STUDY REPORT

A Re-industrialization Roadmap for Hong Kong SMEs of the Textile and Fashion Industry

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CLOTHING INDUSTRY TRAINING AUTHORITY

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Definition of Terms

The term *fashion industry* used in this report covers the entire supply chain of fashion products. It includes the manufacture of textiles, clothing and allied products from the fiber stage, through production to the distribution phase. In the Hong Kong context, *fashion industry* comprises companies in the manufacture, trading, testing, and retail of textile, clothing, fur and footwear products[1]. More details can be referred to the Specification of Competency Standards (SCS) for the fashion industry, which has been developed by the Fashion Industry Training Advisory Committee in 2018 with reference to Qualifications Framework[2].

The term *fashion products* used in this report refers to the textiles, clothing and allied products.

Re-industrialization is a process of organizing all possible resources and using high technologies to revitalize and modernize traditional manufacturing industries, re-establish advanced and high value-added segments, encourage the growth of new industries, and create a novel business system in Hong Kong[3] [4].

[1] https://www.hkqf.gov.hk/filemanager/fashion/en/share/Fashion%20SCS%20(Consultation%20draft)_v2.pdf [24/09-2018]
[2] https://www.hkqf.gov.hk/fashion/en/home/index.html [24/09-2018]
[3] http://www.legco.gov.hk/yr16-17/english/panels/ci/papers/ci20170321cb1-677-5-e.pdf [11-08-2018]
[4] https://www.hkpc.org/en/industry-support-services/latest-information/6639-re-industrialization [11-08-2018]

Introduction

This report identifies the promising directions for the technology and advanced material developments to enable new-comers and SMEs of the local textile and fashion industry to continue playing a major role in the future re-industrialization in the HK economy, which is critically important for the sustainable development of the Hong Kong SME and the society at large. Section 1 summarizes the current situation of Hong Kong manufacturing. Section 2 defines the global technology trends. Section 3 highlights the global trend of sustainability. In Section 4, a far-sighted outlook of Hong Kong fashion industry is concluded through a SWOT analysis to the identification of promising technology for manufacturing and retail opportunities.

The information was collated by desktop research on the existing data of various worldwide latest technology and advanced materials in the textile and fashion industry and the global market. In-depth interviews were conducted with leaders in both the local and global industrial and academic circles. Using SWOT analysis, the opportunities for Hong Kong SMEs to apply innovative technology are identified for formulating a roadmap for future re-industrialization of the Hong Kong fashion industry.

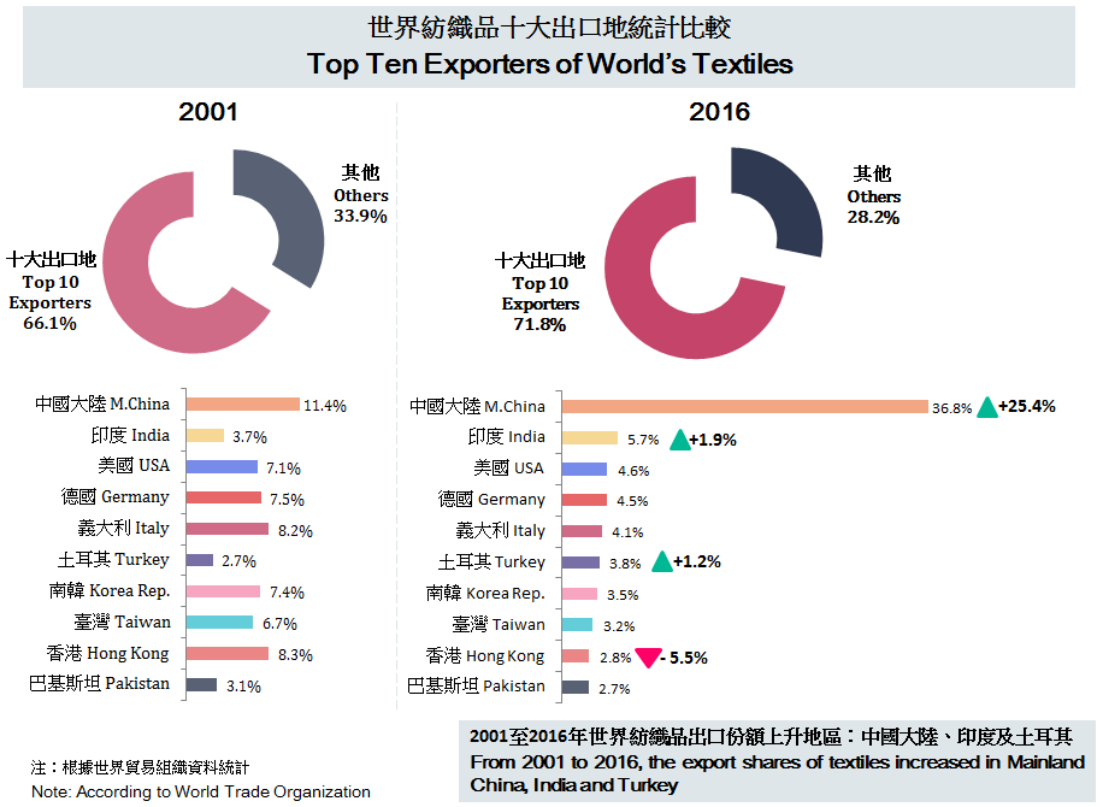
To upgrade SMEs' products and production processes, and to build their confidence in the financial payback of the investment, they need a high-quality technology roadmap to steer the direction of adopting suitable technologies in the innovation chain and to develop new products in the supply chain that meet the market needs of the changing macro & microenvironment.

1. The Global Fashion Industry Today

1.1 Exports – Chinese share exceeded one-third, new Asian exporters on the rise

1.1.1 Textile exports

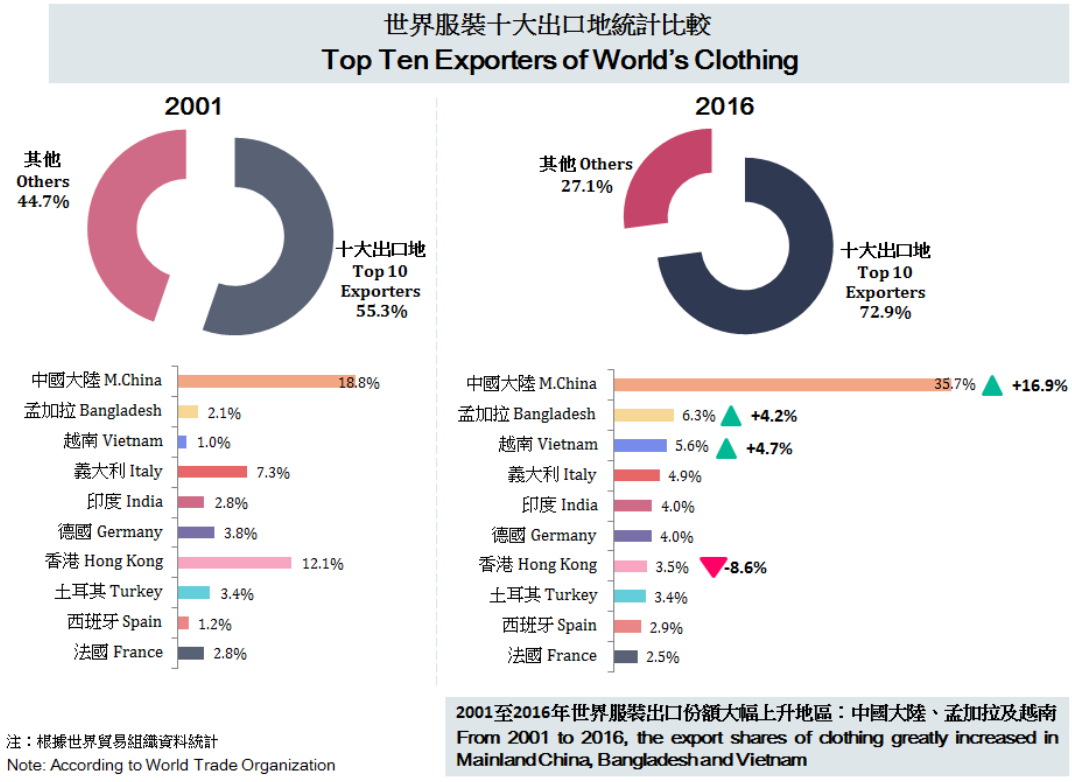
The top ten exporters acquired 71.8% of the world textile shares in 2016, increased by 5.7% when comparing to 2001. China exported 36.8% of the world textiles with a sharp increase of 25.4% from 2001 to 2016. At the same time, only India and Turkey had registered growth while all remaining exporters had reported a drop in shares of varying degrees[5].



[5] https://www.wto.org/english/res_e/statis_e/statis_e.htm [23-04-2018]

1.1.2 Clothing exports

The top ten exporters contributed 72.9% to the world's clothing export shares in 2016, while only 55.3% was accounted for in 2001. Similar to that for textiles, the share from Mainland China exceeded one-third of the global clothing exports. Bangladesh and Vietnam also had tremendous increases in recent years and have become the new top three exporters of clothing products in the world[6].



With the pressure of continuously increasing labor cost and environmental protection legislations, Mainland China has been slowing down in the local development of manufacturing fashion products in the last few years and started to seek for new opportunities of lean, advanced and clean manufacturing or investing abroad in the countries of "one belt one road"[7].

[6] https://www.wto.org/english/res_e/statis_e/statis_e.htm [25-04-2018]
[7] https://www.businessoffashion.com/articles/global-currents/one-belt-one-road-optimistic-fantasy-or-chinas-biggest-fashion-opportunity-yet [25-04-2018]

India is the second producer of fibers in the world, of which cotton fibers take up more than 80%. In recent years, India has also rapidly developed in the production of synthetic fibers with supports of government policies and funds. However, its low labor cost benefits are shrinking, especially when some other South and Southeast Asian nations are beginning to expand in textile and clothing production[8].

Turkey has become an important exporter of textiles for the European Union, including raw materials such as cotton yarn, and processed fashion products, ranging from knitted apparel to home textiles. With convenient transportation between Europe and Asia, Turkey is also good at cotton cultivation and animal husbandry, and the Turkish government provides very supportive policies and guidance on talent training and technology innovation, thus enhancing Turkish textile and clothing exports. However, Turkey relies on energy imports, and the increasing energy price has a negative impact on the manufacturing industries. Its regional stability is another concern in recent years.

Bangladesh gradually becomes a new choice for low-cost manufacturing of fashion products under the government policies of textile and clothing development. There is a strategic driver for the industry to increase export from the projected 31 billion USD in 2018 to 50 billion USD in 2021, which is a growth of more than 60% in three years[9]. Its key exporting destinations included the European Union and the USA. The English level of Bangladesh people is relatively higher in Asia because of long-term British colonial rule; however, the upper stream of the industry and the national infrastructure are still relatively weak.

[8] http://textilescommittee.nic.in/writereaddata/files/GTASF.pdf [30-05-2018]
[9] https://www.textiletoday.com.bd/10-reasons-why-bangladesh-will-be-able-to-achieve-50-billion-apparel-export-by-2021/ [10-06-2018]

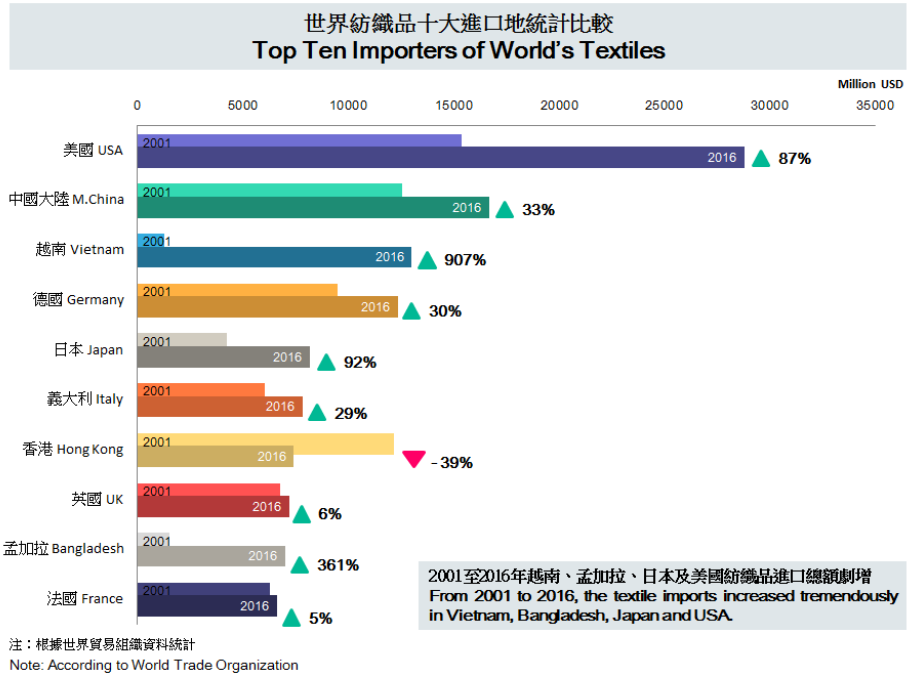
Among the South and Southeast Asian countries, Vietnam is another manufacturing base with low labor cost and better infrastructures. Even a number of traditional Chinese manufacturers have now established factories in Vietnam. The strict environmental protection policy and internal corruption are the main concerns for investors.

By contrast, Hong Kong dropped drastically in both textile and clothing export shares within this period, due to relocation with the corresponding decline of local manufacturing industries in the 1990s and in particular the termination of the global quota era in 2005.

1.2 Imports – Increased textile imports for new manufacturers, traditional developed countries still dominant in clothing imports

1.2.1 Textile imports

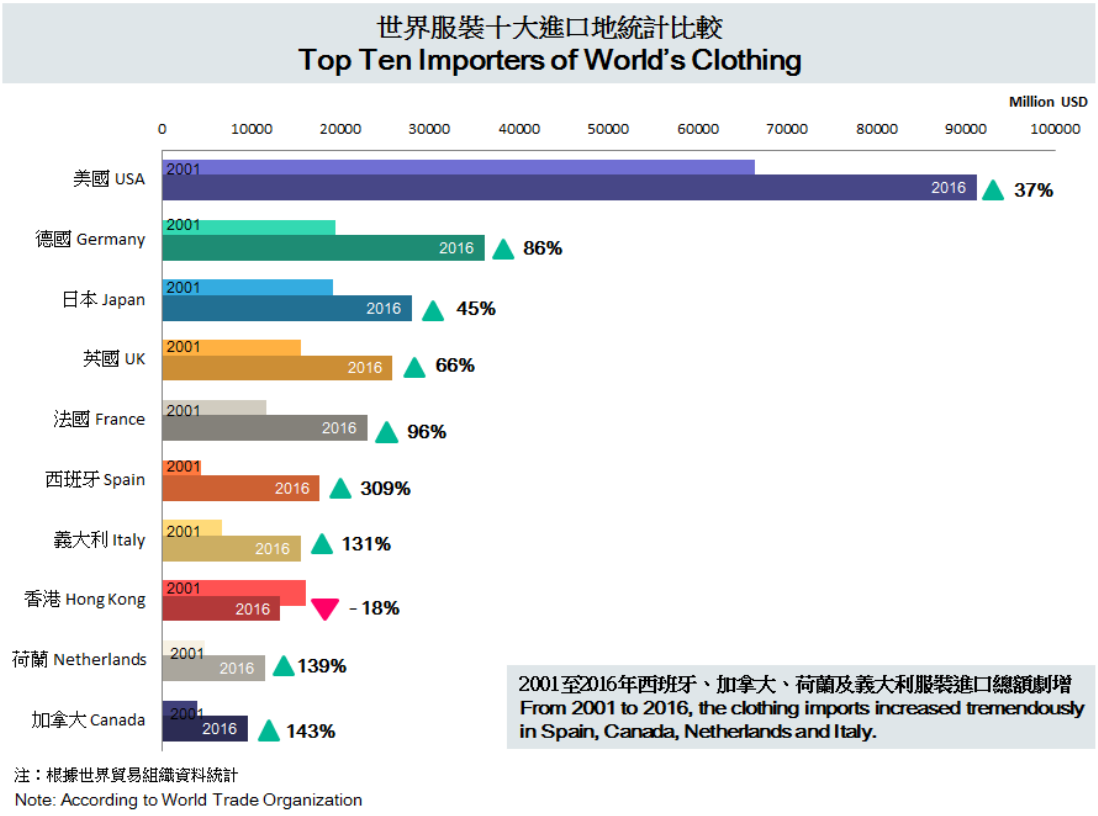
As the top consumer, USA has been leading in the world's imports of textiles and clothing from 2001 to 2016. Both Vietnam and Bangladesh had tremendous increases in textile imports, because of their rapid development of clothing manufacturing industry and their lack of capacity in textile production.



