Sustainable Business Development Through Designing Approaches for Fashion Value Chains

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Abstract Global fashion value chains are expanding rapidly, driven by forces of globalization. Large-scale outsourcing has led to long lead times and forecast-driven apparel value chains, resulting in increased forecasting errors and over-production-related difficulties. Typically, in the developed countries in Europe, United States, and Japan, we see the emergence of strong fashion brands as core manufacturing has faded from the scene, leading to several other challenges related to sharing responsibility in the value chain, unsustainable consumption, etc. This has a lasting impact on the key financial performance of the fashion brands along with the detrimental environmental and social impacts, thus challenging the right balance of the strategic vectors for sustainable business development (SBD) in fashion value chains. Various stakeholders have realized that the future of fashion value chains increasingly depend not only on economic sustainability but also on safeguarding the environment, safety, and welfare of those associated with it. In this context, the work addresses these strategic issues motivating the sustainable design of closed-loop fashion value chain to propose a holistic model towards developing a design for sustainable business development (DfSBD).

Keywords Business development · Design for sustainability · Fashion and apparel · Sustainability

1 Introduction

Sustainable business development (SBD) is a compelling requirement in global fashion value chains, given the market turbulences in the form of current fierce competition and globalization trends, intensive pressure on resources, higher

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S. S. Muthu (ed.), *Roadmap to Sustainable Textiles and Clothing*,
Textile Science and Clothing Technology, DOI: 10.1007/978-981-287-110-7_9,

consumer expectations and awareness, etc. [16, 36]. In the case of fashion value chains, large-scale outsourcing of manufacturing from the developed countries in Europe, United States, and Japan to low-cost bases has led to long lead times and forecast-driven apparel value chains, resulting in increased forecasting errors, mark downs, and lost sales [11, 50]. Chasing a lower cost of production has resulted in an excess of inventory, more discounted merchandise, greater consumer dissatisfaction because of lost sales, and ultimately reduced profits [39, 47]. Estimates are that the amount of merchandise sold at mark-down has grown to over 33 %, while only about one in three customers are able to find their first SKU[1] preference [29, 50]. This has certainly challenged the economic viability of fashion businesses.

In contrast to this, the current industrial system of fashion business is based on extremely fast cycles along with technological advancements, delocalization of manufacturing to lower-cost countries, and consumers' unsustainable desire, resulting in today's value chains predominantly becoming buyer-driven in nature [61]. Such value chains operate by enforcing operational strategies similar to agile manufacturing, lean production, and business process reengineering [36]. Quick response (QR) has been a strategy implemented since the 1980s by major fashion retailers along their apparel pipeline to operate more efficiently and continually meet changing requirements of a competitive marketplace which promotes responsiveness to consumer demand; encouraging business relationships and reliability towards building of resilient value chain [11, 13] by making effective use of resources and shortening the business cycle throughout the supply chain pipeline [63]. For 'seasonal' fashion (fast fashion products), QR management has become essential for fashion companies with multi-season assortments, especially during the re-ordering process by using various QR tools such as bar codes, point-of-sale (POS) data, electronic data interchange (EDI), etc. (cf. QR Practicability Tool-kit in Pal [63]). Even though appropriate implementation and execution of QR strategies has been quite able to solve the problems related to the declining retail performance measures of fashion businesses, other consequences have eventually emerged, related to conformation of the current 'fast' fashion industrial system. Over the last decade, consumers have been conditioned to low-cost changing styles with the fast cycles of fashion trends, continuous new customer needs, shortened product life cycles (a study by Procter and Gamble shows that the life cycles of consumer products have dropped by 50 % between 1992 and 2002 [81]), and increasing pace of planned obsolescence. This has taken its toll in terms of lower product quality and short-term durability, hence increasing textile wastes in various forms and thus causing phenomenal environmental burden [61]. Consumption level has also increased substantially; in a recent survey conducted by Deloitte, it was found that global fiber consumption has reached nearly 12 kg per capita while the average for the Nordic region is 16 kg per capita. On average, 16 kg of clothes is equivalent to 16 pairs of jeans or 64 T-shirts; typically 16 pairs

[1] Stock Keeping Unit.

of jeans requires 58,000 L of water, 48 kg of chemicals, 6,400 MJ of energy, and 208 m^2 area of harvested land[2] [18]. Global Footprint Network 2013[3] measures show that the ecological footprint of production and consumption in terms of the Earth's capacity to regenerate natural resources has increased from less than 0.5 in 1960 to 1.5 Earths currently, and by 2050 we will need 2.3 Earths. Overall, continuing business as usual (BAU) would result in severe resource scarcity, high volatility in resource prices as shown in Fig. 1, and hence threaten the profits and success of fashion industry's business models.

Thus, today the fashion apparel industry is locked in competition for higher profitability amidst downturns in the global economy, facing sustainability challenges and consumer uncertainty. Eventually, the notion of SBD has broadened from just the economic perspective to include the social and environmental dynamics as well. Established international fashion brands such as PUMA, H&M, Marimekko, etc., have all adopted "green" practices in their supply chain. H&M, for example, has joined the sustainable apparel coalition (SAC)[4] in an attempt to reduce the environmental and social impacts of its apparel and footwear products around the world. PUMA, on the other hand, has published an Environmental Profit and Loss statement (in 2012) for calculating the environmental impact for greenhouse gas emissions, water use, land use, air pollution and wastes up to tier four suppliers for PUMA—expected to be circulated to all PPR group members, including brands such as Gucci, Alexander McQueen, and YSL, by 2015 [18].

Despite the acknowledged relevance of designing sustainability along the pillars of "triple bottom line" approach [20] implementation and tackling of these sustainability issues have not been at the forefront; however this is increasing steadily. Even though the green international brands (GIB) have shown different ways to manage sustainability in the supply chain [in terms of managing supplier's code of conduct (CoC), supplier assessment, and corporate social responsibility (CSR) contract amendments] they are still quite poor in engaging with the local networks [18]. Caniato et al. [5] have defined these GIBs as well-established international corporations which have directed themselves towards environmental sustainability through incremental changes in their traditional business models and supply chain structure, such as that of Patagonia—an American outdoor clothing company (also presented by Chouinard and Brown [9], Napapjiri—an Italian

[2] Water consumption during production depends on the need for irrigation: 576–4,377 L/kg with an average of 1,818 L/kg and for finishing 105–145 L/kg (cf. Chapagrain et al. 2005; Blackburn and Burkinshaw 2002) quoted in DEFRA 2010. For chemicals cf. 'Mapping Chemicals in Textiles', Danish Environment Protection Agency, Publication no. 113, 2011. Water and energy consumption during production, manufacturing and for care cf. Levi's LCA for Levi's 501 Jeans Levi's 2010:(http://www.levistrauss.com/sites/default/files/librarydocument/2010/4/Product_Lifecyle_Assessment.pdf) Land use based on Global Cotton Yield 2011/2012 of 752 kg/hectare, cf. Agricultural Outlook Forum 2012, February 2012.

[3] http://www.footprintnetwork.org/en/index.php/GFN/ (February 2014).

