteNet explore with a critical focus in studying the effects of sustainable fashion business strategies. A total of 17 studies were included in the knowledge network during 2008-2020. According to the categories by web of science, nine

research areas are involved in this Clusters. Environmental science, environmental studies, and green sustainable science technologies are the top three research areas. Table 37 presents the list of studies in Cluster 1. It shows that Cluster 1 evolved in 2008 with a steady increase in academic attention. As a turning point, over 40% of the 17 publications in Cluster 1 were published in 2017. Researchers focus more on the studies on the effects of sustainable fashion business operation management and their performance evaluations facilitating sustainable fashion business.

Massive attention has been drawn towards sustainability in fashion industry (Farra, 2017). It is reported (BCC, 2018a) that one of the biggest luxury fashion brands Burberry, is burning unsold clothes, bags, and perfumes worth over 28.6 million US dollars. Burberry is not alone in dealing with the surplus goods. The news shocked the whole fashion industry, and further drew the attention from environmental campaigners and consumers towards fashion brands' business operations. Due to the negative impact on the brand image, the brands' sales and profits drop drastically. In 2018, Burberry announced that they would stop burning the unsold goods. There has a revamp of business operations to avoid over-production and reduce fashion wastes (BCC, 2018b). The knowledge network developed drastically in the same year.

Table 37. The journal papers involved in Cluster 1

MP	Authors	Article Title	Source Title	Year
*	Dicuonzo, G; Galeone, G; Ranaldo, S; Turco, M	The Key Drivers of Born-Sustainable Businesses: Evidence from the Italian Fashion Industry	SUSTAINABILITY	2020
*	Warasthe, R; Schulz, F; Enneking, R; Brandenburg, M	Sustainability Prerequisites and Practices in Textile and Apparel Supply Chains	SUSTAINABILITY	2020
*	Garcia-Torres, S; Rey-Garcia, M; Albareda-Vivo, L	Effective Disclosure in the Fast-Fashion Industry: from Sustainability Reporting to Action	SUSTAINABILITY	2017
	Matthews, D; Rothenberg, L	An assessment of organic apparel, environmental beliefs and consumer preferences via fashion innovativeness	INTERNATIONAL JOURNAL OF CONSUMER STUDIES	2017
*	Shen, B; Li, QY; Dong, CW; Perry, P	Sustainability Issues in Textile and Apparel Supply Chains	SUSTAINABILITY	2017
*	Yang, S; Song, YP; Tong, SL	Sustainable Retailing in the Fashion Industry: A Systematic Literature Review	SUSTAINABILITY	2017
*	Guo, ZX; Liu, HT; Zhang, DQ; Yang, J	Green Supplier Evaluation and Selection in Apparel Manufacturing Using a Fuzzy Multi-Criteria Decision-Making Approach	SUSTAINABILITY	2017
*	Karaosman, H; Morales-Alonso, G; Brun, A	From a Systematic Literature Review to a Classification Framework: Sustainability Integration in Fashion Operations	SUSTAINABILITY	2017
*	Koksal, D; Strahle, J; Muller, M; Freise, M	Social Sustainable Supply Chain Management in the Textile and Apparel Industry-A Literature Review	SUSTAINABILITY	2017
	Bostrom, M; Micheletti, M	Introducing the Sustainability Challenge of Textiles and Clothing	JOURNAL OF CONSUMER POLICY	2016
	Martinez, S; Errasti, A; Rudberg, M	Adapting Zara's 'Pronto Moda' to a value brand retailer	PRODUCTION PLANNING & CONTROL	2015
*	Shen, B	Sustainable Fashion Supply Chain: Lessons from H&M	SUSTAINABILITY	2014
*	Subic, A; Shabani, B; Hedayati, M; Crossin, E	Performance Analysis of the Capability Assessment Tool for Sustainable Manufacturing	SUSTAINABILITY	2013
	Jorgensen, MS; Jensen, CL	The shaping of environmental impacts from Danish production and consumption of clothing	ECOLOGICAL ECONOMICS	2012
	Gunasekaran, A; Spalanzani, A	Sustainability of manufacturing and services: Investigations for research and applications	INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS	2012
	Subic, A; Shabani, B; Hedayati, M; Crossin, E	Capability Framework for Sustainable Manufacturing of Sports Apparel and Footwear	SUSTAINABILITY	2012
*	de Brito, MP; Carbone, V; Blanquart, CM	Towards a sustainable fashion retail supply chain in Europe: Organization and performance	INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS	2008

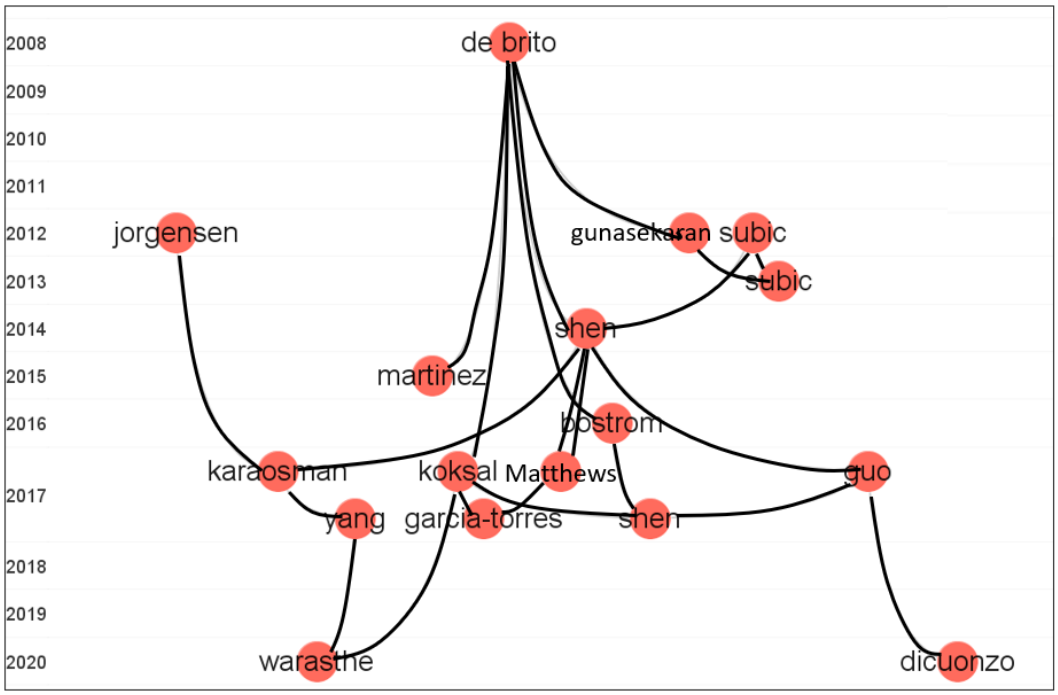


Figure 41. The knowledge mapping of the Cluster 1 derived by CitNet Explorer

Cluster 2 KNA: According to the knowledge network generated by the CiteNet explore (Figure 42), the knowledge network Cluster 2 is being developed between 2011-2021. A total of ten studies are included in the knowledge network, where engineering, environmental science ecology, science technology, and business economics are the key research areas. The focus of Cluster 2 is on the effects of consumers' preferences towards sustainable products on sustainable product development. In the past ten years, researchers paid great attention to study the relationship between sustainable fashion industry and consumer behavior, as well as their interactions. Meanwhile, these studies are gained more attention in the last five years. Especially in 2019, tremendous news reported the consumers' dissatisfaction towards sustainability performance of fashion brands.

According to Jessop (2019), the environmental audit committee (EAC) reports that in 2019, major fashion brands fail to protect industrial workers and cannot engage in environmental sustainability. The failure of the fashion brands draws the attention of fashion consumers upon the brands' sustainability performance. Suppose fashion brands fail to achieve sustainable fashion, consumers would choose other brands, thus ultimately affecting the firm's business in a long run. More academic studies pay attention to the investigations of the relationships between the sustainable fashion industries and consumer behaviors.

Table 38. The journals papers involved in Cluster 2

	MP Authors	Article Title	Source Title	Year
*	Shrivastava, A; Jain, G; Kamble, SS; Belhadi, A	Sustainability through online renting clothing: Circular fashion fueled by Instagram micro-celebrities	JOURNAL OF CLEANER PRODUCTION	2021
*	Chan, HL; Wei, XY; Guo, S; Leung, WH	Corporate social responsibility (CSR) in fashion supply chains: A multi-methodological study	TRANSPORTATION RESEARCH PART E-LOGISTICS AND TRANSPORTATION REVIEW	2020
*	Holtstrom, J; Bjellerup, C; Eriksson, J	Business model development for sustainable apparel consumption The case of Houdini Sportswear	JOURNAL OF STRATEGY AND MANAGEMENT	2019
*	Bech, NM; Birkved, M; Charnley, F; Kjaer, LL; Pigosso, DCA; Hauschild, MZ; McAloone, TC; Moreno, M	Evaluating the Environmental Performance of a Product/Service-System Business Model for Merino Wool Next-to-Skin Garments: The Case of Armadillo Merinox (R)	SUSTAINABILITY	2019
*	Clarke-Sather, A; Cobb, K	Onshoring fashion: Worker sustainability impacts of global and local apparel production	JOURNAL OF CLEANER PRODUCTION	2019
*	Stal, HI; Corvellec, H	A decoupling perspective on circular business model implementation: Illustrations from Swedish apparel	JOURNAL OF CLEANER PRODUCTION	2018
*	Cooper, T; Oxborrow, L; Claxton, S; Goworek, H; Hill, H; McLaren, A	New product development and testing strategies for clothing longevity: an overview of a UK research study	PRODUCT LIFETIMES AND THE ENVIRONMENT (PLATE)	2017
	Dissanayake, G; Sinha, P	An examination of the product development process for fashion remanufacturing	RESOURCES CONSERVATION AND RECYCLING	2015
*	Armstrong, CM; Niinimaki, K; Kujala, S; Karell, E; Lang, CM	Sustainable product-service systems for clothing: exploring consumer perceptions of consumption alternatives in Finland	JOURNAL OF CLEANER PRODUCTION	2015
*	Niinimaki, K; Hassi, L	Emerging design strategies in sustainable production and consumption of textiles and clothing	JOURNAL OF CLEANER PRODUCTION	2011