1.2.2 Clothing imports

The global clothing consumption has kept growing in the past 15 years from 2001 to 2016, with only a temporary setback during the financial crisis of 2008. USA, Japan and European countries are still listed top consumers according to their respective imports. At the same time, Spain increased its clothing imports by

309%, while Italy and the Netherlands have also registered an increase of exceeding 100%[10].



The USA is the biggest market of fashion products in the world, and its textile and clothing imports take around 20% of the global market. Besides its large import demands, USA also has a very powerful production capacity in textile raw materials. For example, its cotton fiber production has been leading the global industry, and carbon fiber production has exceeded one-third of the total global demand. Industrial textile in the USA has become the most competitive segment equipped by high technology, intellectual property and advanced inventions. According to the latest prediction[11], USA's fiber consumptions for industrial textile, including automotive, construction, home furnishing, medical and healthcare, and sports, will soon surpass fiber consumptions for clothing products. The

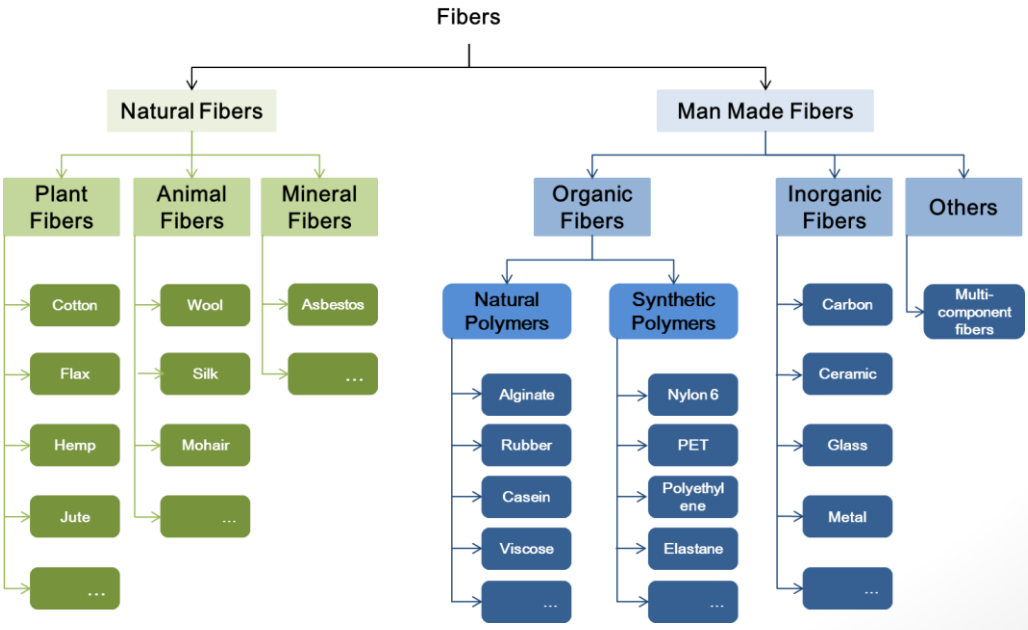
[10] https://www.wto.org/english/res_e/statis_e/statis_e.htm [28-04-2018]
[11] https://ihsmarkit.com/products/fibers-chemical-economics-handbook.html [30-05-2018]

development trends for industrial textiles in the USA include innovative fiber technology, highly modern equipment, integrated with other industries like aerospace and communications, fast-react construction upgrade, mergers and acquisition restructuring, industry specialization, large-scale tailor-made, offshore value chain transfer, and global supply chain network.

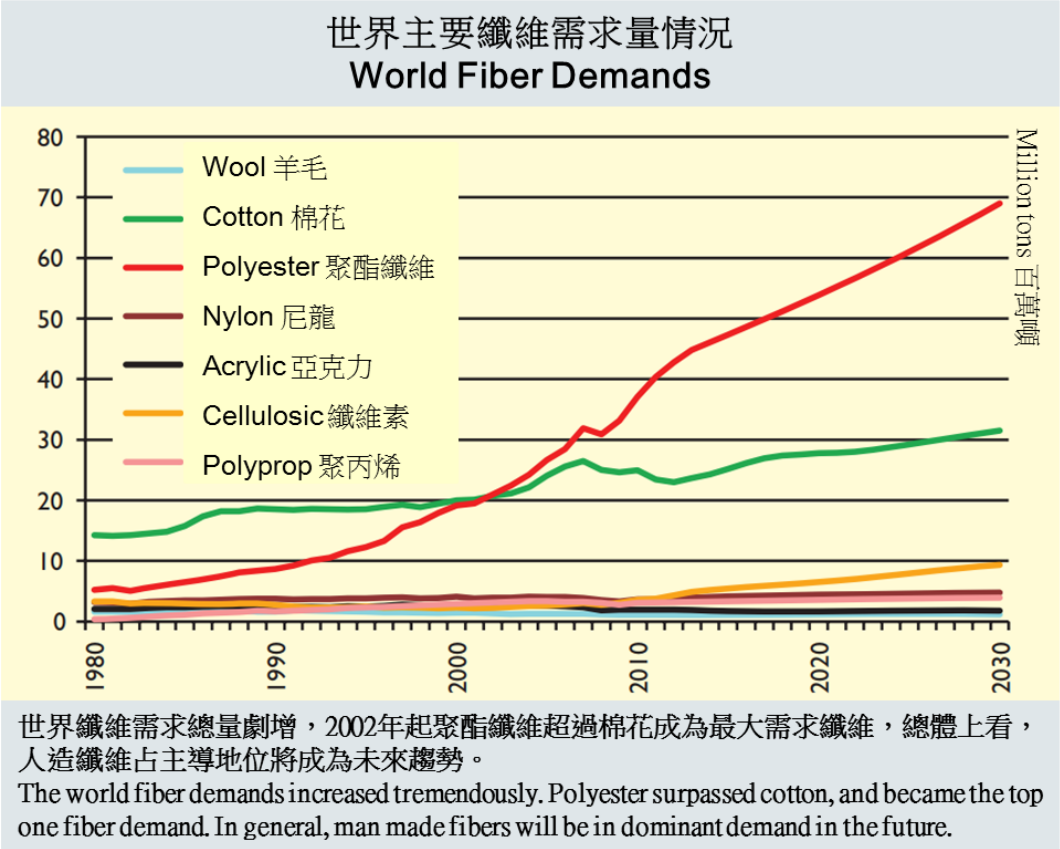
In Europe, Germany is the major importer of textile materials. As the largest producer of automobiles, German car manufacturers have conducted extensive research in natural polymer matrix for door and boot lines and parcel shelves in recent years. Demands of biodegradable and lightweight textile products have increased greatly for fuel efficiency in its automotive industry.

1.3 Fiber consumption – Man-made fiber demands will keep growing globally

Natural and man-made are the two main categories of fibers used for fashion products – details of the most widely-used ones are specified in the figure.



The global demand for fibers has continued increasing rapidly, and polyester occupies a dominant role after surpassing the demand for cotton in 2002. According to the England-based PCI Fibers' forecast[12], polyester will continue to keep its dominance in the next ten years. Cotton is in a stable demand situation with slight growth. Demand for cellulosic fiber, such as viscose, which was third in fiber demand after a decline from 1980 to 2000, has been predicted to continuously grow in the near future. The major demand of cellulosic fiber is from Mainland China for spinning yarns for clothes and nonwoven end uses.



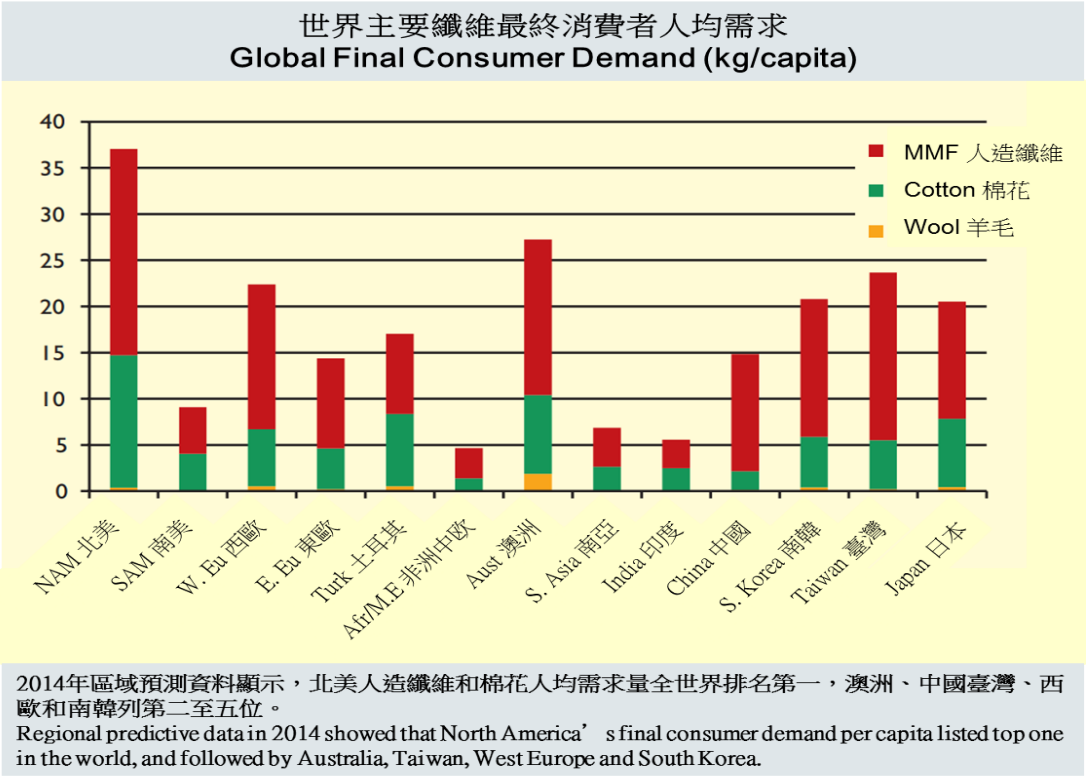
世界纖維需求總量劇增，2002年起聚酯纖維超過棉花成為最大需求纖維，總體上看，人造纖維占主導地位將成為未來趨勢。
The world fiber demands increased tremendously. Polyester surpassed cotton, and became the top one fiber demand. In general, man made fibers will be in dominant demand in the future.

注：根據England-based PCI Fibres & Textile World資料統計
Note: According to England-based PCI Fibres & Textile World

North America, including USA and Canada, is leading the final consumption of man-made fibers and cottons. The major application for man-made fibers in this

[12]http://www.textileworld.com/textile-world/fiber-world/2015/02/man-made-fibers-continue-to-grow/ [30-05-2018]

region is an industrial textile product, such as carpet and rugs; while cotton has been used for clothing. Amongst all other regions, Australia is the country that consumed the most wool.



2014年區域預測資料顯示，北美人造纖維和棉花人均需求量全世界排名第一，澳洲、中國臺灣、西歐和南韓列第二至五位。
Regional predictive data in 2014 showed that North America' s final consumer demand per capita listed top one in the world, and followed by Australia, Taiwan, West Europe and South Korea.

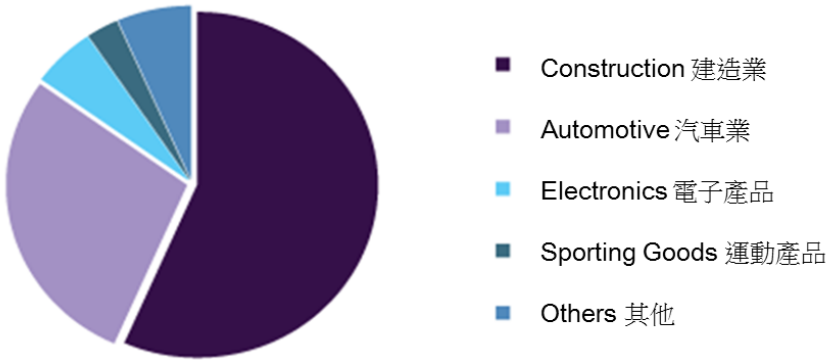
注：根據England-based PCI Fibres & Textile World資料統計　Note: According to England-based PCI Fibres & Textile World

1.3.1 Natural fiber composites

Natural fiber composites have been mainly applied for industrial textile products. The construction industry took more than half the market share in 2015, including the production of decking, railing, window and frames. The automotive industry, the second largest consuming segment of fibers in making door panels, seat backs and dash boards, has benefited in the reduction of CO_2 emissions and improving fuel efficiency. Natural fiber composites have also been widely applied in

electronics and sporting goods, because of lightweight and some unique mechanical properties[13].

2015年世界天然纖維複合材料應用分類份額
Global Natural Fiber Composites Market Share by Application in 2015



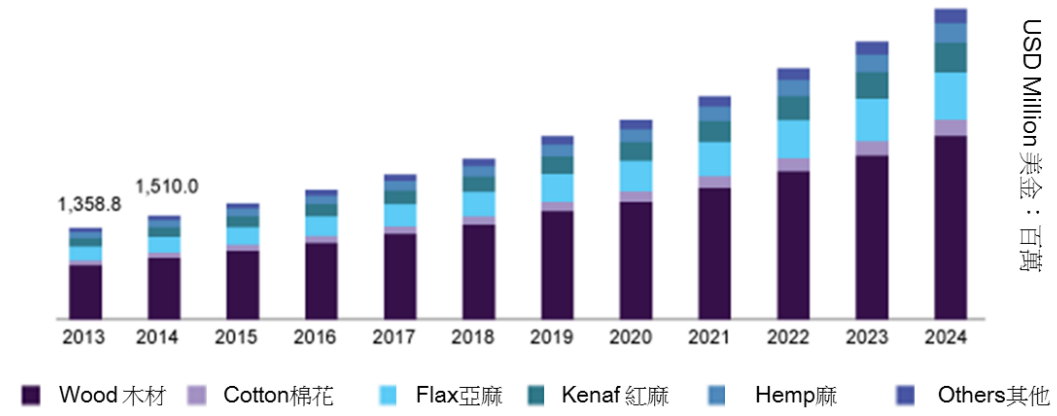
天然纖維複合材料大多應用於建造和汽車行業；電子產品和運動產品也是持續發展的應用領域。
Natural fiber composites were majorly used in construction and automotive industry. Electronics and sporting goods were also promising application segments.

注：根據Grand View Research天然纖維產業報告　Note: According to Grand View Research's NFC Industry Report

In the US natural fiber composite market, wood is the dominant raw material and the consumption of other plants like flax, both kenaf and hemp are predicted to grow in the coming years because of environmental benefits.

[13] https://www.grandviewresearch.com/industry-analysis/natural-fiber-composites-market [30-05-2018]

美國天然纖維複合材料市場原材料金額
U.S. Natural Fiber Composites Market Size by Raw Material



目前，木材和麻類作物是美國天然纖維複合材料的主要原材料，根據預測資料，這種趨勢將在未來幾年更顯著。
Currently, wood, flax, kenaf and hemp are the main raw materials for natural fiber composites in the US, and this trend, according to predictive data, will be continued in the near future.