[4] http://www.apparelcoalition.org/

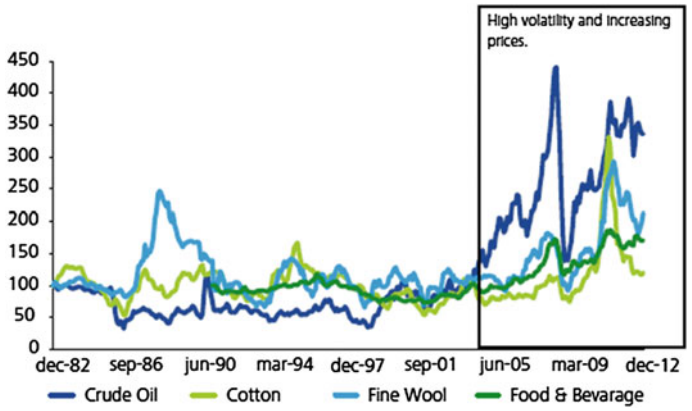

Fig. 1 Price development for crude oil, cotton, fine wool, and food and beverage (1982 index = 100). *Source* indexMundi 2013. http://www.indexmundi.com/ (February 2014)

sportswear company, Nike, etc. These companies have made incremental changes in their organizations persuading suppliers to respond better to the environmental criteria; however, they have not completely revised their inbound supply chain. GIBs are mostly concerned with a wide set of key performance indicators (KPIs) (for measuring water pollution, energy consumption, etc.) by setting up green performance management systems and certifications.

On the other hand, new alternative approaches are provided by small and medium enterprises, known as small alternative firms (SAFs) [5]. These firms aim at finding new ways of competition in the marketplace by redirecting their vision from being small manufacturing firms driven by cost effectiveness towards being branded manufacturers integrating forward in the value chain to reach directly to the final consumers. SAFs are in direct control of their production processes and, hence, are able to influence the product and process design activities to impact the environmental performance strongly through investments in greener processes. As well as redesigning the external value chain architecture, these firms are also able to foster sustainability internally in their respective value chains. It is mainly the active wear brand manufacturers, for example, Astorflex—an Italian shoe company, Ali Organic Wear—an Italian underwear company, etc., which are able to reconfigure their traditional fashion business models by changing the value proposition and arrangement of the value constellation.

In this context, the next section first reviews the main challenges which hinder SBD in fashion supply chains. An impact of these typical fashion business challenges is investigated along the three sustainability pillars: economic growth, social equity, and respect for the environment. First, the chapter highlights and categorizes key issues challenging the sustainability of fashion businesses, in terms of supply and demand problems along with the potential mismatch between them. Then the impacts of these challenges are specified in terms of the three sustainability pillars.

The following section starts with a brief discussion on SBD, proposing the building blocks for designing SBD along the three-dimensional concurrent engineering (3-DCE) approach, viz. product-, process-, and supply chain-designing practices. The next section deals with a thorough discussion on SBD along various fashion value chain activities. The design for sustainable business development (DfSBD) framework as proposed in this work comprises design for sustainability (DfS) approaches along the processes of "Design and Product Development," "Sourcing and Production," "Distribution and Logistics," "Retail and Marketing," and "In Closed Loop." Finally, a concrete model for DfSBD along the 3-DCE pathways is hypothesized to operationalize the construct.

The research conducted has been purely deductive, proposing the SBD model and how to operationalize it along the 3-DCE pathways. Following the development of the framework, desk research is conducted to find relevant fashion business cases available on secondary data sources such as journals, trade and business magazines, blogs and reports, web pages, etc., to ascertain the proposition. A number of cases are used to highlight various proponents of DfSBD. Even though research on SBD has been active for around 10 years, the present viewpoint or lens of 3-DCE provided to design sustainable business development is fairly new and less explored. In this regard, the research aims to set up the platform for advancement in more established and detailed academic future research on this topic.

1.1 Challenges of Fashion Value Chains

The problems in fashion business practices can be summarized in four inclusive challenges, viz. (1) fashion logistics challenges, (2) challenges of overproduction, (3) challenges of irresponsible consumption, and (4) challenges of fulfilling social responsibility. These are explained briefly below.

1.1.1 Fashion Logistics Challenges

Long lead time from order placement by the fashion retailers till its delivery is the biggest challenge to efficient fashion logistics in a globalized setting, also referred as "the lead time gap" by Christopher et al. [10]. Typically, the lead time in case of traditional fashion value chains, with up-front buying based on seasonal forecasting and planning, can sometimes be as high as 8–9 months. In an investigation of the key performance measures of major European fashion retailers, it was found that traditional fashion companies (marked by traditional product designs and slow response) [4], such as Mango—a Spanish branded retailer, Lindex—a Swedish branded retailer, John Smedley—a UK-based retailer, had production lead times

up to as long as 26 weeks.[5] However, the majority of this time is non-value adding, contributed to by activities such as storage or transportation. In the 1980s the American consulting firm Kurt Salmon Associates conducted a supply chain analysis of the textile and apparel industry in the United States which revealed the average lead time from raw material to consumer was 66 weeks [47]. However, only 11 weeks were associated with manufacturing processes (value adding), while nearly 40 weeks were non-value adding waiting time in warehouses or in transit. The remaining 15 weeks were comprised of the shelf time in the store before the garments were purchased. In a similar study, Christopher and Peck [12] identified the processing time (value-added) and inventory time (non-value-added) for a knitwear garment. Out of the total lead time of 167 days, processing time was 57 days, while the waiting time or inventory time was calculated as 110 days.

Geographical spatiality (hence long lead times) in the fashion value chain necessitates long-range forecasts ahead of sales seasons [11]. This has severe negative impact on the financial performance of the companies caused by lack of forecasting accuracy leading to loss of revenue and profits, excess of inventory, and hence a large number of products which must eventually be sold at discounted prices, and risks customers not finding what they want in the shop [50]. Today, a 12-months lead time is quite common and it is estimated that it causes a sales forecast error of approximately 40 %; shortening the lead time to 9 months reduces this error to 23 %. Three months additional reduction of lead time from here reduces the error by only 4 % for each period of 3 months. Eventually, this means that even at the beginning of the sales period the forecast error is still 10 %. The economic impact of long lead times is discussed in Sect. 1.2 (cf. *The economic impact*). In addition, long lead times caused by the dramatic relocation of production sites towards the Far East have resulted in higher transportation costs, loss of employment in the manufacturing sector, and higher carbon footprints (even though transportation has a minor share of total energy consumption of 3–6 % of primary energy) [1]. Regarding transportation costs, the contribution is only a small part of the overall costs with shares between 4 % for European German producers and 7 % for the Chinese. However, the most critical impact is in terms of the decline in 'employability' in the manufacturing sector, with the textile and clothing industries having lost one-third of its jobs within 10 years, since 1996 [48].