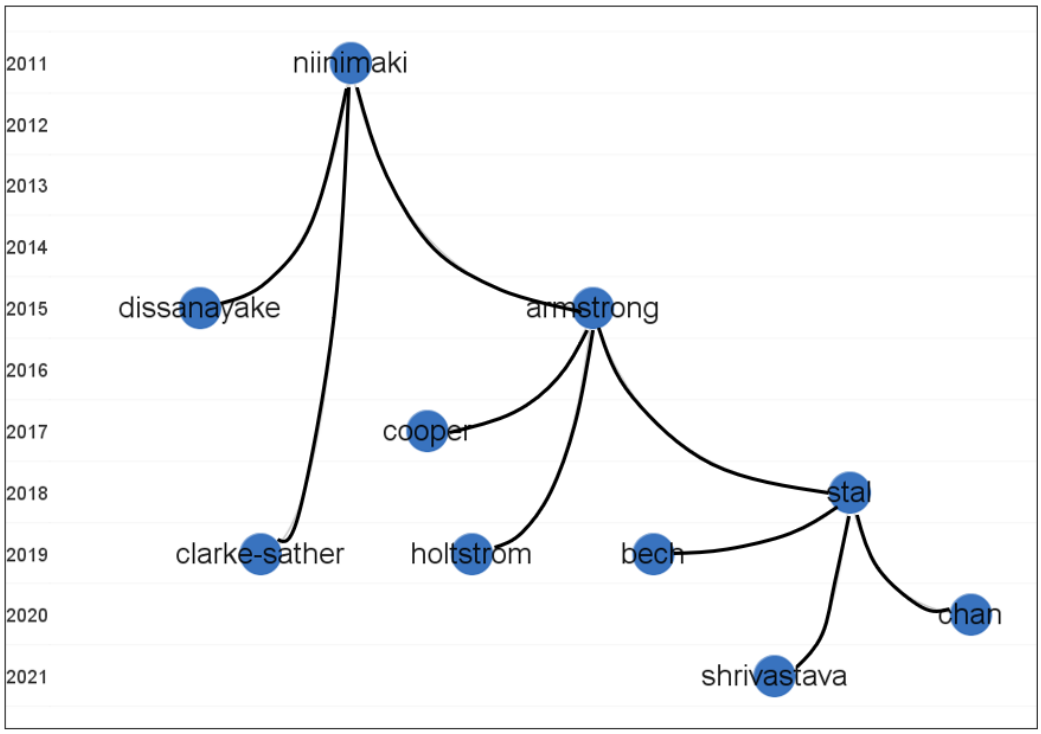


Figure 42. The knowledge mapping of the Cluster 2 derived by CitNet Explorer

Cluster 3 KNA: Figure 43 shows the knowledge network of Cluster 3 generated by the CitNet explore. A total of 7 studies are included in the knowledge network Cluster 3 (2008-2021). The key focus of the Cluster 3 is on the internationalization of sustainable fashion business. According to the research categories of web of science, the knowledge network can be categorized into 8 areas, where many of the studies focus on operation research management science, industrial engineering, and manufacturing engineering.

The knowledge network evolved in 2008 and stay evenly from 2008 to 2021. The Agreement on Textiles and Clothing *(*ATC) restrict the amount of apparel products exported between developing countries and developed countries via quotas. The phasing out of the ATC agreement has a significant impact on apparel exports in both developed and developing countries (Appelbaum, 2004). According to Fugazza and Conway (2010) study, removing the ATC agreement leads to a

reallocation of the trading countries. Without the agreement restoration, companies can source apparel production worldwide and minimize the manufacturing costs. Meanwhile, they can ship the products to various countries, further boost the internationalization of the sustainable fashion industry and the related studies.

Table 39**.** The journal papers involved in Cluster 3

	Authors	Article Title	Source Title	Year
*	Bubicz, ME; Barbosa-Povoa, APFD; Carvalho, A	Social sustainability management in the apparel supply chains	JOURNAL OF CLEANER PRODUCTION	2021
*	Macchion, L; Moretto, A; Caniato, F; Caridi, M; Danese, P; Spina, G; Vinelli, A	Improving innovation performance through environmental practices in the fashion industry: the moderating effect of internationalization and the influence of collaboration	PRODUCTION PLANNING & CONTROL	2017
*	Caniato, F; Crippa, L; Pero, M; Sianesi, A; Spina, G	Internationalization and outsourcing of operations and product development in the fashion industry	PRODUCTION PLANNING & CONTROL	2015
*	Macchion, L; Moretto, A; Caniato, F; Caridi, M; Danese, P; Vinelli, A	Production and supply network strategies within the fashion industry	INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS	2015
*	Caniato, F; Caridi, M; Moretto, A; Sianesi, A; Spina, G	Integrating international fashion retail into new product development	INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS	2014
*	Guercini, S; Runfola, A	Business networks and retail internationalization: A case analysis in the fashion industry	INDUSTRIAL MARKETING MANAGEMENT	2010
*	Brun, A; Castelli, C	Supply chain strategy in the fashion industry: Developing a portfolio model depending on product, retail channel and brand	INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS	2008

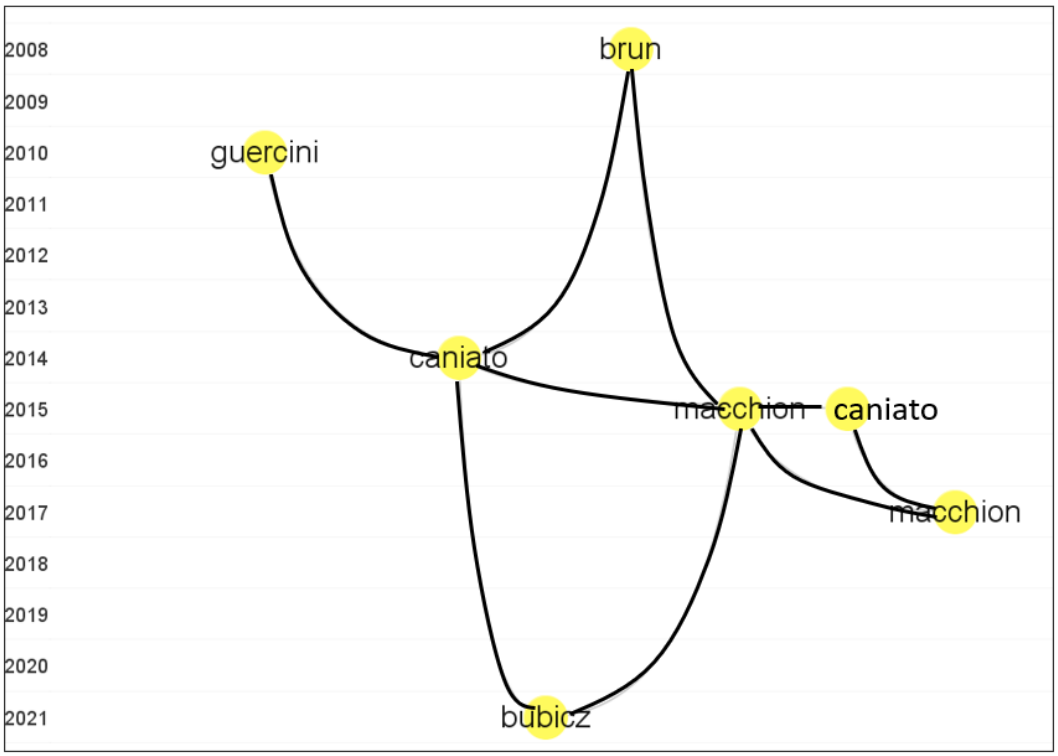


Figure 43. The knowledge mapping of the Cluster 3 derived by CitNet Explorer

Cluster 4 KNA: According to the knowledge network generated by the CiteNet explore (Figure 44), Cluster 4 knowledge network is being developed between 2007-2017 (Table 40). Seven studies are included in the knowledge network, mainly focusing on the sustainable design and manufacturing, including environmental sciences, green sustainable science, and technology, based on the categories of web of science data. Eco-design and eco-manufacturing have a high impact on the sustainable fashion industry.

Table 40. The journal papers involved in Cluster 4

MP	Authors	Article Title	Source Title	Year
*	Wang, L; Shen, B	A Product Line Analysis for Eco-Designed Fashion Products: Evidence from an Outdoor Sportswear Brand	SUSTAINABILITY	2017
*	Clancy, G; Froling, M; Peters, G	Ecolabels as drivers of clothing design	JOURNAL OF CLEANER PRODUCTION	2015
*	Alkaya, E; Demirer, GN	Sustainable textile production: a case study from a woven fabric manufacturing mill in Turkey	JOURNAL OF CLEANER PRODUCTION	2014
*	Moon, KKL; Youn, C; Chang, JMT; Yeung, AWH	Product design scenarios for energy saving: A case study of fashion apparel	INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS	2013
*	Santolaria, M; Oliver-Sola, J; Gasol, CM; Morales-Pinzon, T; Rieradevall, J	Eco-design in innovation driven companies: perception, predictions and the main drivers of integration. The Spanish example	JOURNAL OF CLEANER PRODUCTION	2011
*	Ljungberg, LY	Materials selection and design for development of sustainable products	MATERIALS & DESIGN	2007

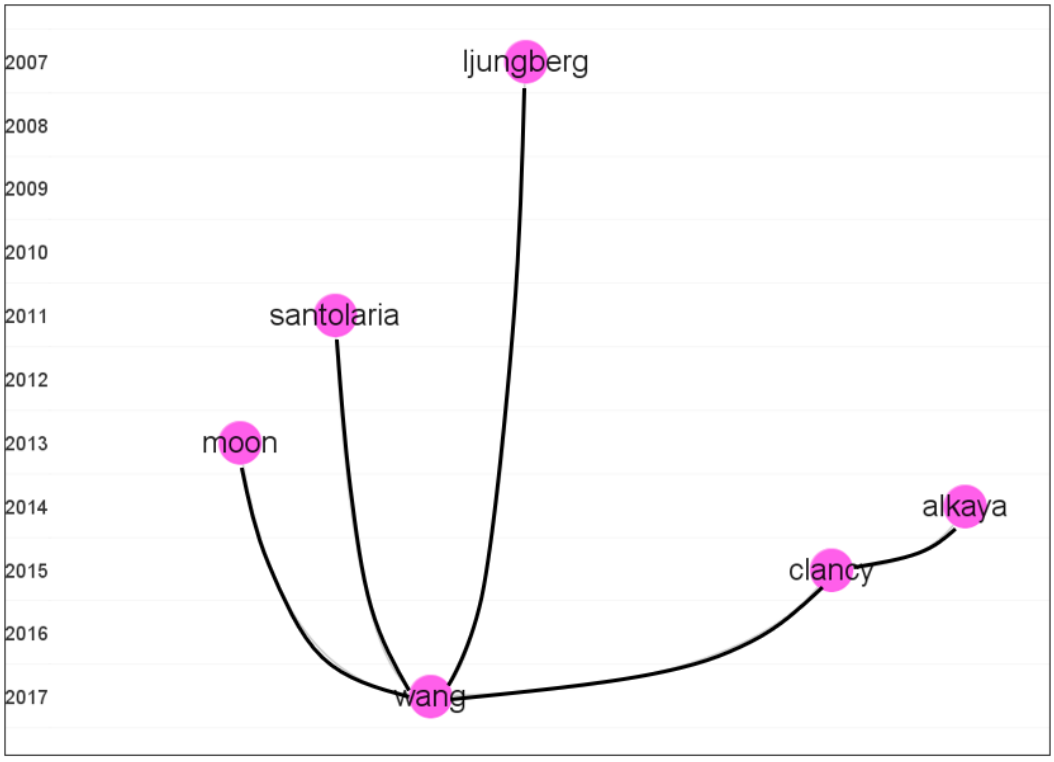


Figure 44. The knowledge mapping of the Cluster 4 derived by CitNet Explorer

7.3.2 In-depth analysis of knowledge network

A main-path analysis (MPA) is further conducted to reveal the knowledge evolution.