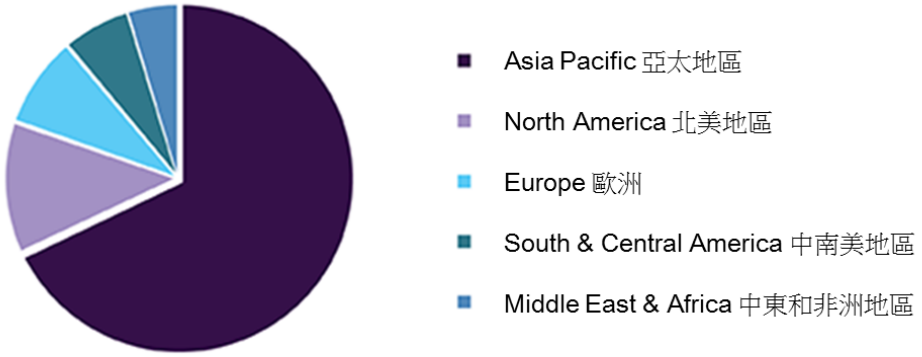
注：根據Grand View Research天然纖維產業報告　Note: According to Grand View Research's NFC Industry Report

1.3.2 Synthetic fibers

For synthetic fibers, clothing manufacturing accounts for over 45% of the global revenue share in 2016. The increasing demand is a direct result of the growth in popularity of functional clothing such as easy-to-maintain style, protective clothing and high-performance sportswear. By region, Asia Pacific leads the demand with a value of 34.77 billion USD in 2016 and is estimated to have a fast growth rate of 7% from 2017 to 2025. Demand for synthetic fibers from North America, the Number 2 region in 2016, is predicted to increase continuously, thanks to their rapid growth of industrial textiles[14].

[14] https://www.grandviewresearch.com/industry-analysis/natural-fiber-composites-market [30-05-2018]

2016年世界複合纖維市場各區域收入情況
Global Synthetic Fibers Market Revenue by Region in 2016

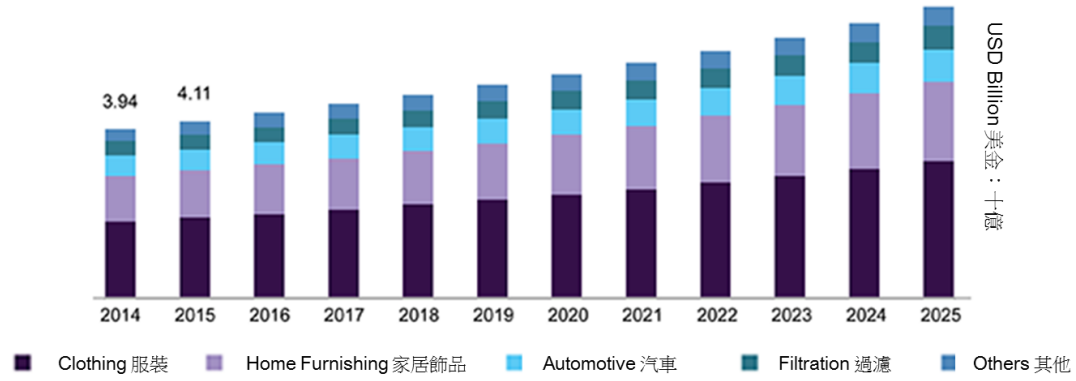


亞太地區複合纖維市場收入占世界超過70%，北美地區占12.51%，其后是歐洲、中南美地區、中東和非洲地區。
Market revenue of synthetic fibers in Asia Pacific took over 70%, and North America 12.51%, followed by Europe, South and Central America, Middle East and Africa.

注：根據Grand View Research天然纖維產業報告　Note: According to Grand View Research's NFC Industry Report

Synthetic fibers in the USA are applied mainly in the clothing, automotive, home furnishing and filtration sectors. It is predicted that this trend will be continued with a steady growth in the foreseeing future.

美國複合纖維市場應用分類金額
U.S. Synthetic Fibers Market by Application



美國複合纖維主要應用於服裝，近年來家居飾品、汽車和過濾的應用也逐步增長，預測未來這一趨勢仍將繼續。
Currently, clothing is the biggest application of synthetic fibers in the US, and applications in home furnishing, automotive and filtration are gradually increasing in these years. This trend has been predicted to continue.

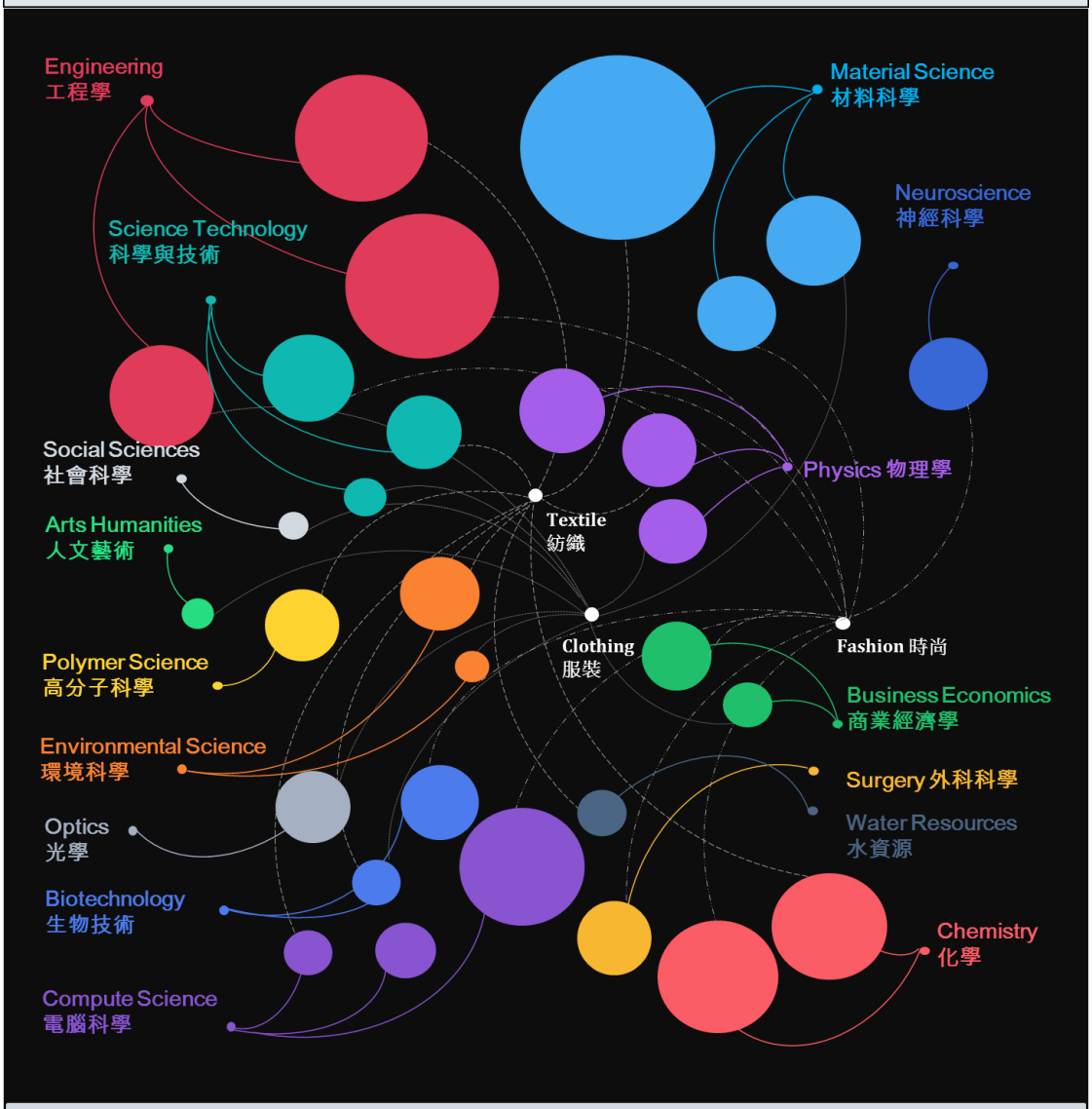
注：根據Grand View Research天然纖維產業報告　Note: According to Grand View Research's NFC Industry Report

1.4 Innovative research – New research fields emerged, USA and China leading the innovation with other traditional powers

Faced with the societal changes, there are some new corresponding trends in innovative research for the fashion industry. According to the data analysis of Web of Science Core Collection[15], the most popular and fruitful research fields from 2009 to 2017 include engineering, materials science, chemistry and computing science, and the rapidly increasing fields include environmental science, biotechnology and business economics. More and more published research results are categorized with the keyword *fashion* instead of the traditional keyword of *textile* or *clothing*.

[15] https://clarivate.com/products/web-of-science/ [25-04-2018]

世界紡織時裝創新研究領域統計比較
The World's Innovative Research Fields for Textile and Fashion

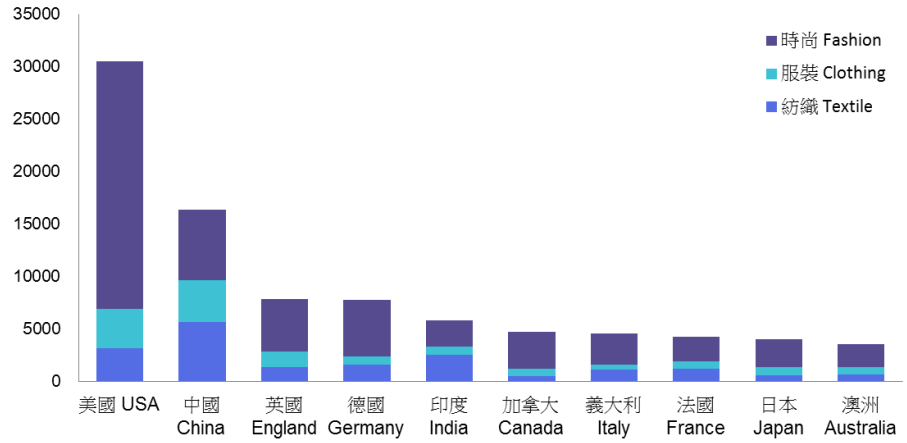


In the past 10 years, top research fields included engineering, material science, chemistry, and compute science. The key word "fashion" had most innovative publications, comparing to "textile" and "clothing".
近十年最熱門研究領域包括：工程學、材料科學、化學和電腦科學。關鍵詞"時尚"擁有最多創新研究成果。
注：根據Web of Science核心合集資料統計
Note: According to Web of Science Core Collection

In terms of publications, USA leads the innovative research relating to textile and fashion since 2009, especially those for fashion. China, the second placed publisher, leads the traditional research for textile and clothing. Some long-established European economies, including UK, Germany, Italy and France, still have very strong innovation ideas in fashion. India has shown a strong initiative

for textile innovative research, which is complementary to its growth trend in textile manufacturing.

世界紡織時裝創新研究十大研發地統計對比
Top Ten Publishers of Innovative Research on Textile and Fashion



近十年，紡織時裝創新研究總發佈量前三是美國、中國和英國；其中“時尚”關鍵詞研究數量最多是美國，“紡織”與“服裝”關鍵詞研究數量最多是中國

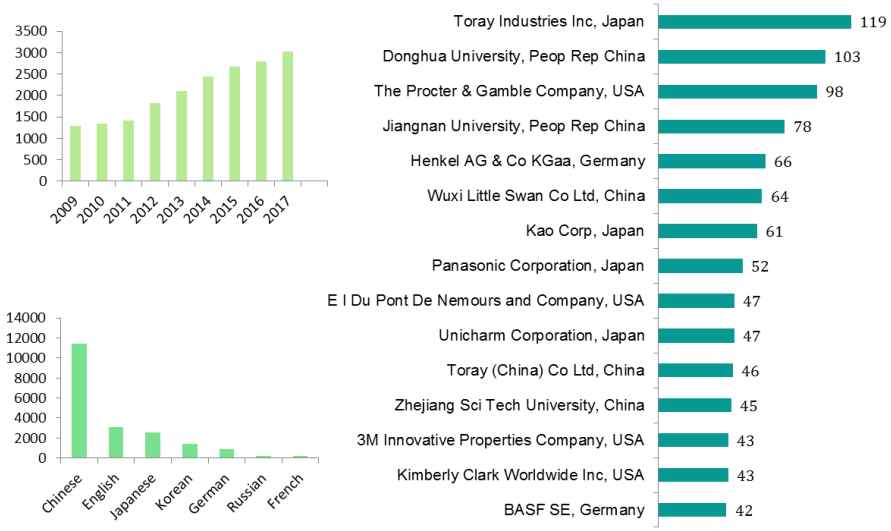
In the past 10 years, the top three for total publications relating to textile and fashion were USA, China and England. USA had most publications with the key word “fashion”, and China had the most with “textile” and “clothing”.

注：根據Web of Science核心合集資料統計
Note: According to Web of Science Core Collection

According to SciFinder[16], the world’s patent applications for textile and fashion have increased year by year since 2009, and the top patent languages used include Chinese, English, Japanese, Korean, German, Russian and French. In terms of application from private institution/company, Toray Industries Inc. in Japan applied for 119 patents relating to textile and fashion, is ranked No.1 globally. Its research center of China Toray (China) Co. Ltd is also listed in Top 15. Five out of the Top 15 companies belonged to Mainland China, and the other ones belong to Japan, USA and Germany. Most of the Chinese institutions are in the academia, while those in Japan, USA, and Germany are commercial companies.

[16] https://www.cas.org/products/scifinder [27-04-2018]

世界紡織時裝專利統計對比
The World's Patents on Textile and Fashion



近十年，全球紡織時裝專利申請數量逐年遞增；專利語言前三位：中文、英文和日文；專利申請前十五位機構主要來自中國、日本、美國和德國。

In the past 10 years, patent applications for textile and fashion increased year by year. The top 3 patent languages were Chinese, English and Japanese. The top 15 organizations for patent application were mainly located in China, Japan, USA and Germany.

注：根據SCIFINDER資料統計

Note: According to SCIFINDER

2. The Global Technology Trends for Fashion Industry

Four new technology trends in the global textile and clothing industry have been categorized through an in-depth study on current technology and innovation of the industry, including:

1) Smart and high-performance materials

2) Advanced digitized manufacturing, value chains and business models

3) Circular economy and resource efficiency

4) High value-added solutions for attractive growth markets.

For each category, key technologies have been identified and highlighted in the following sections.

2.1 Smart and high-performance materials

2.1.1 High-performance fibers and textile materials for technical applications

Speciality fibers, made of polymers, carbon, glass or metals, are engineered for specific use and are able to respond to environmental conditions such as thermal, electrical, magnetic or mechanical and so on. High-performance fibers were invented several decades ago and are generally adopted in niche products for aerospace, defence, construction or protection. Besides focusing on apparel application, there is a global growing interest in technical textiles, and a wide range of industries continue to show interest in developing functional and intelligent textiles.

Carbon fibers differ in flexibility, electrical conductivity, thermal and chemical resistance with different production methods. Carbon fiber reinforced polymers have been widely used in aerospace, automotive, sports equipment and medical instruments. For the fashion industry, carbon filament yarns, fabrics can be used for protective or thermal-controlled clothes. In the coming years, further research would focus on productivity enhancement and cost reduction, and functional composites in 2D sheets and 3D components[17].

There are many types of high-performance synthetic polymer fibers that are commonly used in different industries today[18]. Polypropylene fibers, largely used in nonwoven fabrics, show high-resistance to chemicals, mildew, insects, perspiration, rot, stain and soil, are very lightweight, and have good washability, quick drying properties. Aramid fibers, one of the most representative commodities among the high-performance fiber family because of its high

[17] http://www.fibersource.com/fiber-products/high-performance-fibers/ [3-06-2018]
[18] Bhat, Gajanan, ed. Structure and Properties of High-Performance Fibers. Woodhead Publishing, 2016.