1.1.2 Challenges of Overproduction Caused by Forecasting Error

Forecasting error has severe implications on sustainability along the three pillars. On average, fashion retailers only sell two-thirds of their seasonal fashion products

[5] KELANO (2010–2012) was a joint research project between Tampere University of Technology, Finland and The Swedish School of Textiles, University of Borås, Sweden aimed at finding an ecologically efficient, quick-response sourcing-production-distribution chain for fashion products.

at full price, while the rest has to be discounted [50]. Improving the retail performance measures by reducing lead times explains the method of improving response time in the fashion pipeline through development of QR—a business strategy to optimize the flow of information and merchandise between value chains members to maximize consumer satisfaction [43]. QR implementation by realizing various technologies, such as sharing POS information, EDI, electronic transmission of orders and invoices, computer-aided design (CAD), the use of computer technology and manufacturing, and electronic point of sale (EPoS), i.e., collecting sales information at the cash register from barcodes, etc., efficiently reduces safety stocks, avoids overproduction, and minimizes unsold merchandise [63]. Avoiding overproduction has substantial environmental impact, considering the fact that textile and apparel raw materials production are dominated by energy-intensive processes such as washing, drying, etc. Other major environmental impacts are also related to controlled use of toxic chemicals, release of chemicals in waste water, and generation of solid wastes [1] (further discussed in Sect. 1.3 (cf. *The environmental impact*). At the operational level it is crucial to take timely decisions on what to buy, what to move, and what to make, vital supply chain planning to counter demand uncertainty.

1.1.3 Challenges of Irresponsible Consumption

The high volatility and uncertainty in the demand pattern of fashion products resulting in increasing unsustainability cannot be totally blamed on the production system; consumers are equally irresponsible considering the fact that, on average, Europeans consume 15–16 kg of clothes every year, utilizing nearly 58,000 L of water, 48 kg of chemicals, 6,400 MJ of energy, and 208 m^2 of harvested land. This leaves substantial footprints on the Earth [18]. In a study by MISTRA,[6] the impacts of modern consumerism are along three phases: purchase, use and maintenance, and discarding. During the purchase phase the average Swede spends about 687 SEK per month, showing a significant gap between environmental and social awareness and actual purchase behavior. However, Guardian reports that nearly £1.6 bn of unused clothes are hanging in women's wardrobes annually.[7] In the use and maintenance phase, the use of washing machines, etc., is regular, while, despite the high awareness of environmental and social issues in the purchasing process, this awareness does not seem to translate into the discarding phase [38].

[6] http://www.mistrafuturefashion.com/en/Sidor/default.aspx

[7] http://www.theguardian.com/sustainable-business/fashion-rental-startup-rentez-vous (March 2014).

1.1.4 Challenges of Fulfilling Social Responsibility

The social issues of responsibility along the fashion value chains translate into the role of the fashion retailers in determining their CSR. This can be broken down into the three main areas of wages, working hours, and working conditions [66]. Fashion retailers have been accused of chasing cheap labor and, even though there are traditional monitoring methods such as codes of conduct and inspections in place, they have failed to pay their workers a living wage, have used child labor, have abused human rights, enforced minimum labor standards in the workplace, etc. [49]. Several ethical scandals have been reported in the supply chains of several global fashion retailers, including Zara, Gap, Nike and Marks & Spencer, in recent years. Awaysheh and Klassen [2], in this regard, have identified four broad categories of mechanisms aiming to encourage supplier to assume socially responsible practices: international standards, extended frameworks, supplier codes of conduct, and supplier social audits. However, the effectiveness of the buyer's responsibility to ensure compliance beyond first tier suppliers in an outsourced business model is questionable at present.

1.2 The Economic Impact

The challenges of 'lead time gap' and overproduction reflect on the financial performance of fashion companies in terms of their profitability, activity ratios, and retail measures. Lead times are traditionally long and buying decisions are often made 7–8 months prior to the start of the selling season. This leads to high forecast errors, resulting in sell-through just around 65 % and average mark-down of 35 %, as compared to replenishment sourcing error of just around 8 % [50]. In turn, this leads to low inventory turnover over the year, resulting in higher risk of obsolescence, higher mark-downs, and items being liquidated at clearance. Also, considering that the products are not sold at full price, the cost benefit is minimized as the cost incurred in terms of the factors of production is potentially huge (e.g., for just the UK clothing and textile industry the essential inputs in 2004 were: primary energy consumption—989,000 tons of oil equivalent, water consumption—90 million tons, etc.) [1]. This typically lowers the retail performance measures such as gross margin and gross margin return on inventory (GMROI).

1.3 The Environmental Impact

The textile and fashion industry is one of the biggest sources of greenhouse gas (GHG) emission, because of the huge size and scope of the industry as well as the many processes and products which go into the making of fashion products [24]

(also cf. Vivek Dev, "Carbon Footprint of Textiles"[8]). Based on the estimated annual global textile production of 60 billion kg of fabric, the estimated energy and water needed is at a mind boggling level of 1,074 billion KWh of electricity (or 132 million metric tons of coal) and 6–9 trillion L of water. Moreover, in terms of water consumption, it takes nearly 30,000 L to create 1 kg of cotton (1 cotton shirt uses approximately 2,700 L of water).[9] Along with this enormous stake in the natural capital (water, chemicals, energy, raw materials), outputs from the industry are rising all the time. In the UK alone, the clothing and textile waste is estimated to be the fastest growing waste stream between 2005 and 2010, amounting to 1.5–2 million tons annually [17]. CO_2 emission, waste water, and solid wastes were 31 million tons, 70 million tons, and 1.5 million tons (in UK—2008) [1]. In landfills this waste causes methane emissions to air and pollution to groundwater through toxic chemicals [30]. The increase in textile waste is a consequence of the increase in textile and clothing consumption, which saw a growth rate of 30 % in 1995–2005 in Britain [17], while in Finland Nurmela [62] estimated that the consumption of clothing and footwear will increase by 23 % from 2006 to 2010.

1.4 The Social Impact

The social impacts of fashion value chains are equally derogatory. For instance, there have been several "sweatshop" incidents revealed in the value chain of international fashion brands, such as Nike, Zara, H&M, and many others, while unfair wages have every now and then been a burning issue. Fashion businesses, over the decades, have strengthened their CSR but mostly using self-audits and own internal compliance teams to evaluate factories based on their company values and ranking system. Among other issues, this can threaten labor safety. Outsourcing injustices in apparel has caused fire and similar disasters.

1.5 Scope

In this context, the future of fashion businesses as far as long-term success is concerned depends on developing a holistic SBD model incorporating social and environmental profit formulas along with economic profits, as discussed and argued in the next section.

[8] http://www.domain-b.com/environment/20090403_carbon_footprint.html (March 2014).

[9] http://www.ethical.org.au/get-informed/issues/fashion-footprint/ (March 2014).