MPA of Cluster 1 - Effects of sustainable business strategies

Cluster 1 includes the highest number of studies (17 studies), which indicates that the highest academic interest is placed in investigating sustainable fashion business operations and management. Figure 45 shows the main knowledge development path in Cluster 1. The two strands of research are included, i.e., (1) sustainable fashion business operations management, and (2) sustainable fashion business performance evaluations.

-Strand 1: operations management of sustainable fashion business De Brito et al. (2008) firstly explores the sustainable fashion supply chain in Europe through the investigations on how the sustainability movement affect the fashion supply chain and the corresponding organization performance. The results demonstrates that the fashion supply chain is extremely sensitive to sustainability issues, whereas various conflicts between the supply chain stakeholders incur and affect the sustainability performance. Based on De Brito et al. (2008) study, Shen (2014) investigates the sustainability business operations and supply chain of H&M. Through analyzing the collected public data (Subic et al.,2013), they examine the effects of the H&M CEO's economic preference on the launching of online shopping channels. Shen (2014) explores explicitly how the management team preferences of H&M towards suppliers' selection and inventory level and how it affect the company sustainability performance. The findings show that management preferences and considerations

affect the whole sustainable fashion supply chain operations and performance. When fashion companies develop a sustainable business, their stakeholders would be divided into opposite groups due to conflicts of interests. The conflicts of interests would become barriers for sustainability project excisions. This finding is similar to that of De Brito et al. (2008).

Yang et al. (2017) further investigated in fashion industry and suggest that the retail operations would affect sustainability performance. Karaosman et al. (2017) study the critical operations of the whole fashion supply chains as well as on how fashion companies can integrate sustainability in the supply chain. The findings show that fashion companies should focus on integrating the product design, production process, and supply chain execution concerning the environmental and social considerations to mitigate the stakeholders' conflicts. Based on the study of Karaosman et al. (2017) and Warasthe et al., (2020) examine the 7 companies' business operations from Ethiopian textile apparel industry and the German fair fashion retailing industry. The study identifies the critical prerequisites of the sustainable fashion supply chain and practices from the suppliers' and retailers' perspectives. It brings the idea of customer oriented instead of the management preferences. Customers' preferences are considered to be the most essential prerequisites for sustainability.

-Strand 2: performance evaluations of sustainable fashion business De Brito et al. (2008) and Shen (2014) on the sustainable fashion supply chain at the country and company levels demonstrate that the practice of the participants affect sustainability

performance. It drives the researchers to build another strand of knowledge, that is, the performance evaluation of the sustainable fashion business.

First, Garcia-Torres et al. (2017) explore how fashion companies can report their sustainability activity and information through reliable evaluation. Then, Shen et al. (2017) and Köksal et al. (2017) explore the core factors that affect the value of social sustainability towards fashion and textiles. They indicate that fashion companies' internal orientation and suppliers' collaborations, especially the ethical problems generated by the suppliers, are the critical barriers for social sustainability and affect sustainability performance value, and ultimately affect the company business value, vice versa (Köksal et al., 2017).

Meanwhile, by using a fuzzy multi-criteria decision-making model, Guo et al. (2017) demonstrate how fashion companies can set different criteria (e.g., environmental performance, technology usage, and industrial experience, etc.) for sustainable suppliers' evaluation and selections. Dicuonzo et al. (2020) extend the study to a macro view to further explore how the internal and external factors (e.g., the founders' orientation of entrepreneurship, country of origin's legislation) affect the sustainability performance of a fashion company.

Based on the above MPA, it is discovered that implementing sustainable fashion, operations management, and performance evaluation, is essential. The extended knowledge network presents a vital issue in sustainable fashion business management, that is, conflicts of interests between the fashion band management team and its stakeholders in the supply chain. The conflicts of interests would

become barriers to integrate sustainability into the fashion business model. The second knowledge strand shows the interrelations between the stakeholders affecting the criterial setting and performance evaluations.

From the main path (Figure 45), we find two key knowledge strands emerged in 2017. These studies related to three aspects: (1) how fashion companies cope with the conflicts of interest between stakeholders during the implementation of sustainable fashion product development; (2) whether retailer-driven sustainable fashion supply chain performs better than the suppliers-driven sustainable fashion supply chain; and (3) which stakeholders' relations are most critical within the supply chain and the corresponding criteria affect performance evaluations of sustainability.

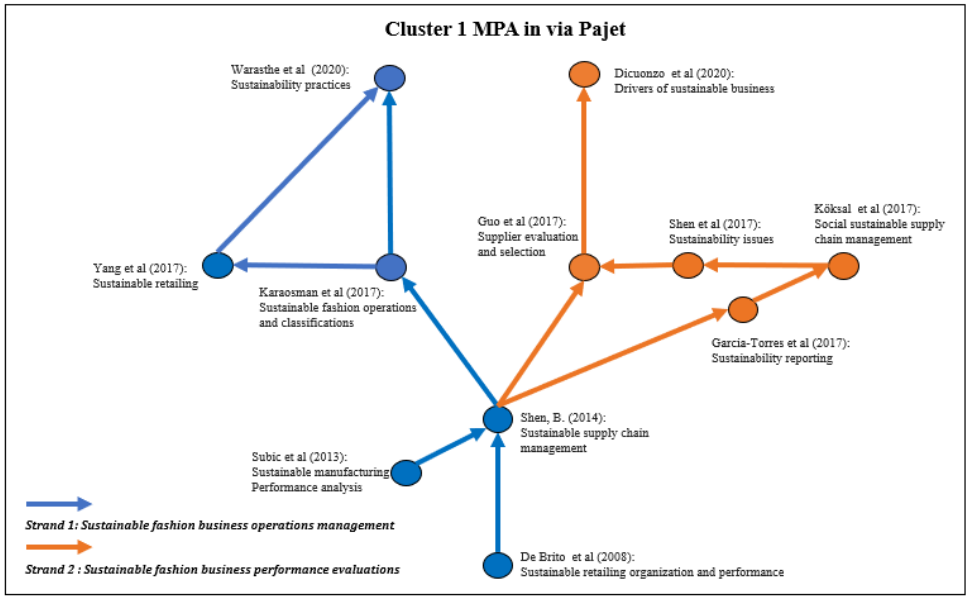


Figure 45. The main path of the knowledge network of Cluster 1

MPA of Cluster 2 - Effects of consumers' preferences towards sustainable products development

Sustainable business development and consumption in fashion and textile industry are the second largest research domain. Four fundamental studies are involved in this Cluster's main knowledge path (Armstrong et al., 2015; Niinimäki & Hassi, 2011; Shrivastava et al., 2021; Stål & Corvellec, 2018). For example, Niinimäki and Hassi (2011) investigate the emerging sustainable fashion design strategies and analyze how the niche sustainable market strategy can affect textile and clothing consumptions. The results show that the business opportunities incurred from consumers' interests in sustainable design can generate new sustainable development value. Based on this study, Armstrong et al. (2015) identify consumers' positive and negative perceptions towards sustainable product service systems. The results show that consumers' perception and actions can affect sustainable product service development in return. Stål and Corvellec (2018) and Holtström et al. (2019) further investigate the interrelations between sustainable business development and consumptions through examination of the circular business model incurred by the consumers' demands towards the circulation of fashion products. This study indicates that through the adoption of business operations separation and outsourcing, fashion companies can flexibly response consumers' demands in the circular fashion business. In addition, Shrivastava et al. (2021) investigate the application of unified theory and explain how the utility of the sustainable operations affect consumers' attitudes towards the sustainable service platform as well as how the communications between the fashion companies affect the consumers' preferences positively.

Based on the four critical studies (Armstrong et al., 2015; Niinimäki & Hassi, 2011; Shrivastava et al., 2021; Stål & Corvellec, 2018), we uncovered the interrelation between consumers' demands and sustainable fashion business development. Consumers' demands for sustainable fashion will generate positive value to the market. After studying the consumers' behavior sand preferences, fashion companies need to adjust their business models to satisfy consumers' demands. Moreover, a flexible business structure is needed to cope with the ever-changing consumers' demands. According to the main path of knowledge network in Cluster 2, more studies are emerged in 2019. These studies relate to two aspects, i.e., (1) studying the flexibility of consumers' preferences towards sustainable fashion product development, and (2) exploring how fashion companies promote flexibility in sustainable fashion product development.

Four critical studies (Armstrong et al., 2015; Niinimäki & Hassi, 2011; Shrivastava et al., 2021; Stål & Corvellec, 2018) focus on more business aspects. For example, Cooper et al. (2017) and Bech et al. (2019) investigate the testing strategy and environmental performance evaluations towards sustainable fashion products and materials selection. Two research directions in this domain include, (1) how to facilitate consumers' consumptions by sustainable product testing and evaluation; and (2) how social sustainability affect consumers' satisfactions.

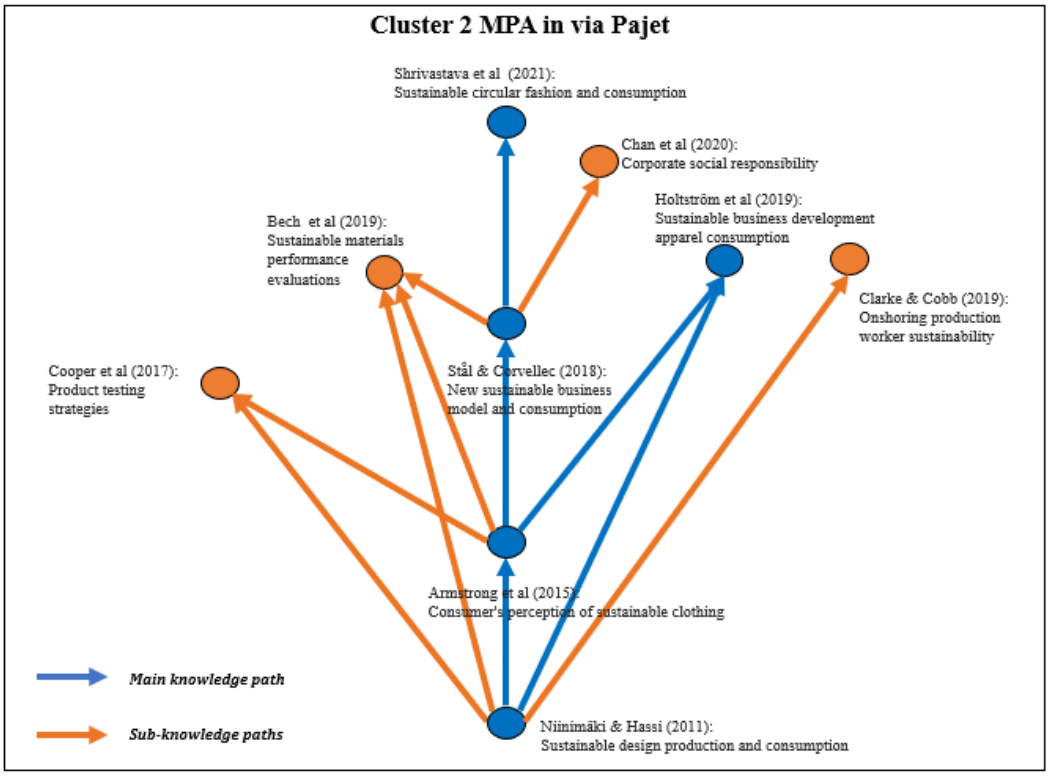


Figure 46. The main path of knowledge network of Cluster 2

MPA of Cluster 3 - Internationalization of sustainable fashion industry

-Strand 1: internationalization of sustainable fashion business: Brun and Castelli (2008) first investigate Milano's fashion supply chain strategy and study how retail channel, brand, and product affect management strategies' adoption. This study reveals that retail channel, brand, and product are the key drivers for supply chain segmentation. The types of retail channel, brands' positioning, and product categories are the key differentiating factor which segment the supply chains. Caniato et al. (2015) extend the study from a local perspective to an international perspective. They investigate the influence of internationalization (e.g., countries' characteristics) on fashion supply chain and the corresponding product development process. Caniato (2015) then continues examining how the

collaborations across different international organizations and industrial segments affect fashion product development activities. The critical drivers for the adoption of international collaborations include product quality, product line positioning, production technology complexity, and sales volume. Macchion et al. (2017) further analyze how the applications of environmental sustainability practices and international supply chain collaborations affect and improve sustainability performance.