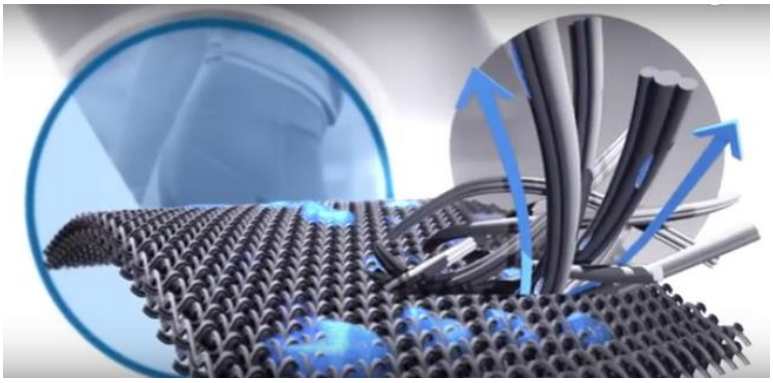
tenacity, high modulus, good heat and flame resistance, can be used for fire protective clothing and bulletproof vests and many other industrial reinforcement applications. Nylon or polyamide is another important man-made polymer for textiles, because of its properties of stiffness, toughness, lubricity, and resistance to temperature, fatigue, and abrasion. Nylon filaments can be used for high-modulus – high-tenacity fibers, flame retardant fibers, chemical resistance fibers and conductive fibers. Nylon-6 and nylon-66 are the most commonly used polyamides for technical fibers.

Nanofibers, with a diameter less than 1 μm, have attracted much attention in recent years because of their unique properties with functionalities from materials resulted in various novel properties and application. Among a number of preparation techniques, electrospinning is distinct from the others for its wide application of materials, ability to control nanofiber diameter, morphology and fibrous structure, ease of adding substances and possibility of bicomponent configuration, porous structure and nanotubes. Electrospun nanofibers have been used for innovative applications in the fields of biomedicine, energy and electronics, environmental protection, functional textiles; details are listed as follows:

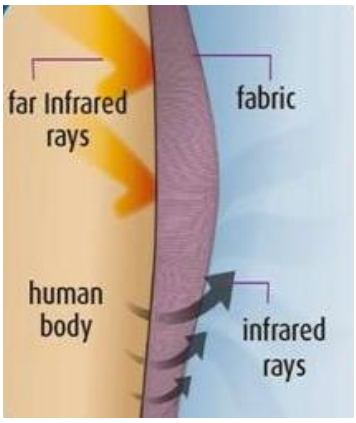
- Functional fabrics

  Moisture management fabric is among the most popular of all functional fabrics. It generally has the properties of transferring sweat from skin to fabric surface with heat absorbing reaction, quick drying and good air permeability. The core technology for the *Coolmax* fabric is illustrated below[19].

[19] https://coolmax.com/en/About-the-COOLMAX-Brand/The-COOLMAX-brand [14-09-2018]



Using natural low-temperature mineral, cooling fabrics are designed to slow down the speed of fabric temperature from rising. Far infrared ray fibers can be used to keep warm as a thermal barrier, in which ceramic is built inside the fiber enabling body heat adsorption and the release of the far infrared ray[20].



- Biomedical applications

  Tissue engineering scaffolds made by electrospun nanofibers are reported to mimic the native extracellular matrix so that functional compounds such as drugs can be encapsulated into the nanofibers. Biodegradable synthetic polymers such as polycaprolactone (PCL), polylactic acid (PLA), or naturally derived materials, including but not limited to collagen, chitosan and cellulose,

[20] http://textilecentre.blogspot.com/2014/04/far-infrared-rays-reflecting-fabrics.html [14-09-2018]

have been selected to prepare scaffolds. Electrospun nanofibers can also be used for drug delivery in a controlled manner.

- Energy and electronics applications

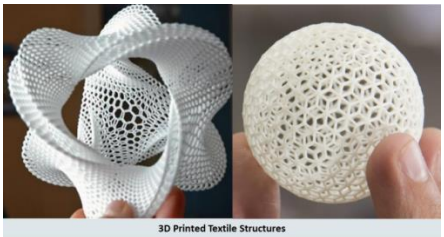
  Intensive research has been conducted for the possibility of electrospun nanofibers for supercapacitors, batteries, sensors, solar cells etc.

- Environmental protection applications

  Electrospun nanofibers can be used for filtration and oil/water separation.

2.1.2 Novel structures for technical applications

In the past 50 years, research with the corresponding applications of advanced polymer composites reinforced with 3D fiber architectures has been intensively conducted. The fabrication of fiber used for composites can be realized by various technologies and processes. Braiding is one of the most versatile and efficient processes. The higher the automation in the whole simulation process will be the future trend. Through weaving, 3D textile composites can be produced near-net-shaped and composed into multilayer fabrics[21]. The current research interest is to increase fiber volume fraction and mechanical properties during the production process. Specially designed knitting process is viewed as the most suitable textile process for making composite materials with tailored properties. Currently, 3D printing technology is adopted in the textile industry to produce some complex structures which otherwise would not be possible to make.

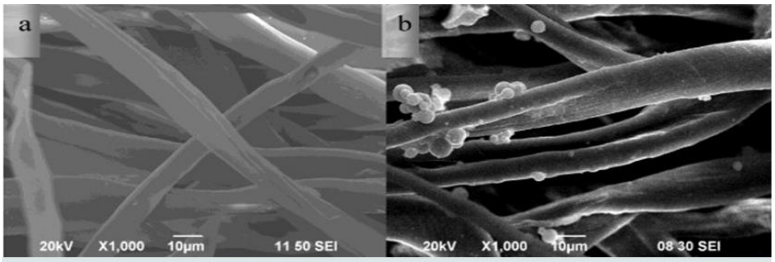


3D Printed Textile Structures

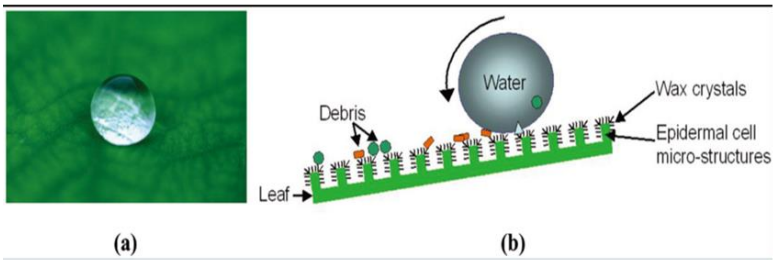
[21] https://www.emeraldinsight.com/doi/full/10.1108/RJTA-06-2017-0034 [06-06-2018]

2.1.3 Multifunctional textile surfaces and related processing technologies

There is an intensively increasing research trend in the multi-functional possibility for processing fibers and textiles in various and diversified ways. In the fiber level, using different additives and finishes in fiber and filament production can have different properties irrespective of base fiber used. A combination of different polymers can also lead to multicomponent fibers or filaments. In terms of yarns or fabrics fabricated by fibers and filaments, different functionalities can be achieved through material surface treatment or additional material layers[22].



Microencapsulation: SEM images of (a) control cotton fiber; and (b) cotton fiber embedded with PentaHerbs microcapsules (1000×).



Nanofinishing: Self-cleaning super hydrophobic nanolayers on individual fiber surfaces like Lotus effect

Multi-functional textiles are in great demand in some high value-added sectors, for example, protective apparels, sportswear, health care products and industrial technical uses. By using layers lamination technology and membranes, fabrics can be secured with waterproof, wind-off or sunblock properties.

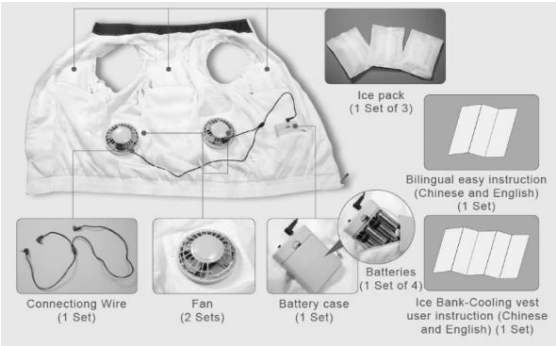
[22] Samaha, M. A., & Gad-el-Hak, M. (2014). Polymeric Slippery Coatings: Nature and Applications. Polymers, 6(5), 1266-1311.

2.1.4 E-textiles for smart structures, functional interiors or smart wearable systems

Thanks to the research on fiber or textile composites with functions of sensing, actuating, communicating and computing, there are increasing attempts to create e-textiles with add-on or built-in electronic functionalities. The possibility for electronic textile systems includes but not limited to flexible circuits, interfacing computers, sensors, radio-frequency identification tags, energy storage and other devices, which are potential applications for personal fitness, public safety, biomedical and health care, and military.

The applications of e-textiles or smart textiles are categorized into attachment, connection, and integration levels[23].

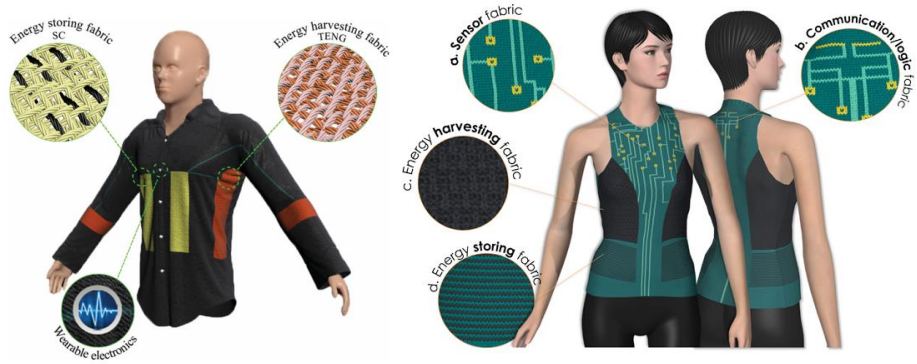
In the attachment level, non-textile functional devices are attached to the garments, for example, the cooling vest[24] to protect workers from heat strokes, and the jacket for music playing.



[23] DIAS, T., 2015. Electronic textiles: smart fabrics and wearable technology. Woodhead Publishing series in textiles .Cambridge: Woodhead Publishing.
[24] https://www.polyu.edu.hk/ife/corp/en/publications/tech_front.php?tfid=7774 [14-09-2018]

The products in the connection level interconnect the functional elements and the textile components. The following figures show glowing clothes with sewable circuitry and the Levi's Commuter Tracker Jacket[25] that realizes smartphone control by swiping or tapping the fabric on the cuff.

In the integration level, specific functions are integrated into the textile structure. For example, the self-charging power textile scheme, illustrated on the left of the figure, integrates the supercapacitor (SC) yarns as energy-storing fabrics, the triboelectric nanogenerator (TENG) cloth as energy-harvesting fabrics, and wearable electronics like button sensors[26]. The figure on the right demonstrates a research outcome for fabric-like materials for storing power with graphene and carbon nanotubes[27].



[25]https://www.theverge.com/2017/9/25/16354712/google-project-jacquard-levis-commuter-trucker-jacket-price-release-date [14-09-2018]
[26] PU X. et al., 2016. Wearable Self-Charging Power Textile Based on Flexible Yarn Supercapacitors and Fabric Nanogenerators. Advanced Materials, V28, I1.
[27]https://www.extremetech.com/extreme/207438-knitted-supercapacitors-could-store-power-in-your-pants [14-09-2018]

2.2 Advanced digitized manufacturing, value chains and business models

2.2.1 New manufacturing technologies for complex textile and composite structures

With the development of new manufacturing technologies, the fashion industry has started to adopt advanced mechatronics and robotics to enable efficient production of complex textile composite structures and the whole product.

In terms of wearables, automation has been gradually realized from raw materials harvest to making thread, weaving, knitting, dyeing, printing and finishing. It is reported[28] that the robotic 3D knitting machines made customized apparels and shoes and some even successfully generated complex patterns for arbitrary 3D shapes. At the moment, dedicated sewing still remains in the hands of skilled workers. However, there is active and intensive research conducted in this field. For example, *Software Automation*, a technology start-up, based in the US, created the *Sewbot* to realize picking up garment pieces and sewing. Because the fabric is floppy and crumbly, the *Sewbot* relies on high-speed cameras to pinpoint the needle location and adjust the sewing pieces accordingly. Tianyuan, a China-based clothing company producing approximately 10 million casual and sportswear garments annually for brands including Adidas, Reebok and Armani, has recently built a facility with 21 *Sewbot* lines by investing 20 million USD in Arkansas, USA.

[28] https://www.cmu.edu/news/stories/archives/2018/march/3d-knitting.html [14-06-2018]
https://www.bloomberg.com/news/articles/2017-08-30/china-snaps-up-america-s-cheap-robot-labor [04-09-2018]

Automation is also assisting the revival of manufacturing in some developed countries. Automated robotics has become one of the most invested fields in the US textile industry in the latest 5 years, and its production of technical textiles is steadily increasing year by year. There have been announcements by foreign-owned textile companies to invest in the Southeast of the US, thanks mainly to the advances of automation in manufacturing, energy availability, policy changes and speed-to-market advantages.

2.2.2 Digitization and flexibilization of production processes and factories

Recent technology development, especially with the advent of the 4th Industrial Revolution, is fast becoming a reality for the fashion industry to adopt digitization and interconnection of every production process.

The digital production fits today's fashion industry perfectly, which changes the traditional annual two-season mode into multiple mini seasons with personalized fashion which require a faster turnaround. Digital printing has been used for making different products from fashion clothing, haute couture and sportswear to soft signage and home textiles. With digital printing, production process becomes more automated, fashion designers can create without boundaries, and the customers can order photo-realistic services. Concurrently, it saves water and energy consumption during the actual printing process.

2.2.3 Virtual modelling and design of fiber and textile based materials and products

Technology advancements in virtual modelling and design have been widely used in high end manufacturing for decades. This technology starts entering into the textile and fashion industry, especially for renowned brands, who adopted this for product design, development and sampling/prototyping.

The 3D virtual modelling technology efficiently shortens the product development process and makes immediate communication possible between customers and service providers. The technology also saves time and money for developing physical prototypes in different sizes and using different fabrics. If cloud service is used, the electronic modelling patterns can be shared within the working group for editing and communicating, which forms a global value chain without location and time limits. This technology is also a useful tool for personalization fashion. Some famous brands, including Under Armour, Coach, Victoria's Secret, Hugo Boss, Nike, Abercrombie & Fitch and more have already entered the market. At the moment, CLO, OPTITEX and BROWZWEAR are the more commonly adopted software in the field.

A further application for textile virtualization is for functional textile products, such as sportswear, medical and healthcare devices, aerospace and military garments. The advances of simulation can be adapted for material performance and various functions under a selected environment with set temperature and moisture. Intensive research has been conducted for realistic modelling of complex, functional and smart textiles for product development.

2.2.4 New digitally-enabled business models

In the period of traditional mass distribution, what the consumer buys is decided by the collection designers, wholesalers, sourcing agents and retailers many months ago. However, the digital era has changed today's fashion business completely. The new generation customers become much more sophisticated and closely follow the latest fashion trend. E-commerce and social media make it possible to have the most popular product on the doorstep virtually the next day when the product is released to the market. Furthermore, customers are increasingly interested in personalized products and service[29].

Under this circumstance, new technologies and business models for agile supply chain, personalization prediction and new consumer interaction could become the 'norm' in the very near future.

2.3 Circular economy and resource efficiency

2.3.1 Novel flexible process technologies to save water, energy and chemicals

The fashion industry has always been recognized as the top resource consumption and pollution industry. Due to the depletion of natural resources as well as stringent legislation on environment protection, intensive research has been carried out for new technologies and process for clean production.