2 Sustainable Business Development

SBD is essential to achieve enhanced financial performance of organizations along with social and environmental objectives, thus balancing profit and planet. For fashion value chains—one of the most complex, 'dirty,' and demanding of all, in terms of fast clockspeed and product life cycle, process modularization, geographical dispersion, footprints, and stake in natural capital, consumer expectations, etc.—SBD has become a global theme for success or survival in recent times, amidst intensified competition, frequent natural, political and financial disruptions and turbulence, changes in government policies, increased society's expectations, and awareness of sustainability [36]. Various stakeholders have realized that the future of fashion value chains increasingly depends not only on economic sustainability but also on safeguarding the environment, safety and welfare of those associated with it. Notably, there have been several pieces of research and a number of articles have been published on identifying the building blocks of SBD, aiming for the creation of a framework. Gunasekaran and Spalanzani [36] enlist the literature (written between 2000 and 2010) on SBD based upon the major building blocks, and most certainly they include advancements in various business processes, such as product/process design and development, supply operations, production, distribution chain operations, and in remanufacturing, recycling, and reverse logistics, along the three sustainability pillars of economic, environmental, and social aspects. However, most studies have investigated these sustainability pillars, in terms of challenges and solutions, along a few supply chain pathways, e.g. Schoenherr [75] highlighted the influence of SBD in manufacturing plant operations. On the other hand, some research provided a more holistic picture of the entire value chain but along just one or two of the sustainability pillars, e.g., Caniato et al. [5] provided an analysis of fashion brands' value chain but only with regard to their environmental performances.

In this context, DfSBD demands a holistic overview of all the aspects which could possibly be 'designed' or configured along the entire value chain to attain sustainability in terms of the 'triple bottom line' approach. For this, it is necessary for researchers and, in practice, for all businesses to identify the building blocks of value chain, viz. products, processes, and supply chain. DfSBD should cover all aspects of product design, process design, and supply chain design along all the value chain operations, both independently and concurrently. This calls for looking into SBD through the lens of 3-DCE as discussed briefly in the next section (cf. *A holistic designing approach for SBD in fashion value chains*).

From the global value chains (GVCs) perspective, companies follow various business models depending on how their value proposition (in terms of a product/service and an associated customer), value constellation (through the company's internal and external value chain networks), and revenue architecture (profit equation based on sales revenue, cost structure, and capital employed) are organized to capture value for the customers [7, 83]. However, rising problems related to climate change, water shortage, industrial pollution, high-priced energy, etc.,

has compelled businesses to expand their classical business models and include a comprehensive ecosystem view, resulting in a fourth component or dimension defining business models, i.e., social and environmental profit equation [83]. Thus designing a sustainable business model should encompass a holistic approach as highlighted in Fig. 2.

3 A Holistic Designing Approach for SBD in Fashion Value Chains

Strategic adoption of independent or concurrent designing of products, processes, and supply chains is essential to develop sustainable competitive advantage in businesses [27]. These practices establish the designing aspects classified by 3DCE, by matching the supply chain design attributes to the product and process design requirements with an overall integration (early supplier involvement—ESI, concurrent engineering—CE, quality management, and customer involvement) to design improved financial performance [28, 67]. 3DCE essentially provides a holistic view towards understanding the intrinsic problems related to non-sustainable performance along all strategic vectors. However, the diagnosis of the functioning of an organization to determine the distinctive competencies through careful understanding and mapping along 3DCE has mostly been performed in measuring economic viability/sustainability [73]. However, the simultaneous design of product, process and supply chain have been proposed as a way to improve traditional new product development (NPD) outcomes, such as reduced time to market, lower costs, and improved customer acceptance [22]. Competitive priorities, such as improved quality, reduced lead time and time-to-market (TTM), delivery performance (speed), cost minimization, reduced relationship risk, improved product innovation, etc., are also considered as measurement characteristics to determine organizational performance together with all three sustainability pillars [76].

3.1 Product Designing

Product designing encompasses all the decisions related to the product's features, such as the choice of materials, development of the product's components, and the design of the packaging [22]. As for any other product, such as textiles and fashion apparel, designing is determined by new product technology, better functionality new material and model—which ultimately lead to enhanced brand value; this leads to better development of the critical success factors (CSFs) and economic profit. In a study of Swedish clothing firms, it was observed that firms with higher level of product innovation in terms of product designs, product models, new

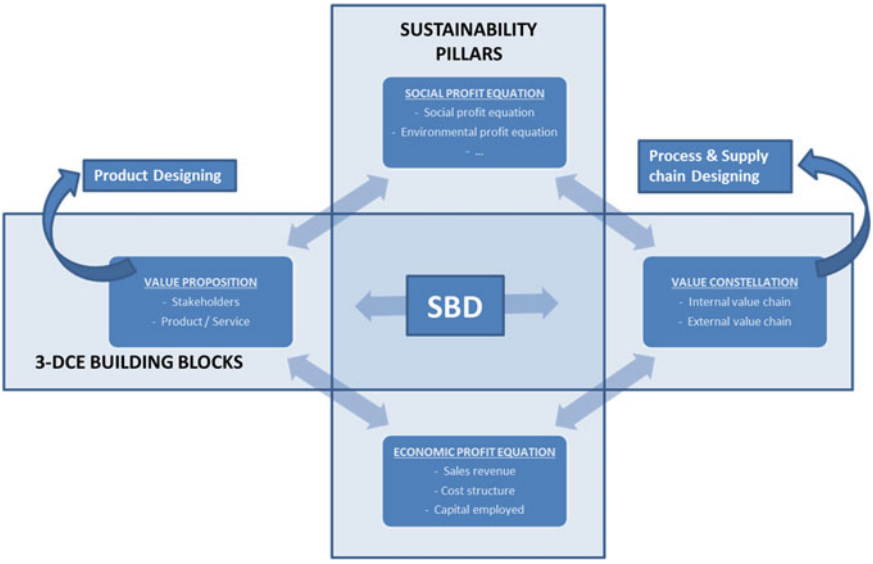

Fig. 2 SBD model

technology, functionality or brand value had higher profits than firms with lower product innovation [64]. Designing aspects related to product variety–volume relationship and portfolio are also crucial to create product development (PD) capabilities such as modularized products [27], better product performance and quality, cost minimization, and higher productivity (through economies of scale), higher product–volume flexibility, and higher service level (through product customization), contributing towards better financial success drivers [64].

In the case of fashion companies, product designing and development generally start with inspiration for the coming season's collection through close monitoring of fashion shows and trends, inspirations from other industries, etc. Following the initiation stage, team meetings and range plans are organized by design managers, designers, representatives from the marketing department, purchase and sales departments to discuss the core brand values, collection details (themes, size and materials, type), philosophy, etc. At this stage, the design team takes a key role in choosing the key materials and shapes for the collection. Corporate values and inspiration from top management, complemented by a radical mindset among the designers, play a critical role in determining the choice of raw materials, product recyclability, hazardous chemical content, etc., with implications on social and environmental profit formulas of the business. Product design strategies during the design and PD stages should focus on extending the product life span, customer satisfaction, and product intimacy, and finally involve the customer in co-designing in an open innovation platform [61]. Such product design practices are also critical in the manufacturing and packaging operations in terms of choice of

new eco-friendly or recyclable material, or sustainable packaging, etc. [5] and have a significant role to play in moderating SBD in fashion value chains along the attributes highlighted in Table 1.