-Strand 2: international networking strategies Another strand of knowledge is evolved from Brun and Castelli's (2008) study on sustainable fashion networking strategies and production configurations (Laura et al., 2015). The results demonstrate how the networking strategy generate a comparative advantage in the international market. Bubicz et al. (2021) immerge the social sustainability consideration with the international networking strategy. The study demonstrates the importance of social sustainability in sustainable fashion business and identifies the critical issues of implementing social sustainability networking. These studies provide managerial implications the implementation of sustainable fashion networking strategy for the development of sustainable fashion business.

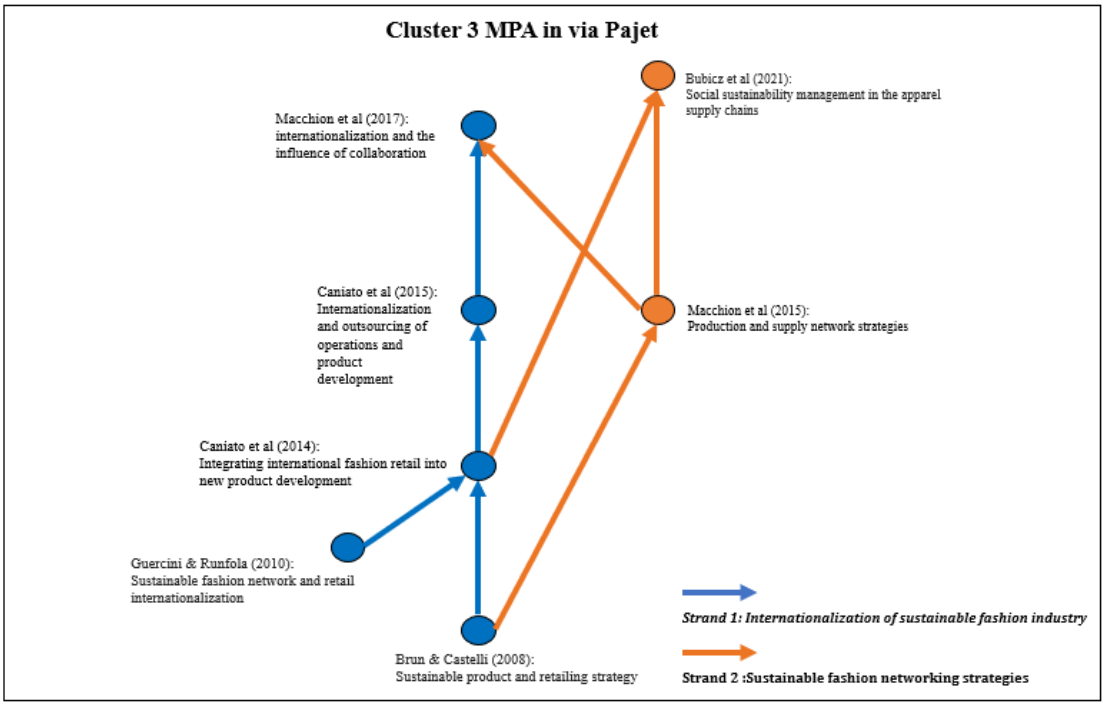


Figure 47. The main path of the knowledge network of Cluster 3

MPA of Cluster 4- Sustainable design and manufacturing correlations

Cluster 4 is a growing Cluster involving 6 studies. According to the world wildlife fund (WWF, 2020), global fashion and textile industry is one of the most waste-generating and polluting industrial sectors. In the United States, the used textile waste being generated each year is over 15 million tons. Meanwhile, only 2.62 million tons were being recycled (EPA, 2014). With the increasing attention to sustainability, researchers start to explore the application of sustainable design and sustainable manufacturing. Alkaya and Demirer (2014) first investigate how sustainable production measurements can facilitate the sustainable performance of the woven fabric production. Clancy et al. (2015) explore how translating the sustainability production measurements to eco-labeling for consumers' demand can become the key drivers for sustainable product design. Wang and Shen (2017) further conduct an eco-design product-line analysis on how the eco-labeling of a

sustainable sportswear brand can be used to collect sustainable product line data for further evaluation. The study shows that the sustainable sportswear brand mainly selects recycle, organic and traceable materials during sustainable product development. The researchers advise that the sustainable sportswear brand should pay more attention to sustainable manufacturing and functionality and aesthetics towards eco-design.

With the support of the three sub-knowledge paths focusing on sustainable design innovation (Santolaria et al., 2011), energy-saving product design (Moon et al.,2013), and sustainable materials selection (Ljungberg, 2007), the knowledge network become more solid to provide a foundation for further knowledge development. In future research, we consider conducting from the following three aspects: 1) how to integrate sustainable design with sustainable manufacturing, 2) how to measure the performance of sustainable design and manufacturing, and 3) how fashion designers and manufactures can facilitate consumers' involvement in sustainable design and manufacturing for a circular economy.

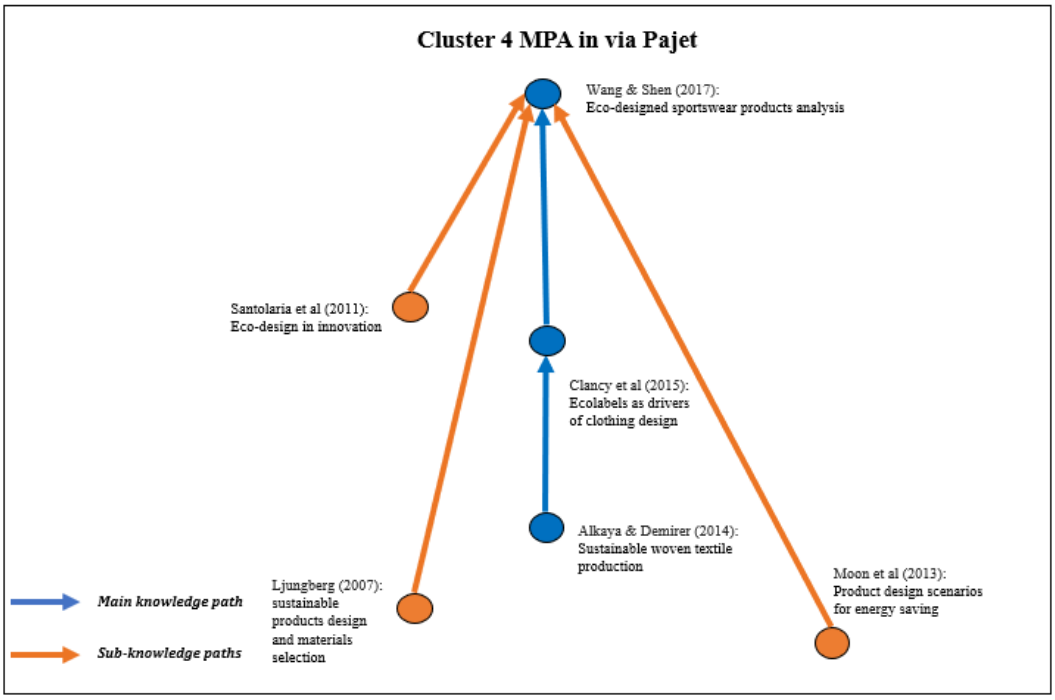


Figure 48. The main path of the knowledge network of Cluster 4

7.4 Discussion and future research directions

7.4.1 On knowledge network clustering

By using the CitNet explore, four Clusters of knowledge are identified. By studying the knowledge clusters, we uncovered that the studies of this thesis covered all four main knowledge foundation of the related research domain.

KNA Cluster 1: From the knowledge Cluster distribution, it shows that KNA Cluster 1 (effects of sustainable fashion business strategies) have the biggest knowledge foundation (17 papers). This shows the importance of developing sustainable business strategies. Thus, in Chapter 3 a sustainable business development strategy framework was developed. With the real-world case study in

sportswear company Nike, we further examined the application of the framework. Through identifying Nike's sports fashion supply chain stakeholders, the performance of the developed sustainable business strategy can be analyzed for future planning.

KNA Cluster 2: Ten related studies are included in the MPA Cluster 2. This second largest knowledge cluster shows that effects of consumers' preferences towards sustainable products on the sustainable product development are highly important. The knowledge network emphasizes the importance of the sustainable product development and consumers' demands. Consumers' preferences and practice towards sustainable operations and development affect the sustainable business' value. In return, the sustainable operation strategies influence consumers' attitudes towards sustainable fashion. However, how sustainable fashion suppliers can facilitate these interrelations to develop a sustainable fashion product has not been addressed. Thus, in Chapter 5, we uncovered the importance of matching consumers' attitudes and suppliers' attitudes towards sustainable sportswear development and explored the attitudes' gap towards sustainable sportswear development between the SSCs and SSSs through questionnaire survey and data analysis.

KNA Cluster 3: According to the Clustering of the CitNet Explorer, the knowledge in Cluster 3 mainly focuses on the internationalization of sustainable fashion industry. However, these studies are mainly based on theoretical studies lacking support in real-world case applications. To fill this gap, we conducted experimental research in Chapter 6 to investigate the applicability of the developed sustainable indicators in the performance analysis of the sustainable fashion product

development through fabricating six sustainable sports leggings. Through life cycle assessment and analysis, our study shows that the stakeholders can be connected and collaborate to facilitate the performance of the SPDP, thus generating a positive networking effect and preparing for internationalization.

KNA Cluster 4: shows the growing importance of sustainable design and manufacturing, especially on how the sustainability measurements and labeling can connect sustainable design, manufacturing, and consumers. However, the existing research findings mainly focus on materials manufacturing, design, and selection. To fill this gap, in Chapter 7, a set of sustainability indicators has been determined and the developed sustainable sports leggings have been applied to test the applicability of the determined sustainable indicators in a real case. The whole SPDP (material selection, product design, prototype development, and final product manufacturing) were considered in the analysis.