Some improvements have been made in various sectors of the industry to reduce the consumption of water, energy and chemicals. Some examples are a better system for raw material usage, production process upgrade, energy emission enhancement, wastewater treatment for recycling, novel dyeing, printing and

[29] https://financesonline.com/understanding-rise-personalized-products-ecommerce/ [09-06-2018]

finishing technologies and hazardous chemicals elimination. Moreover, innovation has also been created to replace the traditional processes or technologies such as waterless dyeing, digital printing, seamless manufacturing and 3D composite production.

2.3.2 High-tech textile recycling for circular economy concepts

The concept of the circular economy – from cradle to cradle, has been widely recommended in the fashion industry. Different technologies and actions have been investigation aiming to make the supply chain move in a circular manner. Besides consumer education for product reuse, the industry is also seeking an industrial scale solution to recycle wastes generated during production. For example, to reuse the clothing wastes and produce carpets, to upcycle clothes into textile composites or yarns and so on. However, there are still many barriers before an authentic and effective recycling of post-use textiles can be realized globally.

2.3.3 Sustainable substitutes

To reduce the fossil-based textile processing and products, efforts have been made to find viable sustainable substitute fibers. Natural fibers like flax, hemp and wool are recommended because of their renewable characteristics, but some natural fibers like cotton are under criticism due to its use of a large amount of water and pesticides. Hemp, one of the oldest and most popular crops for textiles, is renowned for its high-yield without the usage of hazardous chemicals, pesticides and fertilizers. Hemp has tensile strength and durability, as well as other features like breathability and UV resistant. It is widely used in industrial textiles, especially in North America, and for some fashion brands' eco-friendly collection, such as Stella McCartney and Calvin Klein.

Besides, bio-based and forest-based man-made fibers have also been intensively studied for chemicals reduction, better recycling and biodegradation.

By adopting advanced technologies, sustainable substitutes not only benefit the environment but also can have high-performance functionality. For example, in the 2018 FIFA World Cup, at least 15 out of the total 32 team jerseys were made of Taiwan's innovative fabrics produced from recycled PET bottles using seamless knitting technology. Jerseys made from such fabrics are claimed to have breathability, moisture resistance and sweat regulating properties[30].

[30] https://www.taiwannews.com.tw/en/news/3476997 [14-09-2018]

2.4 High value-added solutions for attractive growth markets

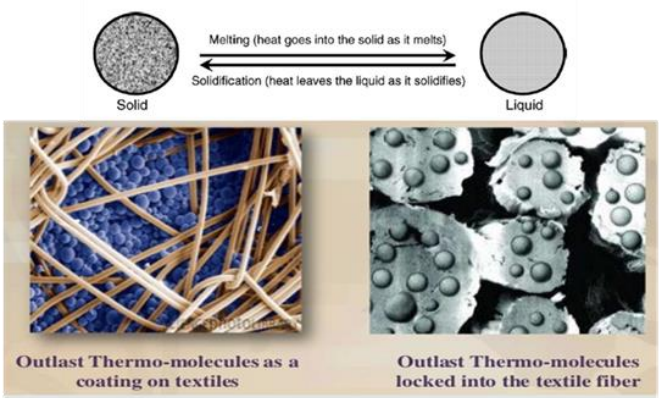
2.4.1 Textile-based functional and smart products for work, health, sports and personal protection

With the advanced development of science and technology, the use of textiles, besides daily common clothing products, has been extensively studied for higher value-added solutions for work, health, sports and personal protection. Due to an ageing society in many developed countries, an ever-growing enthusiast for sports around the world, and increasing safety awareness for the dangerous working environment, there are huge potentials to develop textile-based smart and functional products for such emerging market demands. Several representative applications of different technologies in this field are introduced below.

2.4.1.1 Phase change materials application

"Phase Change" refers to physical state transformation – the process of changing from solid phase to liquid phase and vice versa[31]. To provide thermal protection for astronauts, the technology of Phase Change Materials (PCM) microcapsules into textile structure was developed in the early 1980s under a NASA research program [32] . Using PCM, smart fibers and textiles could have automatic acclimatizing properties, such as thermal energy storage and energy release of the cooling process[33].

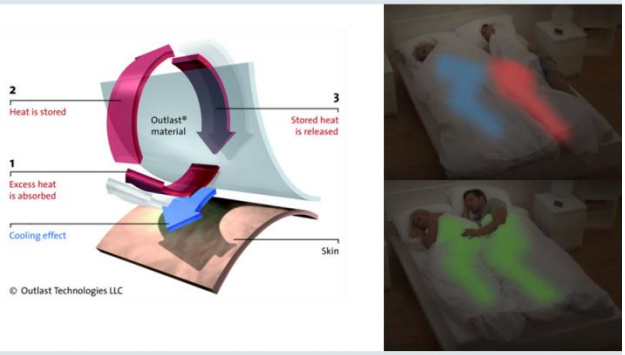
[31] Mondal, S., Phase change materials for smart textiles – An overview. Applied Thermal Engineering, 2008. 28(11–12): p. 1536-1550
[32] Nelson, G., Microencapsulation in textile finishing. Review of Progress in Coloration & Related Topics, 2008. 31(1): p. 57-64.
[33] Weder M., Scale of change, Textile Month, 2001. October: 37–38.



In order to incorporate PCM in a specific textile product, it is first encapsulated.

Besides, PCM has been also applied for thermal protection[34] and regulation for sports[35], personal protection[36] and home textiles[37], as shown in the following figures.

(a) Active thermal and moisture management for chemical protective garments; (b) Cold protective clothing for skiing.



(c) Thermo-regulation and comfort properties

[34] Zhu, F., Feng, Q., Liu, R., Yu, B., & Zhou, Y. (2015). Enhancing the thermal protective performance of firefighters' protective fabrics by incorporating phase change materials. Fibers and Textiles in Eastern Europe, 23(2), 68-73.
[35] http://news.xinhuanet.com/english/photo/2015-01/02/c_133892902.htm [14-06-2018]
[36] http://www.everychina.com/p-z52ed6f7-102417978-fire-department-nomex-fr-firefighter-uniform-flame-retardant-coveralls-with-nomex-iiia.html [14-06-2018]
[37] http://www.outlast.com/en/applications/ [14-06-2018]

2.4.1.2 Conductive polymer materials applications

Having electrical conductivity is often a prerequisite for many smart and intelligent textiles with high demands in antistatic applications, sensing, data transfer, monitoring, corrosion protection and electromagnetic interference shielding.

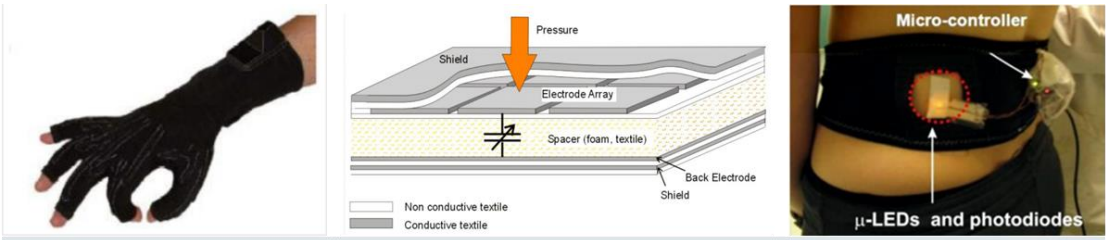
For electromagnetic factor shielding, metal coated or electro-conductive polymers coated textiles have been adopted for surface reflection and adsorption[38]. Such materials can be used as camouflage products for military, shielding EMI and microwaves for the industry[39], blocking electromagnetic waves from electronic appliances for personal health[4041].

(a) Protective apparels for shielding EMI and microwaves;
(b) Personal protection from electromagnetic waves.

The textile-based sensor has become one of the most developed fields for functional and smart textile products. The sensors have different functions. For

[38] Kim, M.S., et al. (2002), PET fabric/polypyrrole composite with high electrical conductivity for EMI shielding, Synthetic Metals, 126(2–3): 233–239.
[39] http://www.swiss-shield.ch/Products.45.0.html?&L=1 [16-06-2018]
[40] Kuhn, h.h. (1997), Adsorption at the liquid/solid interface: conductive textiles based on polypyrrole, Textile Chemist and Colorist, 29(12): 17–21.
[41] http://www.vesttechinc.com/AboutContact.aspx#about [16-06-2018]

example, stretch sensors can sense and monitor body parameters, including heart rate, respiration, movement and pressure blood. Electrochemical sensors augment conventional physical measurements. Applications have been realized in various areas[42] [43] [44].



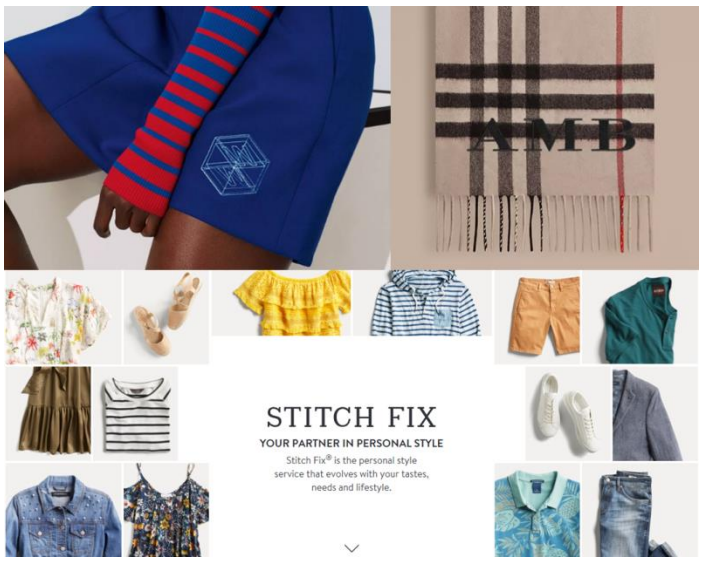
(a) DataGlove by VRLOGIC. Sensors in the glove detect the wearer's hand movements;
(b) A matrix with capacitive pressure sensors by ETH Zurich, to measure pressure on a human body and detect muscle activity on the upper arm;
(c) The wearable chemical sensors, developed by Dublin City University, measure and analyze sweat in real-time on the body aligned with the pH sensitive fabric.

There are other techniques and materials studied for functional and smart textiles, including but not limited to shape memory polymers for medical garments and pressure sportswear, biodegradable materials for drug release medical devices, and energy harvesting and portable power supply systems for healthcare, sports and entertainment.

[42] Pacelli, M.; Loriga, G.; Taccini, N.; Paradiso, R. Sensing Fabrics for Monitoring Physiological and Biomechanical Variables: E-textile solutions. Proceedings of the 3rd IEEE-EMBS International Summer School and Symposium on Medical Devices and Biosensors MIT, Boston, MA, USA, 4–6 September 2006.
[43] Stoppa, M., & Chiolerio, A. (2014). Wearable electronics and smart textiles: a critical review. Sensors (Basel), 14(7), 11957-11992.
[44] Windmiller, J. R., & Wang, J. (2013). Wearable electrochemical sensors and biosensors: a review. Electroanalysis, 25(1), 29-46.

2.4.2 Personalized fashion

Thanks to the digital and technological advances, personalization is no longer a VIP only service in luxury fashion. Nowadays, a personalized product can be simply created online or in brick-and-mortar stores with big labels, small-medium sized brands and even startups. For example, Burberry offers monogramming for a special selection of designs, including scarves, bags and leather accessories; shoppers can also have their item customized in Tommy Hilfiger store in a short time. Some other brands even offer full personalization service of their products, from fabric, color, pattern, and design to personal fitting size. Meanwhile, a new business has taken advantage of this growing trend and provides personal style service and subscription boxes. For example, Stitch Fix, founded in 2011, uses algorithm technology and data science to send subscribed customers personalized clothes in meeting their tastes, needs and lifestyle. Furthermore, body measurement has also become an important field for personalized fashion, for which startup technologies including but not limited to AI, 3D scanner, algorithms and visional data capture are in rapid development.



3. Global Trend of Sustainable Fashion

Much has been published in the sustainability of fashion in recent years. More and more companies have joined the sustainable fashion movement. Leading companies, ranging from Patagonia and H&M to Kering Group and ASOS, have already launched pioneering initiatives on the entire production lifecycle from recycling to regeneration. It has been reported[45] that 64 international fashion companies, representing a total of 142 brands, signed the 2020 Circular Fashion System Commitment and set 143 targets for sustainability at 2017 Copenhagen Fashion Summit – one of the world's most important events on sustainable fashion.

The primary motivation behind this growing trend of sustainability is the awareness of changing consumer minds and behaviors, especially the Millennials and Generation Z. It is also reported[46] that 66% of the global millennials are willing to pay more on those brands with high sustainable credibility. Regarding sustainability involvement, some industry forerunners' successful experience is creating an area of differentiation. These brands address their value through identifying sustainable ways and working with their customers across the whole product lifecycle, which accelerates their transition to a circular system and in return earn them loyal customer base and esteemed reputation.

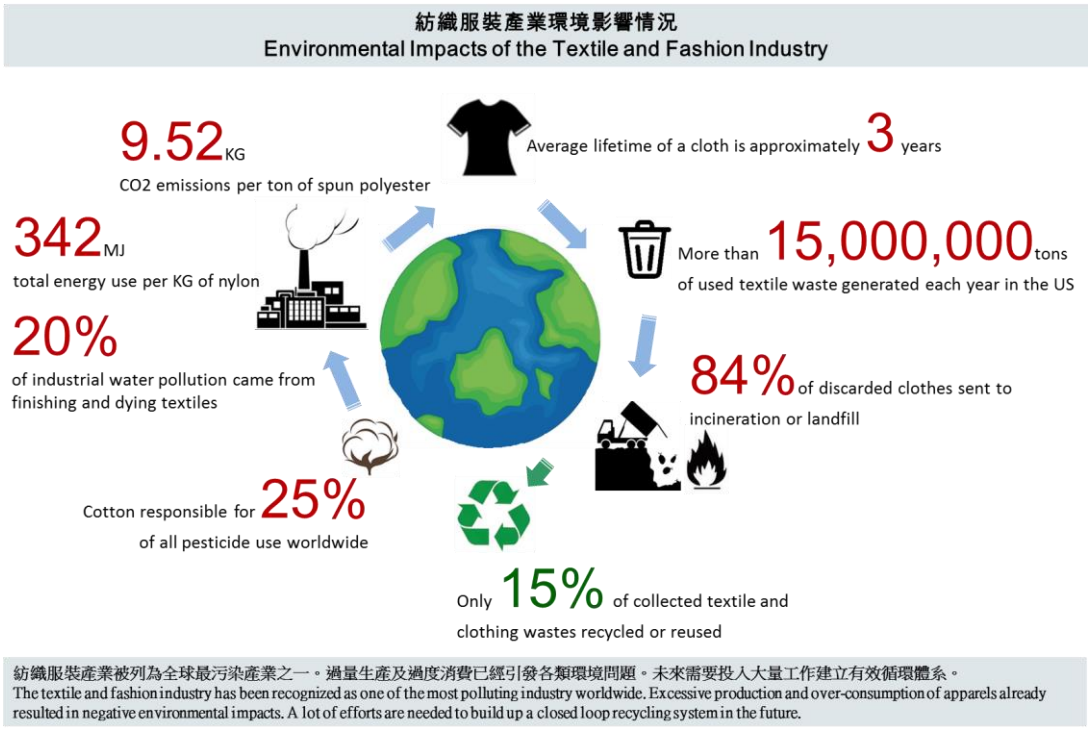
The discussion about the environmental impacts of the fashion industry has existed for decades, much earlier than the sustainable actions taken by major industrial participants. In the following section, the questions listed below will be the focus for discussion:

[45] http://www.globalfashionagenda.com/commitment/ [25-07-2018]
[46] https://www.nielsen.com/ma/en/insights/news/2015/green-generation-millennials-say-sustainability-is-a-shopping-priority.print.html [25-07-2018]

- what kind of environmental problems the fashion industry have today?
- what the major fashion brands have done?
- what do they expect to achieve for sustainability?
- what kind of sustainable business initiatives the industry could have?