3.2 Process Designing

Process design includes the design of production processes from raw materials to the finished product. Designing processes is also key for the foundation of 3-DCE, focusing on management, methods, facilities and equipment, technology and operations used for supply source-make-store and distribute-sell processes [27, 71]. Attributes of process designing include process innovation, identifying and improving process capabilities (through value addition, quality improvement, higher responsiveness, cost efficiency, higher productivity, etc.), higher process engagement, and faster rate of process development [64]. In a study of Swedish textile and clothing firms in Pal and Torstensson [64], companies with increased process engagement showed higher profit, suggesting that higher degrees of process control are significantly important in improving operational, and hence financial, viability. Process innovation is another crucial criterion for process designing to match innovative products and supply chains. Caniato et al. [5] highlighted the requirement of designing clean production processes, low energy consumption operations and facilities, etc., to ensure sustainability along all strategic vectors as well (cf. Table 1).

3.3 Supply Chain Designing

Supply chain design considers the aspects of sourcing decisions, contracting decisions (type of relationship an organization has with other members), make–buy decisions (insourcing or outsourcing), coordination decisions (logistical channels, suppliers, and customers) [8, 64, 65].

Supply chain design innovations through delivering ‘new’ ways for make/buy decisions, enhanced sourcing, and coordination decisions significantly enhance customer–supplier information exchange for ensuring systemic integration [21, 44]. Findings of the study by Pal and Torstensson [64] showed that higher supply chain innovations in terms of sourcing decisions result in higher flexibility in the value chain while higher coordination and trust are developed through enhanced decision making and increased coordination decisions. Sourcing and contracting decisions were also instrumental in controlling the success factors, viz. product quality, lead time, cost minimization, service level, and information sharing among partners. A properly integrated supply chain is essential to optimize the inventory level and hence cost tied up with stock keeping and maintenance, improve demand visibility and hence forecasting accuracy, supplier/customer

Table 1 Product, process, and supply chain designing practices. Based on Caniato et al. [5] and Pal and Torstensson [64]

Contributing directly to economic profit	Contributing directly to social and environmental profit
Product designing practices	
• Variety-volume portfolio (local production vs. customization)	• Natural raw materials (through local suppliers), e.g., organic cotton through fair trade suppliers
• Product life cycle and quality enhancement	• Sustainable packaging
• Product innovations and new product development (NPD)—degrees and rate	• Recyclable products (multiple life cycles) • Product life cycle enhancement (multiple life cycles, modularity, slow fashion)
• Brand value, technology and functionality (slow fashion, co-creation, etc.)	• Low chemical/hazardous substances
Process designing practices	
• Process development and innovations—eco-friendly cleaner process, flexible/agile manufacturing	• Low energy and raw material consumption facilities and processes
• Process system capabilities (value addition, quality, responsiveness, cost efficiency, innovation) (fast fashion, QR, etc.)	• Cleaner production and transportation • Collection and recycling of disposable products
Supply chain designing practices	
• Focus on collaboration, cost minimization, QR, quality functions, flexibility and coordination, social and environmental concerns	• Control over supplier through environmental certifications; code of conduct; development programs; green projects with suppliers
• Coordination decision/logistics; supply chain partnership and integration • Differentiated supply chain strategies	• Logistics integration through transports optimization; short supply chain and local production network; reverse logistics; fair trade for raw materials

relationship and coordination, increased responsiveness and agility, hence economic sustainability [64].

Along the other strategic vectors of sustainability, supply chain designing through efficient involvement of supplier and subcontractor (using code of conducts, certified suppliers, etc.), optimized transportation and logistics, green supply chain management (GSCM) practices, etc., have considerable impact [5] (cf. Table 1).

4 Sustainable Business Development Along Various Value Chain Activities

Fashion value chains are increasingly plagued by lower performance measures in a world of higher demand uncertainty. For development of sustainable businesses it is necessary to achieve an optimum balance between environmental protection,

economic prosperity, and social equity [36]. Clark [14] has emphasized that about 30–80 % of the environmental impact of a product and/or service originates at the design stage. Hence the potential for maximum intervention lies at the design stage to develop an effective approach towards SBD. Maxwell and van der Vorst [51]'s model of sustainable product and service development (SPSD) provides an essential way to products/services more sustainable throughout their life cycle considering the traditional product parameters such as quality, market, technical and cost issues. Furthermore, collaborative planning, forecasting and replenishment (CPFR) can be uses as a tool to improve subsequently the supply chain effectiveness for demand planning, synchronized production scheduling, logistics planning, and new product design. Such supply chain designing approaches essentially lead to SBD by redesigning various business processes such as product development, manufacturing, distribution, retailing, and consumer use. A detailed discussion on how DfS is and can be integrated further into fashion value chains along all the business processes is discussed in the following sections.

4.1 Design for Sustainability in Design and Product Development

Sustainable product design initiatives, such as ecologically intelligent design, product re-manufacture and reuse strategies, recycling and material transformation strategies, green product design, etc., are essential to reduce the stake on the natural capital (water, chemicals, energy, raw materials) [32]. At the same time, they increase the economic benefits of the organizations as well. Simon [78] classifies DfS around two distinct clusters, as "techno-centric design" (weak in sustainability) and "eco-centric design" (strong in sustainability) [31].

For leveraging the key strategic role of sustainable product design (also called environmental design, environmentally sustainable design, environmentally-conscious design, green design, etc.) there is a need for the fashion industry to:

- Comply with the principles of economic, social and ecological sustainability
- Eliminate negative environmental impact completely through skillful, sensitive design
- Reduce use and impact of non-renewable resources on the environment
- Use more recycled and reusable materials
- Relate people with the natural environment.

One way the fashion industry strives to do this is by using life cycle assessment (LCA), which quantifies the impact of everything which happens to make and use clothing, including raw materials extraction and production, manufacturing, product packaging and transport, use, maintenance, and disposal or recycling. For example, a high-impact item that can be worn often and kept for a long time may represent a lesser environmental investment than a low-impact item worn once or

twice for a short fashion cycle. Brands and manufacturers can use the results of LCA to identify areas of environmental impact or risk, optimize product design and processes, and communicate their business and product impacts. Global international brands such as Levi's and Nike have both developed their own eco-matrices for key product areas in order to be more transparent [31].

In this context, another "eco-centric" product designing approach which has gained prominence has been related to the development and implementation of a new sustainable apparel design and production model, called cradle to cradle apparel design (C2CAD) method. The C2CAD model has been developed by integrating the cradle-to-cradle thinking/approach introduced in McDonough and Braungart [53]. Following the C2CAD model, a project funded by the US Environmental Protection Agency under a STAR Research Assistance Agreement was organized to develop a "four-season sustainability" children's knitwear prototype [33]. The C2C design approach has been successfully applied by some textile product manufacturers such as Nike, Designtex, and Shaw Industries [53].

Designtex,[10] for instance, has followed this design principle [McDonough Braungart Design Chemistry (MBDC)] of "waste = food" to develop more environmentally friendly fabrics for compostable upholstery. This ensures the effects of sound product designing for environmental sustainability. Apparently, in a study by Niinimäki and Hassi [61], nearly 80 % of the consumers when interviewed were interested in the concept of slow fashion (marked by long-lifetime, repairability and having multiple life cycles). Such product design strategies were able to increase the uniqueness and personalization of the product. Design-led strategies, for example, developing technologies and systems for slow fashion movement such as multi-functional garments or 'design for empathy' [37, 61], can be highly durable as well. Antithesis[11] is a company advocating this philosophy of 'new' consumerism based on local sourcing and manufacturing, increased transparency and versatility of its products to ensure enhanced connection or relationship between wearer and the garment rather than just its exchange value. A deeper connection is also established when the garment is co-designed by the wearer.