The current knowledge networks and revenue growths relating to sustainable fashion product development located mainly in USA, China, and Europe (Figure 39). And the studied product types are limited. Table 42 shows the product line distributions of the six sportswear brands: (1) Nike (USA), (2) Puma (USA); (3) Li Ling (China), (4) Anta (China); (5) Adidas (Germany), (6) Decathlon (France), and 15 product categories, namely: base layer, long-sleeved T-shirt, short-sleeved T-shirt, tank top, polo, jersey, hoodies, pullovers, jacket, vest pants, tights and leggings, shorts, skirts and dress, and sports bra. Different regions/brands developed their differential products. For example, cut and sew short-sleeved T-shirt and pants are the most common products in USA market for men's and

women’s sportwear, respectively. Cut and sew short-sleeved T-shirts are mostly consumed in China market, similarly in European market. However, the current studies do not conduct data analysis and comparisons based on the market segmentation (Figures 49-50).

Table 41. Assortment distribution of the global sportswear products of brands Nike, Puma, Li-Ling, Anta, Adidas, and Decathlon

	US Sportswear Brands								China Sportswear Brands								Europe Sportswear Brands							
Product Categories	Nike Men	%	Nike Women	%	Puma Men	%	Puma Women	%	Li Ling Men	%	Li Ling Women	%	Anta Men	%	Anta Women	%	Decathlon Men	%	Decathlon Women	%	Adidas Men	%	Adidas Women	%
Base Layer	7	1%	5	2%	12	3%	26	5%	2	2%	2	5%	8	5%	5	6%	13	4%	4	1%	1	0%	7	1%
Long Sleeved	83	13%	32	11%	69	15%	24	5%	14	13%	4	9%	18	10%	10	13%	21	6%	34	12%	67	5%	24	2%
Short-Sleeved	135	21%	41	15%	98	21%	68	14%	17	16%	9	21%	34	20%	20	25%	63	18%	48	17%	307	21%	202	21%
Tank Top	14	2%	4	1%	5	1%	25	5%	1	1%	0	0	3	2%	4	5%	2	1%	15	5%	7	0%	25	3%
Polo	1	0%	1	0%	14	3%	28	6%	1	1%	0	0	2	1%	2	3%	7	2%	0	0%	46	3%	28	3%
Jersey	47	7%	0	0%	13	3%	12	3%	18	17%	0	0	3	2%	2	3%	4	1%	0	0%	69	5%	12	1%
Hoodies	96	15%	28	10%	38	8%	28	6%	1	1%	0	0	20	11%	5	6%	6	2%	8	3%	126	9%	99	10%
Pullovers	3	0%	0	0%	29	6%	21	4%	14	13%	0	0	23	13%	3	4%	10	3%	2	1%	10	1%	78	8%
Jacket	39	6%	14	5%	66	14%	65	14%	12	11%	7	16%	25	14%	10	13%	83	24%	45	16%	173	12%	203	21%
Vest	16	2%	3	1%	1	0%	1	0%	2	2%	2	5%	2	1%	2	3%	5	1%	0	0%	2	0%	1	0%
Pants	111	17%	44	16%	58	12%	93	19%	14	13%	8	19%	8	5%	5	6%	58	17%	15	5%	345	24%	93	10%
Leggings	10	2%	9	3%	12	3%	31	6%	1	1%	3	7%	15	9%	1	1%	17	5%	58	21%	190	13%	61	6%
shorts	83	13%	37	13%	57	12%	14	3%	9	8%	3	7%	13	7%	5	6%	62	18%	38	14%	92	6%	38	4%
skirts and dress	0	0%	23	8%	0	0%	30	6%	0	0	0	0	0	0%	3	4%	0	0%	8	3%	0	0%	42	4%
Sport bra	0	0%	39	0%	0	0%	12	0%	0	0	5	12%	0	0%	3	4%	0	0%	2	1%	0	0%	50	0%
Total	645	100%	280	100%	472	100%	478	100%	106	100%	43	100%	174	100%	80	100%	351	100%	277	100%	1435	100%	963	100%

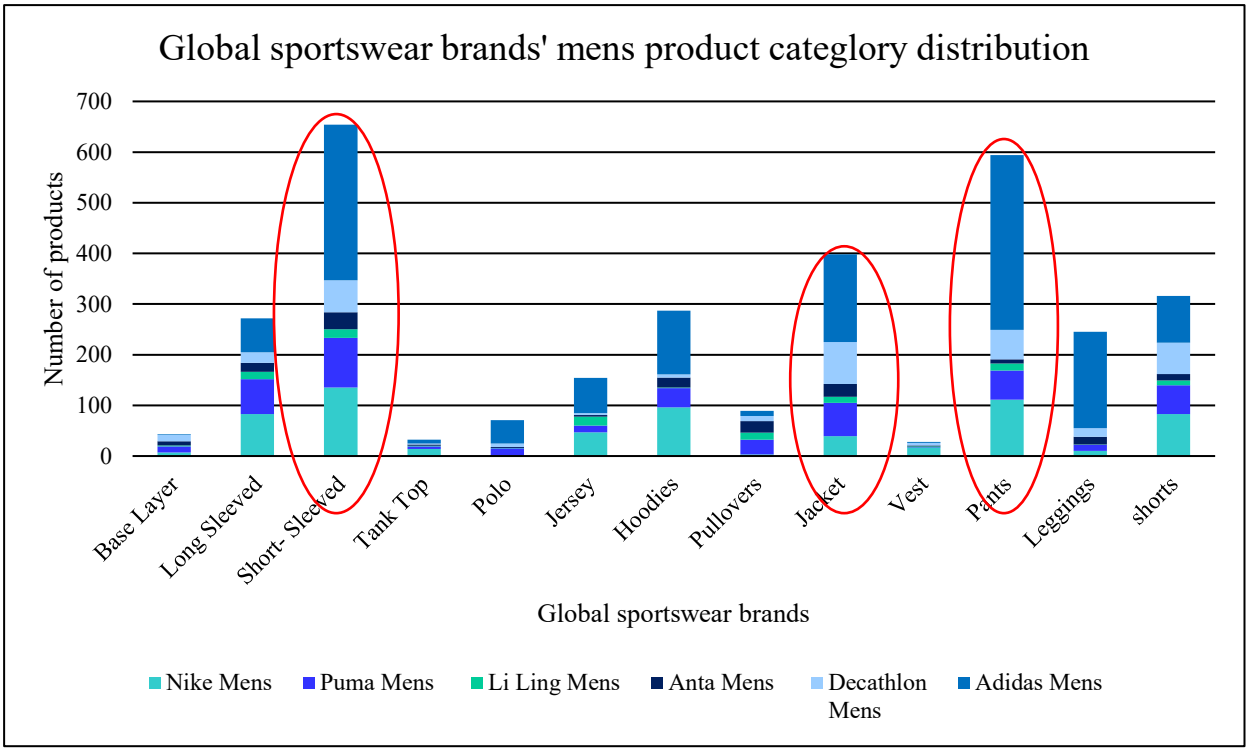


Figure 49. Distribution of the men's products categories of the global sportswear brands

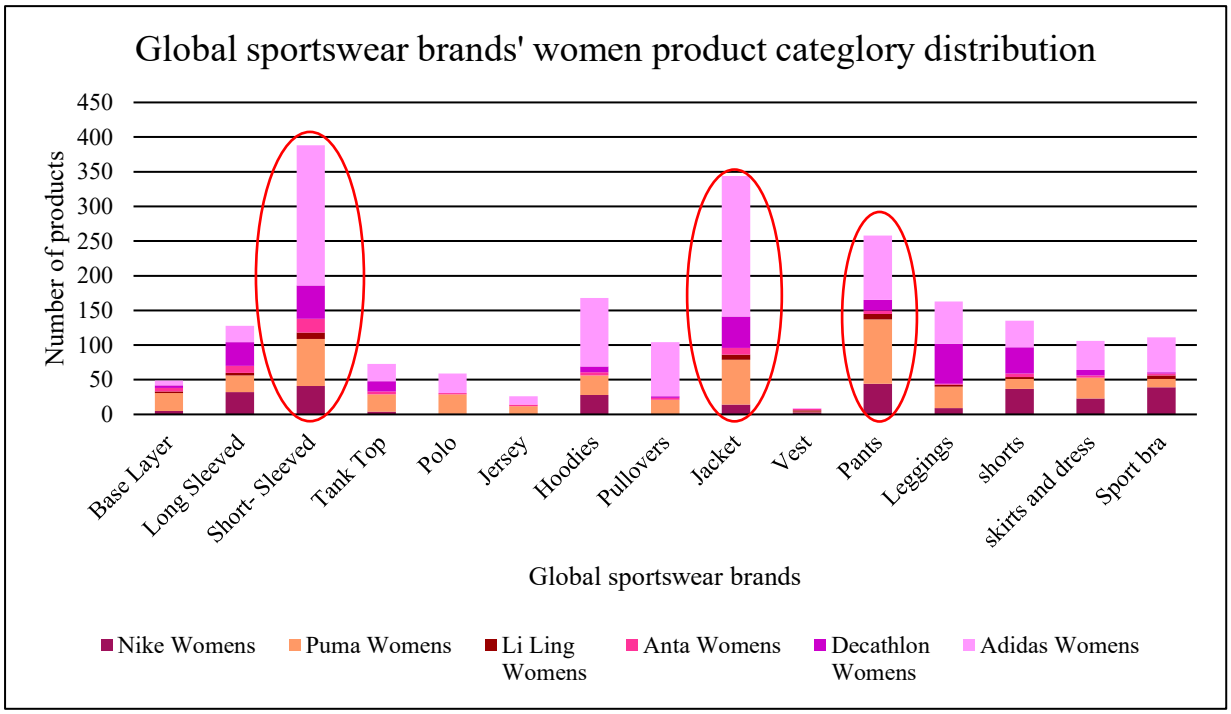


Figure 50. Distribution of the women's products categories of global sportswear brands

7.4.2 Remarks and discussions

A total of 110 publications are collected. As mentioned in Section 7.2.1, CiNetExplore shows the connections between the studies through tracking the citations of the studies. Among the 110 studies, 40 publications have built connections through citing each other. Although the remaining 70 publications have not built knowledge network via citing each other, they are still relevant to the sustainable fashion product development research domain. Thus, it is also worth studying the researches those are not being identified by the CiNet Explorer. To the best of our knowledge, no existing studies have covered the whole SPDP with respects to the TBL model. It is critically important because it is insufficient to achieve the goal of sustainability if we only improve one particular aspect of the fashion PDP or focus on just one of the "three pillars".

To manage the SPDP, we have developed a SPDP matrix (Table 43) for all SPDP participants (i.e., the related sustainable product development members). It can act as a checklist or a guide that SPDP participants can refer to for business decision making and generate economic value through improving environmental and social performance throughout the four critical steps of the SPDP which are the planning, design, manufacturing, and launching.

In the planning stage, the fashion retail brands should explore the sustainability challenges and opportunities (Bostrom & Micheletti, 2016; Moon et al., 2015), and work together with the upstream participants (Moon et al., 2013; Gunasekaran and

Spalanzani, 2012; Karaosman et al., 2016) for development of sustainable policy plans and strategies (Stål & Corvellec, 2018; Santolaria et al., 2011; Jørgensen & Jensen, 2012; Gunasekaran & Spalanzani, 2012). They need to determine the sustainable features of the created products in both environmental and social factors, thus differentiating their products from the non-sustainable products to provide additional values to customers and generating sales and revenue and in turn to benefit fashion brands.