3.1 Environmental Impacts

As one of the world's largest consumer industry, the fashion industry has a 1.5 trillion euro market with over 300 million people across its value chain in 2016[47]. The McKinsey Global Fashion Index forecasts the sales growth to nearly triple between 2016 and 2018. Meanwhile, the industry has always been cited as the second most polluting global industry. The argument over this title goes, yet the fashion industry indeed has severe environmental impacts on our planet. Some striking facts are illustrated in the following figure.



[47] https://www.mckinsey.com/~/media/McKinsey/Industries/Retail/Our%20Insights/The%20state%20of%20fashion/The-state-of-fashion-2017-McK-BoF-report.ashx [24-07-2018]

Cotton, a most common raw material in the industry, is reported to be responsible for 25% of all pesticides used worldwide and is also considered disreputable for land occupation and heavy water consuming[48]. The production and processing of textiles also cause a lot of environmental problems. The large volume of water used and some effluent discarded in the finishing and dyeing processes are toxic and difficult to be recycled. Energy depletion and gaseous emissions also cause concern to the public. For example, 342 mJ in a total of energy is consumed to produce 1 kg of nylon[49]; and 9.52 kg CO_2 is released to produce 1 ton of spun polyester[50]. Besides, there are many other ecological criticism centers on the creation of each fashion item.

Moreover, while the consumption of fashion products rapidly grows year by year, the average lifetime of a cloth has been decreased from 6.8 years (T-shirt)[51] to around 1-3 years[52]. With countless choices of numerous brands from both physical and digital stores, people do generally buy more and each item will have a shorter useful lifespan. Pioneers for sustainable fashion blame such phenomenon on the fast and ultra-fast fashion modes which have been hugely popular in the recent decade. However, the underlying results are that products tend to have a lower quality and that attention must be paid in terms of sustainability regarding excessive production and consumption, and in particular generation of waste. In the USA alone, more than 15 million tons of used fashion waste is generated each year, and this is still not counting those unused discards[53]. It is also reported[54] that an incredibly high proportion, 85% of the discarded

[48] https://ejfoundation.org/resources/downloads/the_deadly_chemicals_in_cotton.pdf [24-07-2018]
[49] https://oecotextiles.wordpress.com/2009/06/16/what-is-the-energy-profile-of-the-textile-industry/ [24-07-2018]
[50] https://oecotextiles.wordpress.com/category/co2-emissions-in-textile-industry/ [24-07-2018]
[51] Langley, E., Durkacz, S., and Tanase, S. (2013). Clothing longevity and measuring active use, WRAP.
[52] Beton, A., *et.al*. (2014). Environmental improvement potential of textiles. European Commission.
[53] https://www.thebalancesmb.com/textile-recycling-facts-and-figures-2878122 [24-07-2018]
[54]https://www.theguardian.com/fashion/2017/jul/29/fashion-must-fight-scourge-dumped-clothing-landfill [22-07-2018]

clothes were sent to the landfill or incineration. Although there are different on-going programs in circular fashion, it is estimated that only 15% of the collected fashion waste was reused or recycled. Many those in fashion believe that the situation is much acute since the industry is particularly complicated with thousands of players, rules, standards and statistics involved and it is most challenging and extremely difficult to find out the exact amount of discarded and recycled garments.

The issue on the sustainability of the fashion industry and a total revamp of its ageing supply chain should be seriously handled in no time.

3.2 Sustainable fashion pioneers

In the 2017 Copenhagen Fashion Summit, and for the first time the organization *Global Fashion Agenda* calls on fashion brands and retailers to publish their commitment to a circular model within the next half year. More than 20 companies have already taken actions for their sustainable development plan afterwards. Some of them have been the pioneers in a sustainable fashion for years or even decades. Cases ranging from big brands, luxury groups to small-medium-size sustainable brands are presented in the following sections.

3.2.1 Big brands and luxury group

BIG BRANDS

Patagonia

Eco-friendly Fibers, Materials and Technologies
Using fibers like hemp, organic cotton, recycled nylon, polyester and wool etc., eco-functional materials, and new technologies with less environmental impacts

Worn Wear
Encourage customers to repair and reuse worn garments, and recycle when beyond repair

Supply Chain
Make sure production under sage, fair, legal and humane working conditions

Action Works
Support activities to find solutions to the environmental crisis

Grants
Pledge 1% of sales or 10% of pre-tax profits to environmental groups

H&M

Ambitious Plan
Promise to use 100% recycle or sustainably-sourced materials

CONSCIOUS EXCLUSIVE

Sustainable Collection
Sustainable materials, recycled silver and ECONYL, regenerated from fishnets and nylon waste in 2018 collection

Reuse and Recycle
During 2017, collected 17771 tons of textiles; partnered with HKRITA to develop technologies to recycle clothes into new clothes

Eco Actions
Reduced water consumption and emissions, set new vision for toxic-free in future

Ethics
100% business partners signed Sustainability Commitment and Code of Ethics

ASOS

15%

Commitment
Signatory to Sustainable Clothing Action Plan's 2020, and Circular Fashion System Commitment

Eco Edit
Launched in 2010, this platform sell products with eco-friendly materials and technologies or meeting other sustainability criteria

Sustainable Sourcing Program
Four pillars: Traceability of materials; lowering environmental impact; craftsmanship; engaging customers on sustainability

Animal Welfare
Animal Welfare Policy applies to all products sold through any of ASOS' websites

Package
Saved 14 meters of plastic shrink wrap, reduced 20 lorries each week

ADIDAS

2020 Targets
Innovate materials & processes to reduce environmental impact, and care about people

Innovation
Partnered with Parley for the Oceans, use BIOSTEEL fibers, drydye and nodye technologies, create low waste and emission product

Materials
Sustainable cotton, recycled polyester, recycled nylon, recycled polystyrene etc.

Chemical Footprint
Launched Chemical Management Program

Take Back Program
Pilot in Canada and Brazil, now launching in New York, Los Angeles, Paris and London

Patagonia, a US brand for outdoor and salient sports clothing, has been recognized as one of the most outstanding pioneers dedicated to environmental protection. The company encourages using eco-friendly fibers, including hemp, organic cotton, 100% recycled down and innovative technologies to reduce

unnecessary harm to the environment[55]. Furthermore, Patagonia initiated various sustainable ways to identify its differentiation. *Worn Wear*, a special hub for keeping materials in use, encourages customers to share stories about their own fashion products, to keep their worn wears in action longer through repair and reuse, and to recycle them when beyond repair. This much-perceived program does more than just educating the concept of conscientious consumption to consumers and gradually cultivating a loyal and highly engaged customer base, also sets a good example to the industry for a model of the circular supply chain. The *Footprint Chronicles*, another initiative from Patagonia, is designed to make sure its supply chain is performing under safe, fair, humane and legal conditions, whereas *Action Works* is to engage with the community and support activities to help to solve various environmental crises. Patagonia's founder even co-established the initiative of *One Percent for the Planet* – an organization conceived to encourage business to donate 1% of sales or 10% of profits to environmental groups.

H&M, one of the leading fast fashion companies, has been actively engaged in sustainable fashion movements in recent years. Earlier this year, the H&M group published its Sustainability Report 2017 detailing important progress and strong commitment towards its vision to lead the change towards a circular and renewable fashion industry, while being a fair and equitable company. In this report, it outlines an ambitious plan to use 100% recycled and sustainably-sourced materials by 2030. Launched for several years, *Conscious Exclusive* is a most sustainable collection in H&M's product line, providing ethical fashion products made from sustainable materials. For example, recycled silver and ECONYL – raw material generated from fishnets and nylon waste are exclusively used in its 2018 collection. The company also rapidly develops programs for reuse and recycling –

[55] https://www.patagonia.com/recycling.html [22-07-2018]

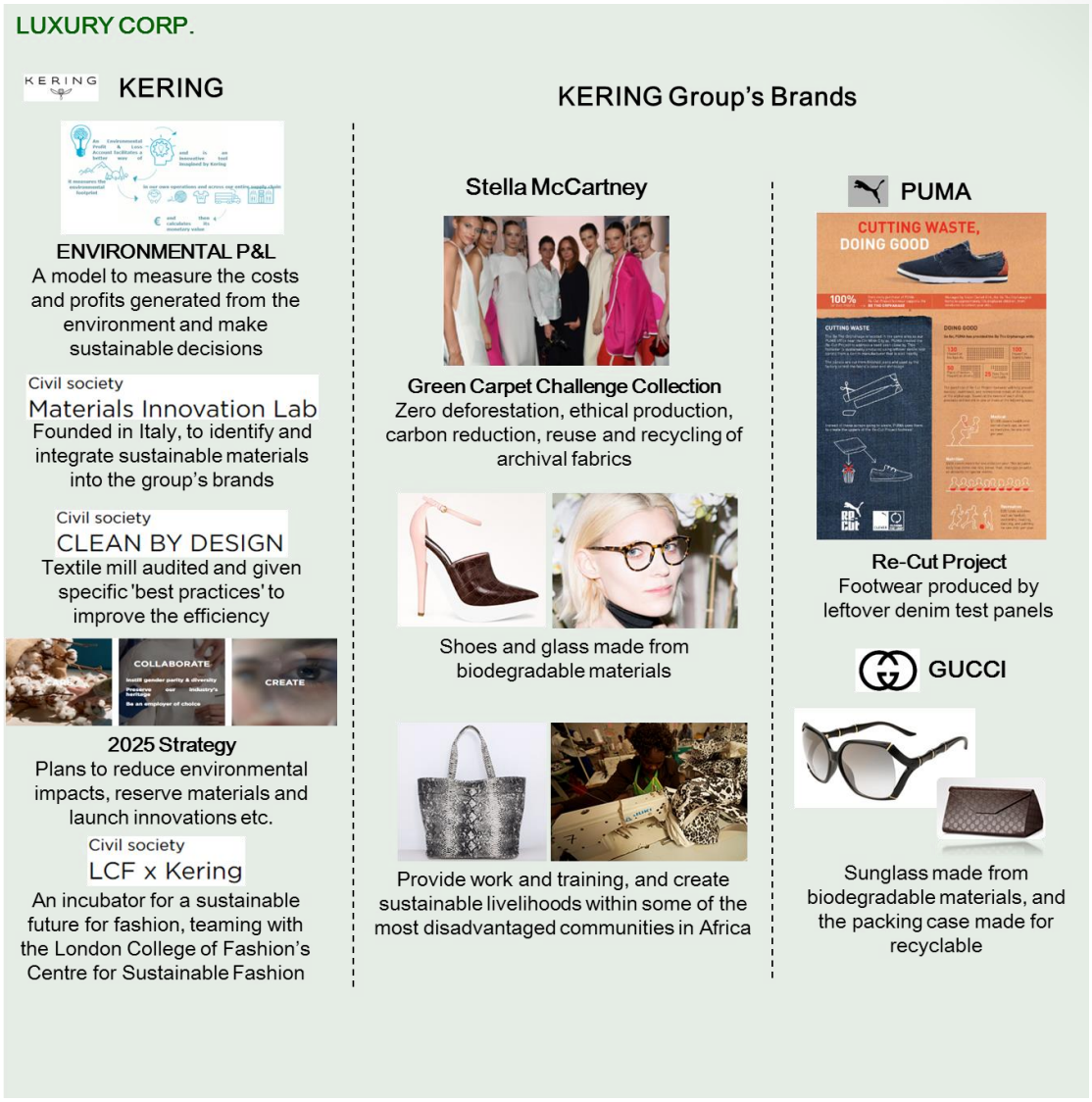
a total of 17,771 tons of clothes had been collected from their stores in 2017[56]. In Hong Kong, H&M partners with the Hong Kong Research Institute of Textiles and Apparel (HKRITA) to develop new technologies to upcycle used clothes into new ones, and the pilot operation in Hong Kong has started in September this year. For production processes, the group promise to reduce water consumption and gaseous emissions and will set a new vision for toxic-free operation in the future. To ensure safe and fair working practice, it requires all of its business partners to sign Sustainability Commitment and Code of Ethics.

ASOS, the UK based online ultra-fashion company, starts to play a leading role in sustainable fashion movements. As the signatory to the Sustainable Clothing Action Plan's 2020 Commitment and Circular Fashion System Commitment at the Copenhagen Fashion Summit, ASOS makes a set of targets regarding carbon, water and waste footprint reduction and circularity establishment. Within the asos.com website, a curated destination *Eco Edit* sells products made by manufacturers and brands with strict sustainable business practices, and the revenues of these items are designated to support related areas of sustainable fashion. A sustainable sourcing program is launched to achieve the traceability of raw materials, lowering environmental impact, investing craftsmanship and engaging customers on sustainability. ASOS carries out the Animal Welfare Policy across all its product lines. As an online company, it also dedicates to manage packaging waste and transport efficiency. It is reported that the company sourced over 40 million plastic mailing bags and 5 million cardboard mailing boxes a year. To reduce transport footprint, ASOS made a change in parcel packaging and reduced 14 to 20 trucks from the road each week[57].

[56] https://about.hm.com/en/about-us/in-focus/sustainability-at-the-centre--rewearreuserecycle.html [22-07-2018]
[57] https://www.asosplc.com/~/media/Files/A/Asos-V2/documents/corporate-responsiblity/reporting-and-policies/asos-ghg-report-2016-17.pdf [24-07-2018]

Adidas, being a global sports clothing and footwear company, has a long history of nearly 30 years for sustainable development, especially in its supply chain management. It develops a Sustainability Roadmap to translate the company's sustainable efforts into tangible goals and identifies strategic priorities from clean production to people catering. Adidas builds up innovation teams to focus on materials and manufacturing processes innovation, for example, using oil-based plastic to reduce carbon emissions, adopting waterless dyeing to save water, chemicals and energy. The company also sourced more sustainable materials such as recycled polyester/rubber, organic cotton, and TENCEL. Their manufacturing suppliers are committed to recycling a high proportion of operation waste back into production. Since 2015, Adidas partnered with *Parley for the Oceans* to support ocean conservation. Besides funding support for activities, Adidas launches *Parley Ocean Plastic*, a range of eco-innovative materials generated from upcycled plastic waste collected from remote shorelines, beaches and coastal communities. Adidas has been running chemical management program for years to systematically supervise product safety, environmental audit, chemical input, disclosure and partnerships. To form a circular system, the company launches the *Take Back* program in Canada, Brazil, New York, Los Angeles, Paris and London as pilot cities to collect clothes and shoes from any brand, raising awareness of consumers and sending the discarded products for reuse or recycling[58].

[58] https://www.adidas-group.com/en/sustainability/managing-sustainability/general-approach/ [25-07-2018]



As the founding partner of *Global Fashion Agenda*, the French luxury group Kering and its fashion brands are leading the sustainable luxury fashion for years. The Group develops an innovative tool *Environmental Profit & Loss* to measure the cost vs benefit generated for the environment, and in turn, making more sustainable business decisions across the entire supply chain. The methodology is now open sourced for other companies. In 2013, Kering founded the *Materials Innovation Lab* in Northern Italy to identify sustainable raw materials for luxury standards and enable the Group's brands to integrate the materials into their collections. It also launches a *Clean by Design* program initiated by the Natural

Resources Defense Council to audit the Group's textile mills for clean manufacturing from spinning, weaving, dying to finishing. Teaming with the London College of Fashion's Centre for Sustainable Fashion, an incubator was established to connect research, education and business to accelerate innovative design for sustainable fashion for the future. Just before Copenhagen Fashion Summit 2017, Kering released its 2025 sustainability goals, which mainly aim to prioritize transparency, to use new raw materials and to clean up the entire supply chain.