Yet another cause of non-sustainability in fashion value chains is demand uncertainty, which leads to mismatch between production systems and consumption patterns. Overproduction in fashion value chains is a characteristic problem which affects supply chain performance to a great extent, and thereby business sustainability. Typically, in forecast-driven value chains, fashion products/collections are developed upfront several months before the season starts. The PD lead time can be up to 6–9 months sometimes. One of the inherent sustainability-related problems originates at the prototyping phase when prototypes of the styles in the collection are demanded by the retailer/marketer from all their potential manufacturers. Only about 40 % of the actual concepts or ideas developed or

[10] http://www.designtex.com/

[11] http://antithesis.co/about/our-brand/

sketched finally end up in the salesmen's sample collection while the rest are lost in the iterative design process. Further, only about three-quarters of the approved samples are confirmed for production (during the preproduction stage) while the rest are canceled depending on the responses obtained by the salesmen on the expected sales volume. On average, about five sales samples (viz. pre-production sample, production sample, shipping sample, reference sample, etc.) are produced per style. The entire decision-making process from idea to production via the reiterative prototyping process, is not only time-consuming but also leads to enormous wastage of raw materials (fabrics) for prototyping and sampling purposes with no role in value creation, and on the top of that creates a huge environmental footprint in terms of resource consumption. Combating sustainable product design strategies can be done in various ways [60, 61] as discussed below.

4.1.1 Innovative Pattern Making and Garment Design for Zero Waste

Around 30–80 % of the environmental impact of a fashion product is decided at its design stage, generating nearly 90 % of the toxic emitted chemicals. Innovative pattern-making and toiling phases of PD are critical in reducing material and resources usage by identifying all types of wastes in the pipeline. Creative approaches to pattern-cutting such as identifying and developing multi-functional garments is a way to reduce the stake on resource consumption. Zero-waste patterns are also developed to improve the efficiency of pattern making and minimize fabric waste. Typically, in conventional cut-order-planning (COP) there is fabric wastage of the order 5–8 %; this can go up to even 15 % [69]. This can be reduced through the design stage, either by working with special geometric shapes, 'new' construction methods, or by approaching techniques not requiring a direct cutting process [37]. The North Face Zero-waste project was, in this regard, a collaboration between North Face and Textile Environment Design (TED) to create a zero waste version of down jackets leading to an increased efficiency of 23.2 % compared to the current pattern. Rapid prototyping techniques are also available and those can be beneficial to open up a number of creative opportunities for designers to support personalization, digital manufacturing processes, etc. This is not only a way to lead to environmental sustainability by reducing wastes but also improves cost effectiveness.

4.1.2 Through Customization, Halfway Products, and Modular Structures

Mass customization (MC) has found an increasing significance for creating a deeper emotional connection with the customers. Using fast, flexible, digital manufacturing technologies and computer-aided designs, companies have had a positive effect on the economic sustainability of fashion value chains, by reducing markdowns, reducing returns (>1 % return rate), and increasing customer

satisfaction [45]. In the fashion business, global brands such as Levi's, JC Penney, Nike, Brooks Brothers, and Ralph Lauren have customized solutions for consumers [82]. Other smaller- and medium-sized brand retailers have also entered into customized product selling, such as Tailor Store[12]—an online retailer in Sweden allowing the customer to configure a shirt's color, sleeve length, and other options, the customer receiving the product in 10–15 days; the Finnish Left Shoe Company[13] (formerly known as The Leftfoot Company), where both feet of a customer are scanned by sales personnel to manufacture perfectly fitting shoes which are delivered to the customer within 3 weeks [77]. Adidas, on the other hand, embraced MC and, instead of producing 230,000 sample models every season, it has now become possible for them to replace the physical shoes by virtual shoes displayed on screens in stores. Adidas expects to save several million dollars per season through this [72]. Various digital technologies and creative tools, such as 3D fashion software and avatars (Lectra's Modaris, 3D Fit, etc.), 2D to 3D converters (TPC Limited base in Hong Kong has developed an automatic pattern generation system to allow designers create the 3D model first and then produce 2D patterns semi-automatically), connecting virtual tools, etc., have been developed to make MC widespread and profitable [34]. This personalized PD scheme also requires significant process designing skills to use the digital technologies effectively. For instance, Caterpillar's production system cuts out shoe parts according to customers' measurements with an automated, computer guided cutter. This necessitates manufacturing process designing to facilitate the customized value chain.

In one way, MC demands investment in the necessary technology and flexible production and distribution, thus increasing the cost of production. U.S. based footwear retailer, K-Swiss allows its customers to choose colors and also to have their name inscribed at the back of the shoe. The price of these customized shoes has a price level approximately 6 % higher than mass produced ones. However, this leads to an increased value for customers, hopefully thereby reinforcing the company's brand [15]. Larsson (2012) discovered that customers who bought the custom-made garments were willing to both wait longer and pay more than in an ordinary clothing chain. Another study by Pal and Torstensson [64] identifies that customized products (with higher brand value and fashion content) strongly influence supply chain design attributes characterized by QR, cost minimization, higher flexibility and coordination, along with sustainability concerns. Such SC designing features are also essential to drive faster cash flow, asset turnover, and hence profitability, implying economic sustainability. Modular manufacturing is also a 'new' designing process aimed at reducing environmental impact and enhancing product longevity. Development of a range of detachable product features can facilitate easy cleaning of parts of garment and easy replacement or repair, thus creating novel and creative attachment systems [37, 61]. From the

[12] http://www.tailorstore.se/

[13] http://www.leftshoecompany.com/home

environmental point of view, both customized production and modular products help in reducing the impact on energy and natural resources and deliver cost effectiveness.

4.2 Design for Sustainability in Sourcing and Production

LCA suggests, in terms of energy consumption, that nearly 25 % of the total energy required (109 MJ) to produce a 100 % cotton T-shirt is used in material and production stages (while it is as high as 80 % of the total energy consumption (51 MJ) for a 100 % viscose blouse). In another environmental report, by the Italian leather industries association UNIC, 1 m^2 of leather requires 113 L of water; total environmental cost amounted to 2.2 % of turnover, around 68 % are caused by water treatment, 24 % by waste management, and 8 % by air emissions and other costs [80]. Delphi studies conducted by Allwood et al. [1] from the University of Cambridge suggest that innovative production technologies with local recycling would be favorable globally in reducing the emission of 'Climate Change Impact' (measured in terms of a thousand tons of CO_2 emission), waste disposal, and 'Environmental Impact'[14] [46].

Efforts in sustainable sourcing, procurement, and manufacturing are growing. Different production processes can affect the environment within the supply chain in many different ways. Some of these include the use of certain raw materials, the ability to integrate reusable or remanufactured components in the fashion industrial system, and how the processes are shaped to prevent waste. A C2C apparel design and production model [33], in this context, considers environmental sustainability in production by ensuring safety of material inputs and sustainable material flows in terms of energy usage, air emissions, water, and solid waste.