From the environmental and social aspects, decision-makers need to plan what kinds of product features benefit the environment and how to achieve it. For example, if the retail companies aim at bringing down carbon emission and eliminate child labour in production, the retail brands need to require their manufacturers to improve the infrastructure and hire mature labour. Fashion retail brands may request manufacturers to apply for certificates to certify the sustainable practices, and designers need to search for materials that consume less energy and perform fair trade.

In the product design stage, the product designers should design actual products that can benefit the economic, environmental, and social aspects. In this stage, the features are not the concept as in the planning stage, it needs to be more precise. Firstly, they need to conduct market research to understand the sustainable product features that are commonly accepted by the targeted customers. For example, they need to find the solutions to the following issues: what kinds of sustainable materials are highly demanded in the market? How can they apply in the specific products (e.g., fair-trade organic cotton tee shirt with natural color dying)? When

the design is confirmed and adopted, then can move on to the manufacturing stage. To meet the consumers' sustainability requirements, the manufactures should consider improving their infrastructure. When the manufacturers are producing the product, they need to make sure the whole manufacturing process meets the environmental and social commitments in the planning stage and produces the products as requested in the design stage. In the launching stage, fashion retail brands are the key participants to bring the products to customers and generate sales and profits. In this stage, they need to consider what promotion strategies shall be adopted to differentiate the products from non-sustainable goods so as to increase sales and revenue. The fashion retail brands may educate the consumers about the sustainable concepts and the values behind the products, thus raising social awareness on their contribution as the participants in the whole fashion supply chain.

Table 42. The sustainable product development process matrix

	Economic	Environmental	Social
Launching	• Explore Sustainable Retailing Opportunities (Yang et al. 2017), (Jung and Jin, 2016) • Develop Sustainable product-service systems and eco-promotion for clothing (Na and Na, 2015), (Armstrong et al., 2015) • Fashion sustainability reporting (Garcia-Torres et al., 2017)	• Explore Sustainable Retailing Opportunities (Yang et al. 2017), (Jung and Jin, 2016) • Develop Sustainable product-service systems and eco-promotion for clothing (Na and Na, 2015), (Armstrong et al., 2015)	• Consumer product life cycle consideration (Cox et al. 2013) • Consumer education and product labelling (Zurga and Forte, 2014) • Polluter pays principle (Freitas et al. 2004)
Planning	• Explore the sustainability challenge and opportunities (Boström and Micheletti, 2016), (Moon et al., 2015) • Develop sustainability business strategies and capture the market opportunities (Stål and Corvellec,2018), (Santolaria et al., 2011), (Jørgensen and Jensen, 2012), (Gunasekaran and Spalanzani, 2012) • Investigation sustainable supply chain management and operation (Kuo et al., 2014), (Shen et al, 2017), (Shen, 2014), (De Brito et al., 2008), (Karaosman et al., 2016), (Macchion et al., 2017) • Set up clear direction on sustainability assessment (Hannouf and Assefa, 2017)	• Explore the sustainability challenge and opportunities in terms of environmental considerations (Boström and Micheletti, 2016), (Moon et al., 2015) • Work with Design and Manufacturing partners on environmental management (Moon et al. 2013), (Gunasekaran and Spalanzani, 2012), (Karaosman et al., 2016) • Develop product environmental performance measurements (Gloria et al. 2014)	• Explore the sustainability challenge and opportunities in terms of Social considerations (Boström and Micheletti, 2016), (Moon et al., 2015) • Work with Manufacturing partners on social supply chain management, (Köksal et al., 2017), (Gunasekaran and Spalanzani, 2012), (Karaosman et al., 2016)
Design	• Develop sustainability design strategies (Niinimäki and Hassi, 2011)	• Design for adaptability and useful life extension (Kasarda et al. 2007) • Materials and technology selection on sustainable design (Ljungberg, 2007), (Hutchison, 2016)	• Sustainable Design Labelling and communication (Clancy et al., 2015)
Manufacturin	• Explore third-party competition, and consumers' perceived value of re-manufactured products (Agrawal et al., 2015) • Investigation on sustainable production and re-manufacturing (Dissanayake and Sinha, 2015), (Alkaya and Demirer, 2014) • Develop sustainable manufacturing framework (Subic et al., 2012)	• Eco-efficient production (Parisi et al., 2015) • Sustainable textile production (Alkaya and Demirer, 2014) • Sustainable supplier selection (Guo et al. 2017) • Sustainable Textile Waste Recycling (Pensupa et al., 2017) • Sustainable manufacturing life Cycle Assessment (Pineda-Henson and Culaba, 2004)	• Sustainability production social implications, inequities (Kjaerheim, 2005) (Mair et al. 2016)

7.4.3 Future research directions

By using KNA, four Clusters of knowledge networks have been identified. Through importing the data of the knowledge clusters to the main path analysis (MPA) software "Pajek", the maximum connectivity among the collected studies in each knowledge Cluster is identified. The most important studies of each Cluster and the linkage of the studies is visualized to form a main knowledge path. Through studying the linkage between the

critical studies in the MAP, we further predict the future knowledge trends and future research directions in the sustainable fashion product development domain. Table 41 shows the key focused knowledge Clusters and how our study can contribute to these Clusters. Meanwhile, the main path of each Cluster is investigated to provide research directions and guidance for future fashion industrial practice.

MPA 1 involving two strands shows the complex of sustainable fashion supply chain. Many participants (management team, stakeholders, and customers) are involved in the supply chain. The strand-1 indicates that the preferences of the participants affect the operations and performance of the sustainable fashion supply chain. While the strand-2 indicates the factors affecting the company's sustainability performances (e.g., supply chain level, company level, and country-level). Both strands of knowledge addressed the critical issues in sustainable fashion operations and management. However, what stakeholders' relations are the most critical within the supply chain and what are the corresponding criteria which will affect the sustainability performance evaluations have not been identified. Meanwhile, how fashion companies cope with the conflicts of interests between stakeholders during the implementation of sustainable fashion product development are not being addressed. This would be the research questions for future study.

MPA 2 involves four critical studies (Armstrong et al., 2015; Niinimäki & Hassi, 2011; Shrivastava et al., 2021; Stål & Corvellec, 2018) from the main knowledge path. The four studies focus on business strategy and environmental performance evaluations. However, how company can improve promote consumers satisfaction is under explore. For future research direction, it might be fruitful to explore how

fashion companies can promote flexibility in sustainable fashion product development. Also, it is interesting to study what are the consumers' preferences in sustainable fashion product development flexibility. Also, as the fashion companies pay high attention in sustainability performance evaluation, a further study on how fashion companies can facilitate consumers' consumptions by sustainable product testing and evaluation.

MPA 3 focuses on the internationalization of sustainable fashion business and networking strategy. This main knowledge path examines the internationalization business strategies applied in fashion supply chain and demonstrates how supply chain collaboration and networking strategies can improve industrial sustainability performance. However, how to integrate economic considerations during the implementation of sustainable fashion internationalization is not being addressed. Meanwhile, what are the management risk associate with different supply chain structure during the implementation of internationalization, and how international networking can strengthen the linkage between the sustainable fashion supply chain stakeholders requires further investigations.

MPA 4 shows a growing of academic interest in studying the sustainable design and manufacturing. The studies of the main knowledge path and the three sub-knowledge paths shows high attention in drivers of clothing sustainable fashion design and sustainable fashion manufacturing. However, the integration between sustainable design and manufacturing towards design is being under addressed. Also, how to measure the performance of sustainable design and manufacturing and how fashion designers and manufactures can facilitate consumers' involvement in

sustainable design and manufacturing for a circular economy need further investigation.

Table 43. Knowledge networks and future research questions

Cluster	Sustainable product development issues/ focus	Current study coverage	Future research questions
Cluster 1: Sustainable fashion business operations and management	(1) Supply chain integrations barriers and management issues (2) Stakeholders' conflicts of interest (3) Drawbacks of management preference	(1) Stakeholders' identifications (2) Sustainable business development strategy	(1) How fashion companies cope with the conflicts of interest between stakeholders during the implementation of sustainable fashion product development? (2) Will retailer driven sustainable fashion supply chain perform better than the suppliers driven sustainable fashion supply chain? (3) What stakeholders' relations are most critical within the supply chain and what are the corresponding criteria which will affect the sustainability performance evaluations?
Cluster 2: Sustainable product development and consumption	(1) Effects of consumer preference in sustainable fashion product (2) Difficulties in new business strategy implementation which matches with the consumers' demand. (3) Importance if sustainable fashion production flexibility	(1)Integrate consumers preference in sportswear product design and development (questionnaire survey) (2)Gap analysis between SSC and SSS for new product design and development strategy (3)Explore the gap between SSC and SSS, and develop new products which aim at filling in the gap	(1) Explore how fashion companies can promote flexibility in sustainable fashion product development? (2) What are the consumers, preference in sustainable fashion product development flexibility? (3) How to facilitate consumers' consumption by sustainable product testing and evaluation. (4) How to improve social sustainability and promote consumers satisfaction.
Cluster 3: Internationalization of sustainable fashion business	(1) Key drivers of sustainable fashion internationalization (2) Segmentation strategy of sustainable fashion internationalization (3) International collaboration and networking	(1) Sustainable fashion supply chain structure identification (2) Product development process identification (3) Practical fashion product development process and stakeholders' relationships identifications	(1) What are the management risk associate with different supply chain structure during the implementation of internationalization? (2) How international networking can strengthen the linkage between the sustainable fashion supply chain stakeholders? (3) How to integrate economic considerations during the implementation of sustainable fashion internationalization?
Cluster 4: Sustainable design and manufacturing	(1) Sustainable woven textile production (2) Ecolabels as drivers of clothing design and consumption (3) Eco-designed sportswear products analysis	(1) Integration of sustainable design with sustainable manufacturing, (2) Develop performance indicators for sustainable design and manufacturing	(3) How fashion designers and manufactures can facilitate consumers' involvement in sustainable design and manufacturing for circular economy.

7.5 Summary

In this chapter, the knowledge networks (KNA) and main research activities (MPA) relating to sustainable fashion product development are analyzed. There is a growing trend in this study area (Figure 51), where China, United States, and European countries contribute the most knowledge development. The latest five years are the fast knowledge development period, especially the year 2017.

A total of 110 studies were analyzed by "CiNetExplore" system. Through tracking the citation relations between the studies, it shows that 40 studies have cited each other and form a knowledge of network. Meanwhile, the 40 studies can be classified into four different knowledge network clusters, namely: (1) effects of sustainable fashion business strategies, (2) effects of consumers' preferences towards sustainable products on sustainable product development, (3) internationalization of sustainable fashion industry, and (4) sustainable design and manufacturing correlations. The knowledge on sustainable product development is developing rapidly but remain far from maturity (Table 51). Although the existing research filled a few of gaps in knowledge mapping, each of the knowledge cluster needs more research to support. For example, cluster 1 MPA shows the demand in solving the conflict of interest among the SPDP participants. Meanwhile, cluster 2 MPA shows the need of further investigation towards SPDP flexibility. Furthermore, investigation towards SPDP networking enhancement is needed for the research domain of cluster 3 MPA. Finally, cluster 4 KNA provide research motivation on consumers' involvement towards sustainable design and manufacturing.