With sustainable strategies and management of the Group, Kering's fashion brands are playing important roles in sustainable luxury fashion within the industry. Before her split with Kering in 2018, Stella McCartney was one of the most outstanding pioneers in promoting sustainable fashion for the Group. Among the first for green carpet, Stella McCartney launched her capsule Green Carpet Challenge collection in 2014 London Fashion Week, with zero deforestation, ethical production, carbon reduction, reuse and recycling of archival fabrics. To replace leather, she used innovative bio-synthetic materials for shoes and bio-plastics for eyewear, which was then expanded into her fashion collection. Furthermore, Stella McCartney created a range of hand-made recycled canvas tote bags and engaged more than 100,000 people in the most disadvantaged areas in Africa to work from printing to stitching for sustainable livelihoods.

Within the Kering Group, PUMA collaborated with its denim partner Saitex to run a *Re-Cut* Project and use the test panel denim waste for the uppers of footwear. From the beginning of the lifecycle, the denim cutting down waste is designed to be sent to the end of the footwear's cycle, which sets a good example for closing

the loop across the supply chain. All the profits gained from this collection go to support the local venture in Vietnam for medical care and food in the orphanage.

To share Kering Group sustainable responsibility, Gucci launched an innovative sunglasses model made in liquid wood, a biodegradable material, representing an alternative to the plastic. Certified recyclable packaging has been used for Gucci brand eyewear, with an instruction for the customers on how to return the case to the recycling centers.

Some leading companies have set specific sustainable targets across the supply chain, from materials, resources, manufacturing, recycling to ethics and others. The table below lists the detailed targets of Kering, H&M, ASOS, Adidas and Eileen Fisher.

	Materials	Resources	Manufacturing	Recycle	Ethics	Others
KERING	Tracing 95% of raw materials by 2018		Develop standards across 100% of supply chains			Reducing EP&L across supply chain by 40% by 2025
H&M	Use 100% cottons from sustainable sources in 2020	Climate-positive across the entire value chain by 2040		Use 100% recycled or other sustainably sourced materials in 2030	100% of the garment manufacturer units in Bangladesh conducted democratic election of worker representatives in 2018	
ASOS	Source 100% more sustainable cotton by 2025		Reduce the carbon, water and waste footprint of our own-label clothing by 15% by 2020			Train 100% design teams and product team on circular techniques, principles and best-practice
ADIDAS	20% waste reduction at our strategic suppliers by 2020 100% sustainable cotton by 2018	35% water savings at apparel material suppliers and per employee at own sites by 2020 20% energy savings at our strategic suppliers by 2020	100% sustainable input chemistry by 2020 3% absolute annual reduction in CO2 emissions at our own sites by 2020	50% waste diversion for owned operations to minimize landfill by 2020		75% paper reduction per employee at our own sites by 2020
EILEEN FISHER	100% sustainable sourcing by 2020		100% sustainable manufacturing by 2020			

3.2.2 Other sustainable brands

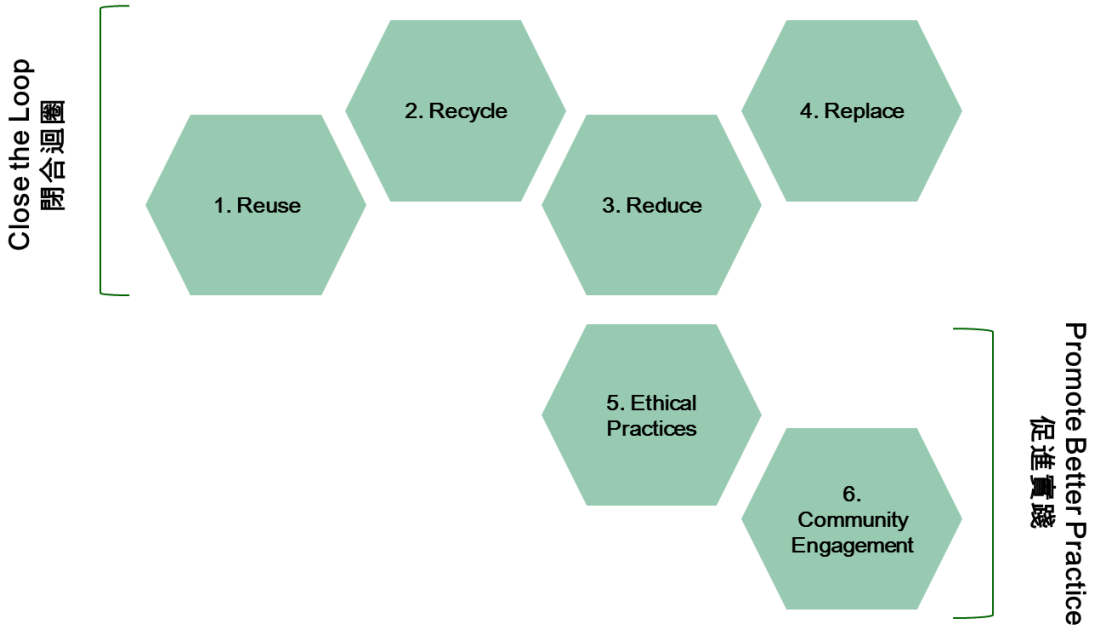
One new independent British brand, *Know the Origin*, is performing quite outstandingly in the sustainable fashion scene. The main selling point of this brand is that all its products are made from 100% organic cotton, with some *Fairtrade* certified. It is also unique that consumers can follow the production journey of each product for processes and factories on the website.

Founded 27 years ago, *People Tree* has become one of the most recognized sustainable fashion brands. It was the first to achieve Global Organic Textile Standard certification on a supply chain for organic cotton from farm to final product. It claims that the majority of their cotton certified organic and *Fairtrade* and all clothes are dyed using non-hazardous and azo-free dyes. It sources as many products as possible locally, chooses natural and recycled products, weaves fabric by hand and ships products by sea to reduce impacts on the planet.

Reformation, a startup based in Los Angeles, has gained much attention for its spirit of sustainability since its first pop-up store launched to sell upcycled vintage clothing in 2009. It aims to offer accessible, sexy and sustainable fashion to everyone. In a very short period, *Reformation* has built 8 stores across the US and an international website. It purchases deadstock fabrics and vintage clothing accounting for 10 per cent and 5 per cent respectively of its collections. It uses cellulosic fibers such as Tencel, Viscose and *Refibra* for lifecycle reasons. It also runs its own free, garment recycling initiative *Recycling*, and reports the transparent environmental impact of its products through *RefScale*. Besides, it established a sustainable sewing factory in Los Angeles with about 500 workers, and controls the factory waste, water and chemical and recycling in a vertical way.

3.3 Sustainable business initiatives

Based on the successful experiences of sustainability in the fashion industry, six sustainable business initiatives are proposed for reference, including 4Rs - Reuse, Recycle, Reduce and Replace to close the loop across the supply chain and promoting ethical practices and community engagement.



3.3.1 Reuse

Prolonging the lifetime of each apparel product is the key approach to lower a product carbon footprint. Fashion designers can set circular consuming plans before each product is designed; the manufacturers should be dedicated to producing products in higher quality for a longer lifetime, and the retailers should encourage conscious consumption and continuing usage of used products and guide their customers to send the discarded clothing and footwear to certified collection points. In this way, a more sustainable circular system can be gradually established from the beginning till the end of a product life cycle.

3.3.2 Recycle

When the lifetime of a fashion product ends, recycling is the first choice for sustainability, while landfill and incineration should be the last choice due to their negative impact on the environment. Fashion brands have been urged to use more recyclable materials for product development and create effective methods to recycle worn products at least those from their own brands. A more transparent supply chain with traceable sources from materials to manufacturing as well as certification standards will be necessary for circularity.

3.3.3 Reduce

To reduce the environmental impacts, manufacturers are recommended to increase use efficiency of resources such as water and energy, to improve technologies and processes for lower carbon footprints and gaseous emissions, and to reduce hazardous materials and processing. Clean production is the crucial target for the fashion industry.

3.3.4 Replace

To achieve fashion arts with a sustainable focus, more and more brands seek alternative materials to replace traditional yet considered unsustainable ones and improved technologies to enhance the polluting processing. For example, Stella McCartney's bio-synthetic materials replacing plastics, and Adidas's waterless dyeing and bio-dyeing replacing the traditional chemical dyeing processes.

3.3.5 Ethical practices

Ethical practices are highly recommended across the entire supply chain to ensure fashion products produced under safe, humane, fair and legal conditions.

3.3.6 Community engagement

Community engagement is a common strategy taken by many sustainable fashion pioneers. Some fashion brands establish organizations to proactively guide and accelerate their own sustainable development goals; some others work with a charity or ecological groups and donate funds for better socio-environment initiatives, and several of them even participate in global activities to help to solve environmental crises together with their customers.

4. The outlook for Hong Kong Fashion Industry

4.1 Overview of HK fashion industry

The textile sector of the Hong Kong fashion industry had 446 manufacturing establishments with 2,569 workers in total till March 2017, covering the spinning, weaving, knitting and finishing sectors[59]. After a decline of 13% in 2016, Hong Kong's textile export decreased further by 7% in the first five months in 2017[60]. Re-exports has been dominating with more than 99% of the total exports of textile goods. The majority of the textile sector focuses on a high value-added section of the supply chain, including retailing and marketing, design and product development and quality control, with manufacturing almost totally depends on offshore factories. More and more Hong Kong's manufacturers relocate their factories to Vietnam, Cambodia, Myanmar and Bangladesh, due to higher labor costs, stringent environmental regulations and the recent uncertainty of US trading in the Mainland China.

[59] http://hong-kong-economy-research.hktdc.com/business-news/article/Hong-Kong-Industry-Profiles/Textiles-Industry-in-Hong-Kong/hkip/en/1/1X000000/1X0040EM.htm [29-08-2018]
[60] https://www.textiletoday.com.bd/hong-kongs-declining-textile-clothing-business-revitalized/ [29-08-2018]

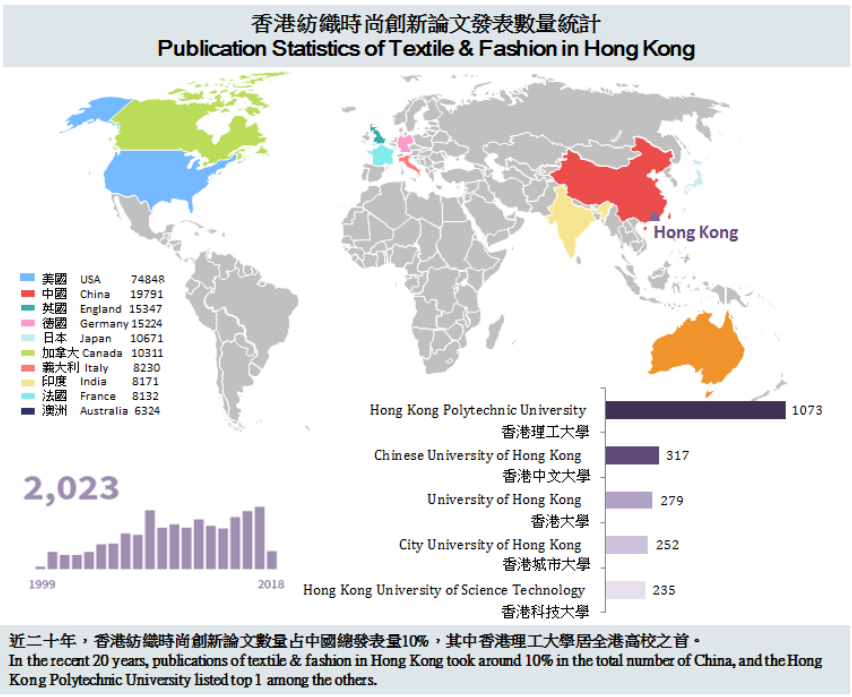
The clothing sector of the local fashion industry, the fourth largest manufacturing employer in Hong Kong, had 657 establishments and 4,763 workers till March 2017[61]. Hong Kong's total export of clothing dropped by 10% year-on-year in the first five months of 2017, after a 15% decline in 2016[62]. Hong Kong's clothing manufacturers have good competence in sourcing and products, and the exporters have good knowledge of international and national rules and regulations. Some of the local manufacturers have established their brands and run retailing business globally. Besides, Hong Kong, as a global sourcing hub in Asia, also attracts international trading houses, major retailers and premium designer labels to conduct their sourcing activities.

4.2 Innovation of HK fashion industry

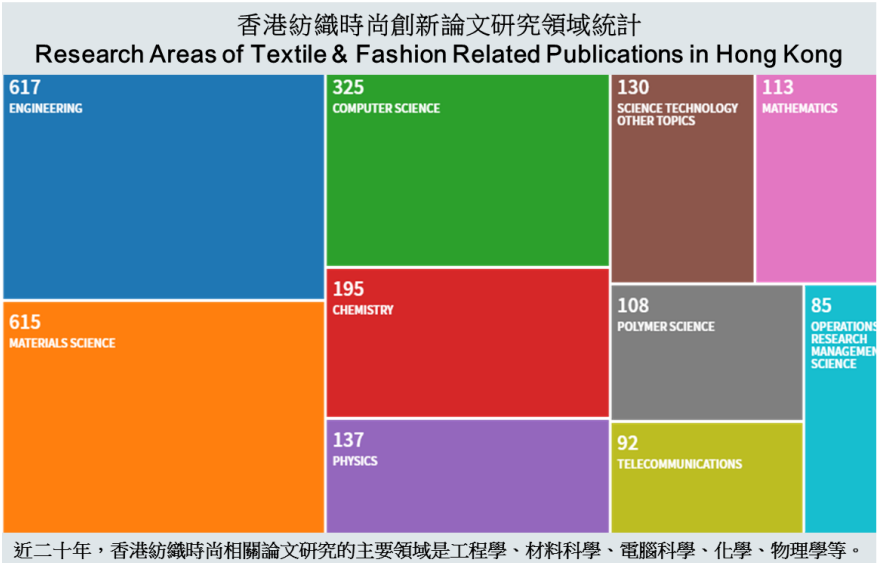
The research innovation power of Hong Kong fashion products has been recognized as one of the best in the world. According to the published statistics from Web of Science Core Collection[63], USA, China, England, Germany and Japan listed the top five in the field of textile and fashion in the recent 20 years. In terms of scientific publications, Hong Kong contributes around 10 per cent to the total number of that of China, publishing 2,023 papers from 1999 to 2018 with a relatively stable increasing trend after a decline in 2009. The Hong Kong Polytechnic University published the most, three times the number of the second-placed Chinese University of Hong Kong.

[61]https://www.fashionatingworld.com/new1-2/tough-times-for-hong-kong-clothing-sector-with-global-competition [29-08-2018]
[62]https://www.textiletoday.com.bd/hong-kongs-declining-textile-clothing-business-revitalized/ [31-08-2018]
[63] https://clarivate.com/products/web-of-science/web-science-form/web-science-core-collection/ [07-06-2018]

The research areas of the publications in Hong Kong included engineering, materials science, computer science, chemistry and physics.