Several certifications, labels, and standards exist, aiming at facilitating, supporting, or monitoring sustainable practices in sourcing and production. The Bluesign® system[15] is such a standard solution, aiming at sustainable textile production. It eliminates harmful substances from the start of the manufacturing process and sets and controls standards for environmentally friendly and safe production. This ensures the final textile product meets very stringent consumer safety requirements worldwide, but also provides confidence to the consumer that he has acquired a sustainable product. Table 2 lists all the textile-only certifications.

[14] Representing the combined effect of ozone depletion, acidification (acid rain), nutrient enrichment (algae growth that can cause fish death), and photochemical ozone formation (smog). The aggregated environmental index is measured in 'person equivalent targeted' (PET) units, i.e., the impacts are normalized to one person's share and weighted according to political reduction targets.

[15] http://www.bluesign.com/

Table 2 Certification in the textile industry. *Source* ecolabel index (February 2014)

BioForum biogarantie and ecogarantie—a Belgian organic label	Made by—umbrella label used by fashion brands and retailers to show consumers that their clothes are produced in a sustainable manner
Bluesign standard—analyzes all input streams from raw materials to chemical components, to resources with a sophisticated "input stream management" process	'Made in green'—certifies that the product, throughout its traceability chain has been manufactured in factories which respect the environment
BMP Certified Cotton—Australian cotton industry's guide for growing cotton in harmony with natural environment	Migros ECO—label for textiles guaranteeing no substance likely to cause allergies or irritation, or to be harmful to the environment. It also attests to environmental preservation and workforce health and safety
China environmental labelling—provides environmental standards for construction materials, textiles, vehicles, cosmetics, electronics, packaging	Naturland—association for organic agriculture is a private certification body and an organic farmers association
Coop naturaline: Switzerland—standard for textiles and natural cosmetics made from cotton by controlled biological cultivation according to the guidelines of BIO Suisse or the European Union	Naturtextil BEST—a holistic standard valuing environmental and social criteria along the whole textile production chain
eco-INSTITUT—supplies clients with a reliable and significant label for building products and textiles without any health hazards	NSF/ANSI 336: sustainability assessment for commercial furnishings fabric—ecolabel addressing the environmental, economic and social aspects of furnishing fabric products
Ecoproof—label for textiles, especially textiles made from cotton	Oeko-Tex (100, 100 plus, 1,000)—are globally uniform testing and certification systems for textile raw materials, intermediate and end products at all stages of production
Global organic textile standard—comprehensive rules for ecological and socially responsible textile production	Sustainable materials rating technology or SMaRT—consensus sustainable products standard and label for building products, fabrics, apparel, textiles, and flooring
Global recycled standard—standard for companies manufacturing products with recycled content. The standard applies to the full supply chain and addresses traceability, environmental principles, social requirements, and labeling	Soil association organic standard—organic certification for farmers, growers, food processors and packers, retailers, caterers, textile producers, health and beauty manufacturers and importers, in the UK and internationally
Green shape—a VAUDE's label for products featuring special ecological manufacturing	Tunisian ecolabel—type 1 national ecolabel to facilitate the access of Tunisian products and services to the European and International markets
Institute for market ecology (IMO)—international agency for inspection, certification and quality assurance of eco-friendly products	

http://www.ecolabelindex.com/

Environmental issues addressed by these eco-label standards mostly consider categories including organic production, energy usage, pollution, and biodiversity conservation, thus concentrating on all aspects of 3-DCE. DfS, in the sourcing and production stages, for producing eco-textiles and clothing mainly concerns the need for less pesticides, allergens, and biologically active compounds. The toxicity profile of a cotton T-shirt suggest that 93 % of the total toxicity is produced in the cotton production phase (in terms of five major chemical groups—insecticides, herbicides, fungicides, growth regulators, and defoliants) [1]. Use of sustainable raw materials, products, technology, and energy such as crops employing no pesticides or have a reduced need for water, use of materials made from renewable resources with 'alternative-green' substituted chemicals,[16] and the use of renewable energy are the best practices at this stage. This can lead to economic sustainability, as it was found that use of organic over conventional cotton reduces the number of pest management days needed per year by around 40 %, hence the costs of fertilizers and pest management falls significantly [25].

Additionally, process designing during sourcing and production stages guarantee low energy consumption, less waste production, etc. The University of Cambridge study suggests that the combined waste from clothing and textiles in the UK is about 2.35 million tons,[17] 13 % going to material recovery (about 300 thousand tons), 13 % to incineration, and 74 % (1.8 million tons) to landfill. Several other indicators suggest about 0.6 kg of oil equivalent primary energy is used in the industry per 1 kg of output, about 2 kg of CO_2 equivalent emitted to air per 1 kg output, approximately 60 kg of water used, and about 45 kg of wastewater discharged per 1 kg of output [1]. High water consumption being a major concern in cotton production (ranging from 7,000 to 29,000 L for producing 1 kg of cotton fibers), price of organic cotton is expected to rise in the near future due to increased resource utilization.

Collaborations with other industries, such as companies producing renewable energy or using solid waste from apparel production as their biological nutrients or raw materials, are additional means to reduce or eliminate harmful impacts during production. In C2CAD, collaboration and co-development of fabric with vendors is a component (cf. May-Plumlee and Little's NICPPD model) [52] and so it is in the "cradle to cradle" model—as McDonough and Braungart [54] proposed *intelligent materials pooling* which emphasizes collaborative approaches, such as sharing knowledge and resources between apparel designers and manufacturers with other companies in the supply chain, as important strategies in sustainable development. Other options include enhanced information exchange through EDI [74]. Closer collaboration among the producer, supplier, and final consumer through various

[16] Greenpeace, 'Moda sin tóxicos, for a future free of harmful Chemicals', June 2006. Information about the chemicals used in the textile and clothing industry, their effects on human health and claims they can be replaced by other kinds of chemicals; www.greenpeace.org/espana/reports/moda-sin-t-xicos.

[17] ONS, May 2006. Environmental Accounts—spring 2006, Office for National Statistics, pages 23, 35 and 39, www.statistics.gov.uk.

environmentally conscious purchasing practices, by ISO 14000 standards, etc., guarantees integrated chain management (ICM) for higher environmental management, information sharing, and transparency [56]. From a holistic approach, these issues of environmental certification and codes of conduct incorporate green supply chain design management aspects.