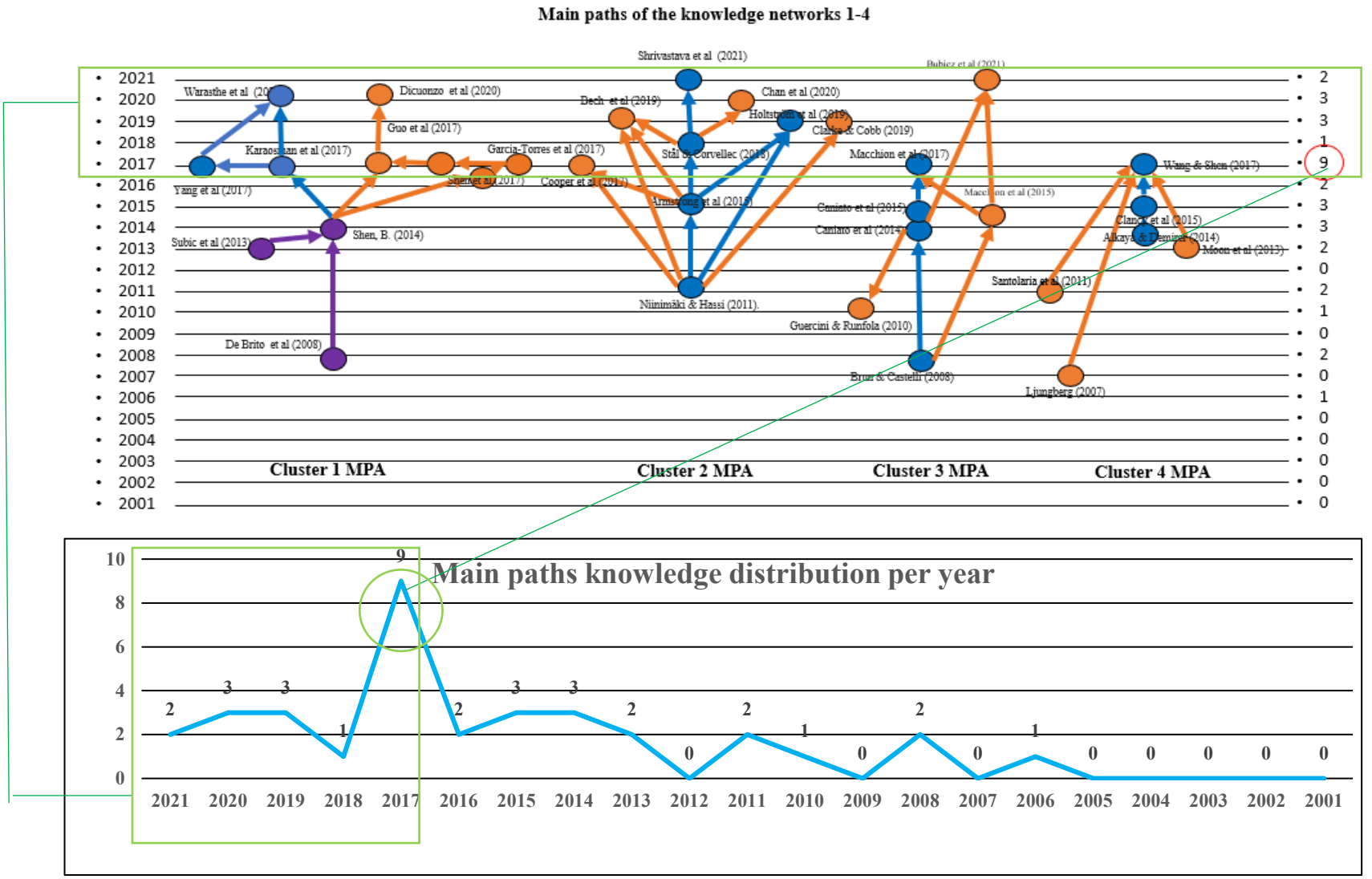


Figure 51. Main paths of the knowledge networks and the knowledge trends throughout the study period (2001-2021)

CHAPTER 8

Conclusion and Future Work

Motivated by the real-world demands on sustainable fashion and the growing sportswear market, this thesis focused on the study of the sustainability of sports fashion product development process. Through studying the supply chain structures of the fashion industry, critical steps of the fashion product development process can be identified. Then, by studying the management theories, this thesis aim at developing a novel strategic framework for sustainable business development. After developing the Then, this thesis first identified the attitudes' gaps between the SSSs and SSCs to provide managerial insights for sustainable sportswear development. A set of new 3D performance assessment indicators is introduced to assess sustainability performance of the sportswear development process through analyzing the collected data from the practical sports leggings' development process. Thus, the applicability of the designed indicators was examined in a real case. Through studying the knowledge network of the related research domains, important insights are derived and highlighted for future research directions relating to sustainable fashion product development.

8.1 Conclusion and insights

Insights from literature review: a comprehensive literature review was conducted in Chapter 2. Through studying the related literature and discussions with industrialists, we identified the structures of the fashion industry and the critical

steps of fashion product development. We further demonstrated the differences between TPDP, NPDP, and SPDP. Second, we analyzed the factors that affect the implementation of SPDP under TBL. Third, the critical elements of the SPDP are studied. It can act as a key reference guide for SPDP participants towards the development of a sustainable fashion business.

Insights from strategic framework development and case study: After studying the structures of the fashion industry and the corresponding product development process in Chapter 2, in Chapter 3, we then explored how a fashion company can develop a successful sustainable business strategy throughout sustainable fashion product development process. The sustainability attributes and mechanisms of the sustainable business development strategy are discussed. Based on the institutional theory and resource-based theory, we first analyzed the external pressure and internal motivations for companies to adopt sustainable business development strategy in the fashion supply chain. We then identified the core stakeholders related to the sustainable business development strategy and proposed how the decision-making theory can help to develop the mechanism of sustainable business development strategy. Next, we established a sustainable business development strategy framework (SBDS). Via a case study on the fashion giant brand Nike, we explored the applications of our proposed sustainable business development strategy framework in Chapter 4. The findings indicate that the strategic planning on sustainability can improve the performance of the stakeholders throughout the whole sustainable fashion supply chain.

Insights from analysis of SSSs and SSCs attitudes' gaps: although fashion

companies can improve the performance of the stakeholders throughout the whole sustainable fashion supply chain with the adoption of SBDS. However, since the fashion supply chain involves many stakeholders, this increases the difficulty in the implementations of the SBDS. It is because that stakeholders may have different attitudes towards sustainable product development. These attitudes' difference between the sustainable sportswear suppliers (SSSs) and the sustainable sportswear consumers (SSCs) may lead to a gap between the consumers' expectations and the developed sustainable sportswear products. Thus, an in-depth study has been conducted to examine the attitude gaps existing between the SSSs and the SSCs. In Chapter 5, we identified the key attitudes towards sustainable sportswear product development and analyzed how sustainable attitudes affect the products being developed, as well as the effects of the attitudes' difference between the SSSs and the SSCs on the consumers' satisfactions towards sportswear products. A gap analysis methodology was adopted to analyze the collected data by questionnaire survey. The results indicate that a significant difference exists between SSSs and SSCs' attitudes towards sustainable design, manufacture, product features, and branding. Based on the in-depth interviews, major causes of the attitudes' difference are studied to provide managerial insights for sustainable sportswear product management and business development.

Insights from three- dimensional SPDP assessment: based on the studies in Chapter 5, we uncovered the needs of a measurable and understandable indicators for both SSSs and SSCs towards the performance assessments of sustainable fashion product development. Thus, in Chapter 6, we first explored the sustainability assessment approaches which is applicable for the fashion product

development under the three dimensions of TBL model. Then, we identified the indicators corresponding to the 3D assessment approaches for sustainability performance assessment of SPDP. We further examined the applications of the indicators through analyzing the 3D sustainability performance of the SPDP process towards 6 pairs of sports leggings. The findings in Chapter 6 show that the determined indicators provide SSSs the management insights upon product selections and performance evaluation of SPDP.

Insights from knowledge network analysis: Finally, to enhance our understanding of the research and industrial progresses relating to sustainable fashion product development in a global scale, in Chapter 7, a knowledge network analysis (KNA) has been conducted to systematically investigate the related studies carried out by the researchers and teams from different countries and regions. Through main-path analysis (MPA), the correlations among these existing studies have been established, which shed light on the future research trends/interests and facilitate strategic planning of industrial activities for sustainable fashion product development.

8.2 Research contributions

Motivated by the real-world demands on sustainable fashion and the growing sportswear market, this study contributes to the sustainable sports fashion product development domain in various aspects. Based on the literature review, there are few referable studies to guide fashion companies to develop a successful sustainable business. Through investigations on the sustainable fashion industry and studies on operational theories, this study proposed a novel sustainable business development strategy framework with a theoretical support for sustainable business development, which is verified by a case study

on Nike.

In the complex fashion industry, consistent cognitions of the participants towards sustainable fashion development have not been formed although such cognitions much influence decision making and product development strategies. The current studies either focus on the suppliers' attitudes or on consumers' attitudes. There are no comprehensive studies to estimate the attitudes of the two groups on the sustainable fashion development. This study fills the gap by analysing the differences of attitudes between SSSs and SSCs. Moreover, the managerial insights are provided to facilitate the suppliers (SSSs)' cognitions and development strategies on sustainable fashion to fulfil consumers' (SSCs) expectations.

In addition, there is no existing performance measurement system on fashion sustainability with consideration of the triple bottom line. This study firstly proposed a new three-dimensional assessment indicator system. Its applicability is examined by the experimental study based on the real development of athlete sportswear.

Through knowledge network analysis and main path analysis, this study, from a global view, uncovers four main knowledge clusters and research directions in the sustainable fashion product development domain, which has never been reported before. These outcomes would be highly valuable to provide insights to guide fashion industrial practice and sustainable fashion product development in the future.

8.3 Future works

Through the above studies, the research areas that have not yet been well-explored

are discovered for future studies.

Closed-loop system of the SPDP*:* as proposed in Chapter 2, the SPDP is categorized by its closed-loop nature in which every single step in the SPDP needs to take the TBL model (including recycle and reuse) into consideration. However, from the literature, we find that the consideration of the closed-loop economy is under-explored. To achieve a closed-loop economy, the fashion retail brands need to work with all the SPDP participants to develop optimal recycling and reuse strategies. The current literature mainly focuses on how manufacturers contribute to the circular economy such as remanufacturing (Dissanayake & Sinha, 2015) and sustainable textile waste recycling (Pensupa et al.,2017) in manufacturing process. Whereas the responsibilities and contributions of other members such as fashion retail brands, product designers, and product launching parties, in the closed-loop supply chain, should not be neglected.