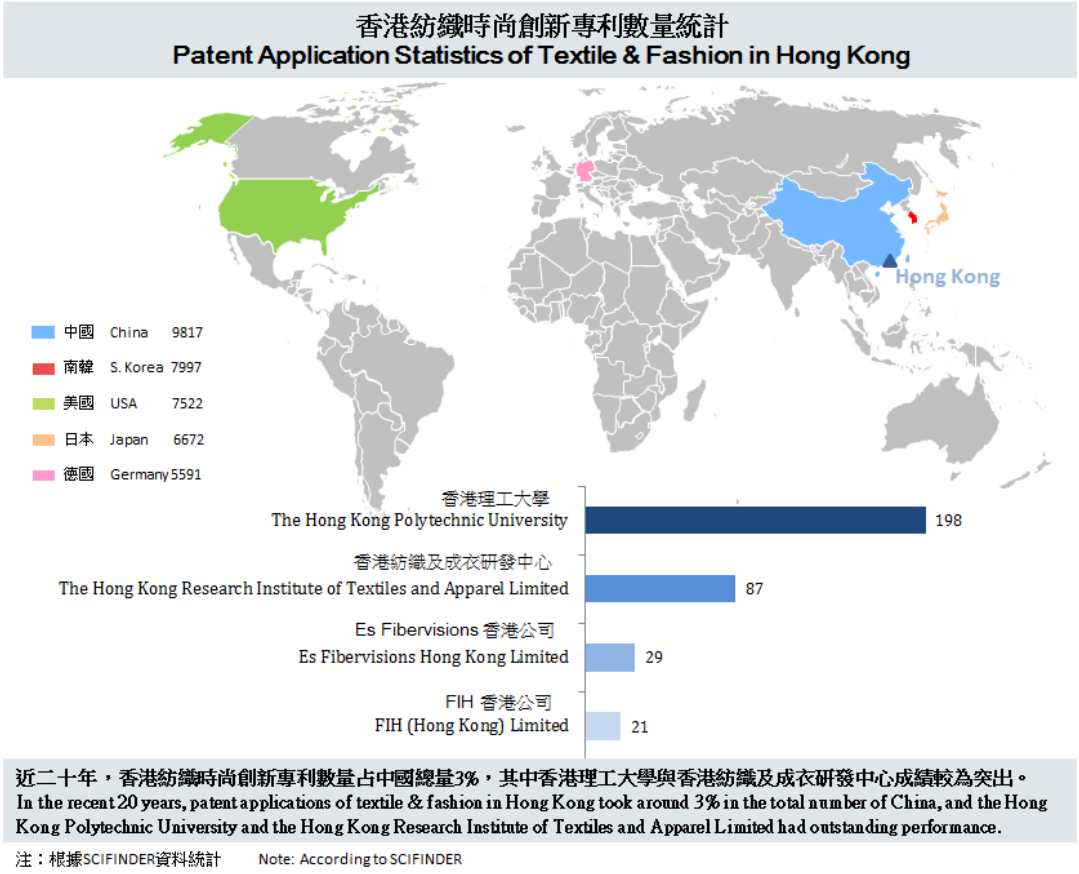


注：根據Web of Science核心合集資料統計 Note: According to Web of Science Core Collection



注：根據Web of Science核心合集資料統計 Note: According to Web of Science Core Collection

In terms of patent application in textile and clothing, China, South Korea, USA, Japan and Germany are the top five countries from 1999 to 2018, with Hong Kong sharing around 3% in that of the application number of Mainland China. The Hong Kong Polytechnic University and The Hong Kong Research Institute of Textiles and Apparel are the major contributors to the patent applications.



近二十年，香港紡織時尚創新專利數量占中國總量3%，其中香港理工大學與香港紡織及成衣研發中心成績較為突出。
In the recent 20 years, patent applications of textile & fashion in Hong Kong took around 3% in the total number of China, and the Hong Kong Polytechnic University and the Hong Kong Research Institute of Textiles and Apparel Limited had outstanding performance.

注：根據SCIFINDER資料統計　Note: According to SCIFINDER

4.3 E-Commerce of HK fashion industry

According to *Euromonitor International*, the total sales value of internet retailing in Hong Kong reached to 13.7 billion in 2016 with a 15% annual growth rate, in which the sector "apparel and footwear", amounted to 1.5 billion, or around 11 per cent of the total value. Up to 2021, apparel and footwear are expected to see an annual growth rate of 4%. Compared with some other regions like Mainland

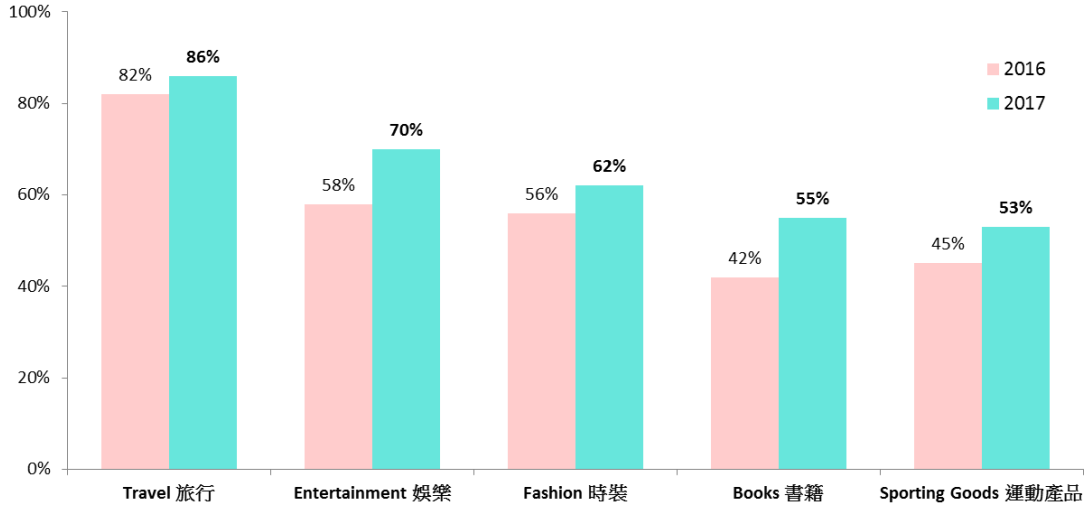
China, USA and UK, the pace of development in e-commerce business is not considered impressive in Hong Kong.

The unique features of the Hong Kong market that lead to the tepid development of local e-commerce in the past five years include but not limited to the following:

1. The local market is relatively small, and the merchants prefer to develop e-commerce business in larger markets for higher profits;
2. Hong Kong is a free port and the local residents can easily buy products from different online shopping platforms or social media platforms around the world;
3. A key barrier for e-commerce business model is last-mile delivery in Hong Kong. The failure rate of first-time home delivery is high, and there is still a lack of effective solutions to deal with the warehousing problems;
4. Compared to Mainland China and USA, the acceptance of electronic payment and mobile wallets are relatively low in Hong Kong. The traditional payment culture slows down the development pace of e-commerce to a certain degree.

A research on consumer behaviors of online shopping in Hong Kong was conducted by KPMG and GS1. Some important data and information have been analyzed in the following section.

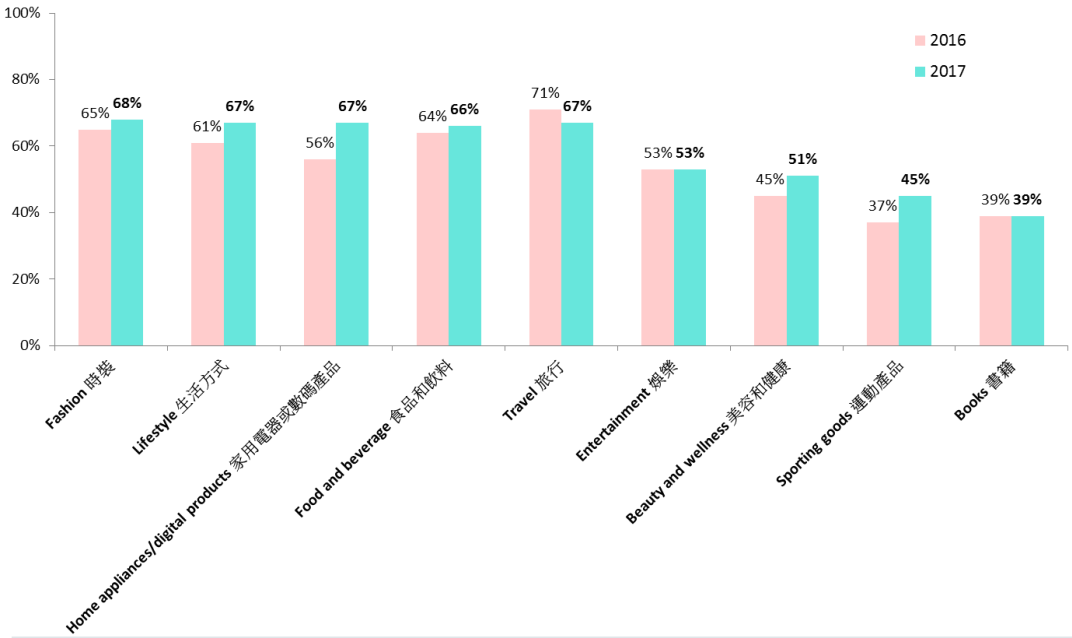
最近12個月網上購物類別統計
Online shopping category in the last 12 months



2016-2017年香港網上購物類別中，時裝排第三位，2017年較2016年增長6%。
Fashion listed No.3 in the online shopping category in both 2016 and 2017, with an increase of 6%.

注：根據KPMG and GS1 調查統計 Note: According to KPMG and GS1 Survey analysis

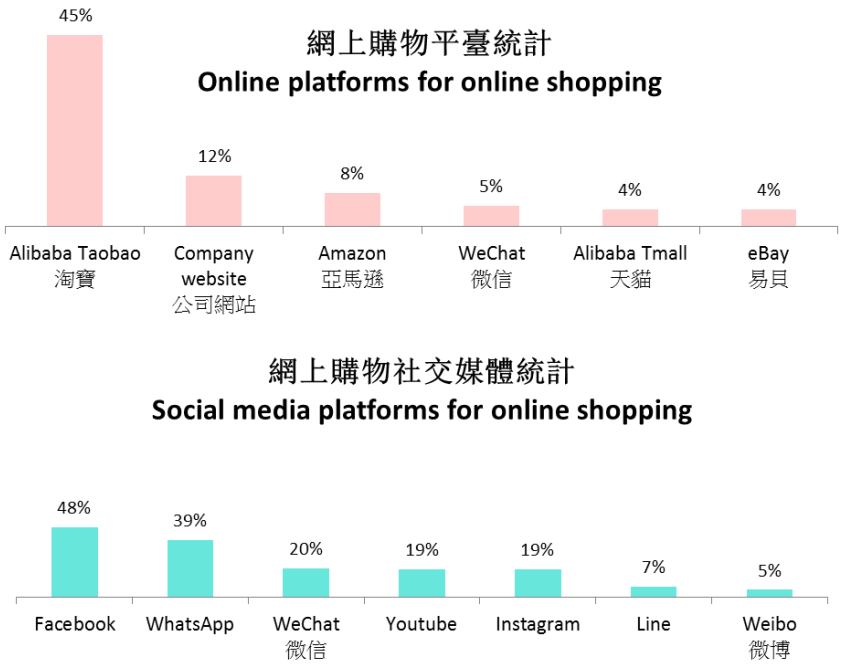
未來兩年網上購物類別統計
The most likely online shopping category for the next two years



調查發現未來兩年香港最可能網上購物類別中，時裝从2016年第二位跃居到2017年第一位，2017年較2016年增長3%。
Fashion listed the first place in the most likely online shopping category for the next two years in 2017, with an increase of 3% compared with 2016.

注：根據KPMG and GS1 調查統計 Note: According to KPMG and GS1 Survey analysis

香港網上購物平臺及社交媒體統計
Online platforms and social media for online shopping in Hong Kong



據2017年調查發現香港人網購平臺第一位是淘寶，其次是各公司網站及亞馬遜等；購物社交媒體包括Facebook, WhatsApp, 微信, YouTube及Instagram等。
According to 2017 statistics, online shopping platforms in Hong Kong included Taobao, company websites and Amazon etc., and the most used social media included Facebook, WhatsApp, WeChat, YouTube and Instagram etc.

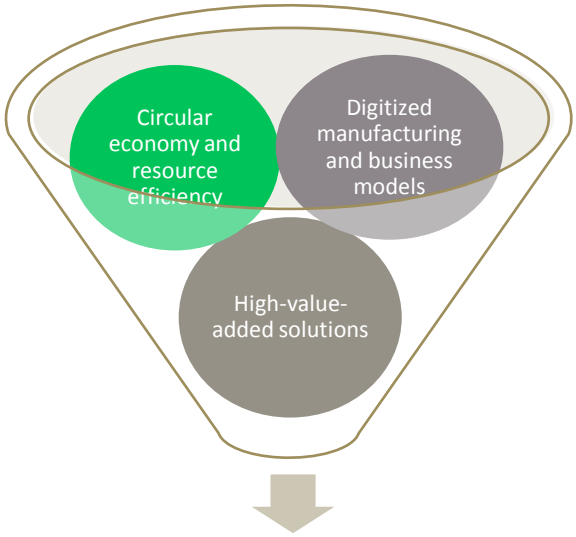
注：根據KPMG and GS1 調查統計 Note: According to KPMG and GS1 Survey analysis

5. Conclusions

Using a SWOT analysis, the internal factors (strengths and weaknesses) and the external factors (opportunities and threats) are identified for setting possible strategies for the reindustrialization of HK SME fashion industry. A comprehensive analysis is outlined in the following table.

	STRENGTHS (S)	WEAKNESSES (W)
Internal Factors / External Factors	1. Traditional manufacturers 2. High-quality products 3. Good industry reputation 4. Great trading environment 5. Convenient financial transfer 6. Strong speciality in sourcing 7. Convenient connection with manufacturing bases in Guangdong and SE Asia 8. Speciality in design and product development 9. Strong education resources 10. Rich blend of cultures	1. Weak manufacturing base 2. Fragmented supply chains 3. High cost for land use 4. High labor cost 5. Shortage of skilled workers 6. Weak innovation transfer 7. Weak E-commerce culture 8. Lack of policy supports 9. Lack of supporting infrastructures 10. Lack of collaboration platform
OPPORTUNITIES (O)	**SO STRATEGY**	**WO STRATEGY**
1. Expanded global market 2. Global supply chain 3. Increase of ageing population 4. Awareness of personal care 5. Interdisciplinary technology development 6. Development of digital automation 7. Opportunities in e-commerce 8. Opportunities in new retail technology 9. Opportunities in eco-friendly materials and technologies	Increase internal strengths and seize external opportunities - Develop a high-end market - Take advantage of HK's trading environment - Upgrade sourcing speciality and adapt new business mode - Develop a digital platform for design and product development in HK - Exploit HK's good reputation for ecological products	Seize external opportunities and overcome internal weaknesses - Establish digital supply chains - Take advantage of the latest e-commerce and retailing technologies - Take advantage of automation - Set up a public technology platform for innovation transfer - Introduce new job positions of the novel industry development
THREATS (T)	**ST STRATEGY**	**WT STRATEGY**
1. Changing trading policies 2. Unstable political environment in some manufacturing countries 3. Increasing the price of traditional raw materials 4. Increasing labor cost in traditional textile countries 5. Poor image of the industry 6. Threats for traditional brick and mortar business models 7. Dominance of fast fashion 8. Stringent environmental rules and regulations	Exploit internal strengths and reduce external threats - Exploit HK's strength to adapt to the global changing trading environment - Develop high added value products - Establish local sourcing and product development hubs - Explore new business models - Participate in eco-friendly markets	Minimize internal weaknesses and face external threats - Find out the niche markets - Develop e-retailing - Rebuild the industrial image to HK's new generation - Encourage collaboration and establish industry clusters - Take advantage of industrial associations for fast-react to different situations

Combining findings of this analysis with the global technology trend of the fashion industry, it is perceived that the most promising strategies for HK SMEs are in three main directions, namely; a) digitized manufacturing and business models, b) circular economy and resource efficiency, and c) high-value-added solutions.



In order to successfully realize and accomplish the strategic directions, steps must be taken to first comprehend the technology requirements and the corresponding improvements to be made by the HK fashion industry. A Technology Roadmap outlining such steps has been drafted based on further analysis of four key critical success factors, including 1) market drivers for each direction, 2) product/service to be offered in each direction, 3) technology required to meeting the changing market needs, and 4) research and developmental work required in future. Details of the analysis and the Technology Roadmap are presented in the Recommendation Report.

PRACTICAL HANDBOOK

A Re-industrialization Roadmap for Hong Kong SMEs of the Textile and Fashion Industry

Published in October 2018

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