Applications of SBDS in fast fashion and luxury fashion**:** in Chapters 4 and 5, we mainly studied the sports fashion market which cannot represent the whole fashion industry. From Interbrand's Best Brands ranking (Interbrand, 2017), the top three fashion brands are Nike, LV, H&M. Different from Nike, LV is a luxury brand, while H&M is a fast fashion brand. The business models of luxury brands and fast fashion brands are different from sportswear brands. According to the recent study (Chan et al., 2018), H&M and Nike perform best in environmental and social categories while LV need fulfil customers' sustainable expectations along with its intrinsic brand value. This shows that brand's positioning will affect its level of

efforts towards sustainability. Further explorations will be made on the fast fashion and luxury brands in future studies.

Application of the determined indicators in woven, cut and sew, and sweater manufacturing: fashion apparel manufacturing can be largely divided into cut and sew and sew-free methods (e.g., bonding and fully fashion). Woven and knitting manufacturing have different processes and technologies input. Cut and sew manufacturing are commonly applied in woven materials, while sweater manufacturing commonly applies v-bed knitting machines in fabrication. The shaped panels of the garment can be knitted by using fully fashion technology to save material usage. However, extra time is demanded to link the panels together loop by loop. Thus, various manufacturing methods have different requirements in resources, manpower, and monetary support. It is worth studying whether the developed three-dimensional sustainability performance assessment indicators towards SPDP are able to apply in different fashion apparel manufacturing processes.

Appendix A

Questionnaire survey

I am PhD research student **Fung Yi Ning (1790)** from the Hong Kong Polytechnic University. I am conducting a survey about consumer attitudes towards sustainable sportswear. I would appreciate if you would spend a few minutes finishing the questionnaire below. All information will be for academic use only and kept strictly confidential. Thank you very much.

Part 1A Consumption pattern (Please choose the appropriate answer)

1. Have you bought any functional sportswear in the past 12 months?
   _____Yes
   _____No (End of Questionnaire)

2. I will take product's sustainability features into consideration during consumption
   _____Yes
   _____No (End of Questionnaire)

3: What kind of sports you participate? (More than one options can be selected)

Out-door sports	In-door sports	Water sports
Athletics (Track and Field)	Judo	Swimming
Canoeing	Table Tennis	Diving
Equestrian	Wrestling	Rowing
Football (Soccer)	Weightlifting	Canoeing
Tennis	Badminton	Sailing
Triathlon	Basketball	Water polo
Baseball	Boxing	Others
Beach Volleyball	Cycling Track	yoga
Archery	Fencing	Kick boxing
Cycling Mountain Bike	Handball	Gym
Cycling Road	Gymnastics	Thai boxing
Goff	Hockey	
Hiking	Taekwondo	

4. What categories of sportswear do you usually buy?

_____ Sport tops _____ Sports bra

_____ leggings _____ Shorts

_____ Body suit _____ stockings

_____Others (please specify)_____

5. Pls specify the price range of the sportswear you usually buy in question 4?

_____HK$100or below _____ HK$101-HK$500

_____HK$501-HK$1000 _____HK$1001-HK$2000

_____HK$2001-HK$3000 _____HK$3001-HK$5000

_____HK$5001 or above

6. How many sportswear have you bought in the past 12 months?

_____0-5 pieces _____10 pieces-20pieces

_____21 pieces-30pieces _____31 pieces-40pieces

_____41 pieces-50piece _____51 pieces or above

7. How much have you spent on purchasing functional sportswear in the past 12 months?

_____HK$100 or below _____ HK$101-HK$500

_____HK$501-HK$1000 _____HK$1001-HK$2000

_____HK$2001-HK$3000 _____HK$3001-HK$5000

_____HK$5001 or above

8. Percentage of sustainable functional sportswear out of the total sportswear being purchased.

_____10%-20 % _____ 21%-30% _____31%-40% _____ 41%- 50%

_____51%-60% _____ 61%- 70% _____61%-70% _____ 71%- 80%

_____81%-90% _____ 91%- 100%

_____ I don’t know

Part 2 Research background

1.Key features of triple bottom line (TBL) and the corresponding relationships with sportswear industry.

TBL	Key Features	Relations to the sportswear industry
Economic	Refers to how the business organizations practices' affects the economic system	- Proper management in business which interoperate with environmental considerations can generate positive economic outcomes (Raza et al 2018). - Consumers' buying behavior is positively related to is attitude towards sustainability
Social	Refers to long-term planetary and human society ecosystem equilibrium, the growth of the human society cannot be neglected	- Conduct a fair business practice, such as fair wages, equity, education, health care coverage and family development - Beneficial to labor's capital and the surrounded society or community, and ultimately ensure a healthy growth of the global human living environment
Environmental	Refers to how the business organizations engage in resources planning which safeguard the natural resources without compromising it for the further generations	- Efficient use of resources, such as water and energy as long as minimizing the greenhouse gas emission and ecological footprints - Develop good business reputation

2. Key suppliers and functions of the sustainable product development process (SPDP)

SPDP	Sustainable sportswear suppliers (SSSs)	Functions
Planning	• Sportswear Retailer board of management • Retail Buyers • Retail Planning Managers • Retail Sales Managers	• Business planning • Research of product • Product planning and costing • Line building production optimization
Product Design	• Sportswear Designers • Materials Designers • Sundries Designers • Technical Designers	• Development of origin style and design • Materials and sundries development • Refine the business objectives
Manufacturing	• Garment Manufacturers • Material Manufacturers • Sundries Manufactures • Merchandisers	• Apparel assembly, finishing and washing • Fiber production; yarn spinning and dying; knitting and weaving. • Sundries production (e.g., buttons, zippers, grosgrain etc.)
Launching	• Marketing Managers • Logistics Company • Warehouse Managers • Retail Shop Managers	• Supply chain management • Resources and product shipping and delivery • Product distribution and allocation • Customers service

Part 3 Attitudes towards sustainable sportswear development

1. Please advise the level of importance towards the key focus of TBL towards sustainable sportswear development.

	Least important				Most important
(i) Economic	1	2	3	4	5
(ii) Environmental	1	2	3	4	5
(iii) Social	1	2	3	4	5

2. Please advise the level of importance upon the sustainable sportswear product development process which you consider will affect the product sustainability level most

	Least important				Most important
(i) Planning	1	2	3	4	5
(ii) Product design	1	2	3	4	5
(iii) Manufacturing	1	2	3	4	5
(iv) Launching	1	2	3	4	5

3. Please advise the level of importance of below items towards the sustainable sportswear development

(i) Product Branding

e.g., sustainable branding of the sportswear product

Least important				Most important
1	2	3	4	5

(ii) Product pricing

e.g., price considerations of the sportswear product

Least important				Most important
1	2	3	4	5

(iii) Sustainable product Attitudes

Least important				Most important
1	2	3	4	5
1	2	3	4	5
1	2	3	4	5
1	2	3	4	5

- Sustainable product features
  e.g., use of sustainable materials
- Sustainable product functionality
  e.g., reducing the recurrence of muscular injury
- Sustainable product product quality
  e.g., comfort materialz
- Sustainable product design
  e.g., special stitches and constructions

4. According to the relative importance, rank the follow factors discerningly

_____ Product Branding
_____ Product Pricing
_____ Sustainable product features
_____ Sustainable product functionality
_____ Sustainable product product quality
_____ Sustainable product design

Part 4 Preferences towards sustainability, functional, design and quality features of sportswear

5. To what extent do the following sustainability features have influence on your buying decision on purchasing sportswear?

Sustainability	Not at all				Extremely influential
1) Use of sustainable materials (e.g., organic cotton)	1	2	3	4	5
2) Sustainable design (e.g., design for recyclability)	1	2	3	4	5
3) Sustainable manufacturing (e.g., energy saving)	1	2	3	4	5
4) Social sustainability (e.g., fair trade)	1	2	3	4	5

6. Please specify how much more will you willing to pay for additional sustainability features for seamless sportswear.

_____5% more
_____6-10% more
_____11-15% more
_____16-20% more
_____21-25% more
_____26-30% more
_____others (please specify)

7. To what extent do the following functional features have influence on your buying decision on purchasing sportswear?

Functionality	Not at all				Extremely influential
5) Enhancing blood circulation	1	2	3	4	5
6) Reducing the recurrence of muscular injury	1	2	3	4	5
7) Aiding recovery	1	2	3	4	5
8) Reducing muscle soreness	1	2	3	4	5
9) Enhanced lactic acid removal	1	2	3	4	5
10) Breathability	1	2	3	4	5
11) Enhance sports performance	1	2	3	4	5
12) Waterproof	1	2	3	4	5
13) Wind Proof	1	2	3	4	5
14) Body Protection	1	2	3	4	5
15) Others (Pls specify_____)	1	2	3	4	5

8. Please specify how much more will you willing to pay for additional functional feature seamless sportswear.

_____5% more
_____6-10% more
_____11-15% more
_____16-20% more
_____21-25% more
_____26-30% more
_____others (please specify)

9. Please indicate the importance of the following product quality aspects when you buy sportswear

Materials	Not at all				Extremely influential
1) Soft material and fabric	1	2	3	4	5
2) Functional Fiber content	1	2	3	4	5
3) Good pilling resistant	1	2	3	4	5
4) Seamless / minimize the number of seams	1	2	3	4	5
5) Good dimension stability	1	2	3	4	5
6) Good durability	1	2	3	4	5
7) Good color fastness	1	2	3	4	5
8) Machine washable	1	2	3	4	5

10. Please specify how much more will you willing to pay for better quality seamless sportswear

_____5% more _____6-10% more

_____11-15% more _____16-20% more

_____21-25% more _____26-30% more

_____others (please specify)

11. Please indicate the importance of the following product design aspects when you buy sportswear:

Style	Not at all				Extremely influential
1) Design details (stitches and constructions)	1	2	3	4	5
2) Brilliant color	1	2	3	4	5
3) Trendy	1	2	3	4	5
Fit	Not at all				Extremely influential
1) Large size range	1	2	3	4	5
2) Enough ease for movement	1	2	3	4	5
3) Sportswear cutting	1	2	3	4	5
4) Comfort fitting	1	2	3	4	5

12. Please specify how much more will you willing to pay for additional design feature seamless sportswear.

_____5% more _____6-10% more
_____11-15% more _____16-20% more
_____21-25% more _____26-30% more
_____others (please specify)

Part 5. Background Information

1. Your gender: □1. Male □2. Female

2. Age range: □1. 15-20 □2. 21-25 □3. 26-30
□4. 31-35 □5. 36-40 □6. 40-45
□7. 46-50 □8. 51-55 □9. 56-60
□10. 61-65 □11. 66 or above

3. Marital Status: □1. Single □2.Married □3. Others_____

4. Education level: □1. Primary school or below □2.Secondary school
□3. Tertiary school or institute □4. Degree
□5. Master or above

5. Occupation □1.Student/temp, Unemployed □2. Wholesale/Retail
□3. Fashion Designers □4. Professional Service
□5. Manager and Administrator □6.Goverment Body
□7. Fashion Manufactures □8. Professional Athletes
□8. Others_____

6. Family monthly income:
□1. <$6,500 □2. $6,500-13,000
□3. $13,001-20,000 □4. $20,001-30,000
□
5. $30,001-53,000 □6. Above $53,001

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