The social issues across this category include labor practices, worker health and safety, consumer health and safety, economic development, and animal treatment. Clean Clothes[18] is an example of a pan-European campaign, which has institutionalized a voluntary CoC based on the International Labor Organization (ILO) standards. Other organizations, such as the World Fair Trade Organization (WFTO),[19] The Ethical Trading Initiative (ETI),[20] etc., are concerned with the issues guiding social sustainability, by adhering to the principles concerned with reaching the economically disadvantaged, transparency and accountability, capacity building, promoting Fair Trade and implementing corporate codes of practice, and improving the situation of women, child labor, supply chain working conditions and meeting international labor standards, the environment, and the payment of a fair price. Deloitte's fashion survey investigates how large companies and small companies manage supply chain sustainability. The approach to GSCM has been of two types, viz. (1) conventional approaches including supplier CoC, contract amendments, supplier self-assessment, and audits, and (2) stakeholder-based approaches including supplier worker and stakeholder surveys, supplier-based partnerships, engagement with local networks, etc. Results showed that large companies have a higher degree of focus on both conventional (79 %) and stakeholder-based approaches (44 %) [18]. For example, Nike through Fair Labor Organization (FLA), an NGO, openly shares the results of the audits of its suppliers for maintaining high degrees of transparency. Yet, sometimes these codes of conduct are not really checked in practice, and the code may be paradoxical in nature, given strategic decisions towards low cost, which will likely dominate daily practices on the shop floor [23, 79]. Large companies, as highlighted in the Deloitte study, put a great deal of effort into using supplier CoC but do not significantly engage with local networks for sustainability. There have also been many initiatives from different organizations to gather the industry around a common way of measuring environmental and social impact of fashion and apparel supply chains. Whether these initiatives have failed because of lack of interest or because the tools were too complicated remains unclear. However, major fashion and apparel brands have now gathered around one tool which measures the environmental and social impact of fashion supply chain, the SAC index accepted by a wide range of industry partners such as H&M, Patagonia, Adidas, Asics, Coca Cola Company, New Balance, Nike, and Puma. The SAC-index is a common, industry-wide tool for measuring social and environmental performance of apparel

[18] http://www.cleanclothes.org/

[19] http://www.wfto.com

[20] www.ethicaltrade.org

products and the supply chains producing them. Since several of the major fashion companies have agreed to use this index it is possible that this index will serve as a benchmark in the future.

From the point of redesigning the supply chain, a major change in organizational and value chain structure was catalyzed by the global financial crisis, the ensuing recession, and an uneven global recovery becoming key driving factors for new supply chain business models. "Re-shoring" or "next-shoring" are terms used to describe the return of manufacturing to developed markets with increased wages in developing nations and increased environmental issues [35]. Next-shoring strategies encompass elements such as a diverse and agile set of production locations, a rich network of innovation-oriented partnerships, and a strong focus on technical skills. There have been some attempts already to revive production in the developed nations based on these concepts. For instance, France has created competitive clusters ('Les pôles de Compétitivité'[21]) on technical textiles as a national strategy for manufacturing competitiveness. European brands which have sought to retain parts of domestic production have focused mainly on technological change, particularly increasing the use of just-in-time and QR (such as Zara) [26] with increased digitization and applications of computer techniques in design, cutting, and finishing along with automation of manufacturing. A very recent step taken in the United States, through the partnership of Royal Park USA (RPUSA) and Industries of the Blind (IOB), is establishing a project (RPUSA-IOB) to re-emerge domestic sewn products and the supporting United States manufacturing companies 'back to US' by creating a comprehensive Full Package Center (FPC).[22] The FPC is expected to offer expanded design, product development, and end-model manufacturing based in the United States and also to serve as a centralized resource center connecting brands, manufacturers, entrepreneurs, suppliers, and retailers in the apparel industry. This is also a collaborative attempt to re-shore production, fabric and trim providers, contract manufacturers, equipment companies, and service providers, etc., back to US. From the DfS aspect, this would lead to social–cultural innovation through job creation in the manufacturing sector, extending existing best practices, and development of a constraint-based lean manufacturing model. In essence, a "one stop shop" is being created to enable companies currently using off-shore production to move the business quickly to the United States at very competitive costs.

One challenge is to attract and keep retraining highly-skilled labor. Companies rely on their personnel's adaptability and their innovation capacity. This implies investment in training, retraining, and good careers advice, aimed at developing transverse and managerial skills to manage organizational adjustments. So, even in a context of production flexibility (as it is the case for the fashion industry), skill development plans for employees, managerial skills, and transverse competencies development can contribute to consolidation. Investing in the skills of employees

[21] http://competitivite.gouv.fr/

[22] http://www.industriesoftheblind.com/royal-park-usa/

is part of a sustainable and responsible human resource management. This is not only beneficial in the long run to the company, but is also one of the numerous facets of the social pillar of sustainability (together with fair labor conditions, discrimination, gender issues, and so on). Better-trained employees can more easily reposition themselves in the labor market if they lose their jobs. Considering the pillar of economic sustainability, nearby production has the added advantage of shorter logistics lead times. Thus companies can keep a major part of their product open for seasonal buying (represented by open-to-buy—OTB) rather than buying upfront based on forecasting before the seasons [50]. This accurate QR approach can enable fashion businesses to achieve a higher inventory stockturn, thus resulting in higher cash flow and GMROI. According to a survey in the United States, forecasting accuracy achieved by firms using QR can be as high as 95 %, sell-through 95 %, and distribution center lead-time can be reduced [41]. A much more recent study in Mustonen et al. [58] indicates that the net profit margin and a rapid turnover of inventory were significantly higher for brand retailers, resulting in higher profitability than for traditional multi-brand retailers.

4.3 Design for Sustainability in Distribution and Logistics

In the global fashion value chains, sustainable initiatives also concern the logistics and transportation functions within each company and also along the entire supply chain, thus demanding reduction in global pollution and increasing awareness among businesses and consumers to contribute towards a greener lifestyle [24]. This is aimed at optimizing the physical flow of goods (through flow management optimization), increasing adoption of resource-sharing solutions, and also, by availing cleaner transportation modes, countering the increased footprints of fashion logistics with increased transportation distances [16]. In the road transport sector, the increase in energy consumption is at a faster pace than that consumed by cars and buses, and is expected to surpass it in the next 10 years [24, 55]. Moreover, the average grams of CO_2 emitted per tonne-kilometer for a deep sea container ship, freight train, heavy truck, and long haul airfreight are around 14, 30, 80, and 570, respectively [55]. In this context, attaining sustainability along all three SD pillars, in the logistics and distribution functions, calls for a holistic 3-DCE approach.

First, logistics integration through optimized flow management and consolidation plays a critical role in economic sustainability along the value chain by exercising better control (mainly by downstream fashion retailers). Increased coordination by leveraging effective relationship management is beneficial in favoring reduction in transportation-related costs by ensuring better responsiveness, reliability and shorter throughput times [16]. For instance, H&M has built its distribution centers in their international locations in order to cut down lead times and potential logistical costs. Setting up specific production planning along with centralized warehousing and regional distribution centers, as used by Mango, is

also critical for consolidating the flow of fashion goods—supported by clean transportation modes.

Sustainable logistics are also optimized through increased use of different tools, including CPFR, aimed at sharing resource use in transportation and warehousing, joint routing, scheduled deliveries, etc. This subsequently reduces the logistics costs and time, along with the negative impacts on the environment [16]. Such intermodal transportation solution (based on resource sharing), along with the use of clean transport modes, are beneficial in implementing both economic and environmental sustainability—through process and supply chain design approaches. In this context, Clean Shipping[23] is a project aimed at minimizing the environmental impact of shipping. The Clean Shipping Index is a benchmarking tool which calculates and tanks ships on the basis of their environmental performance, based on nitrogen oxide, carbon dioxide, and sulfur dioxide emissions, and control of fuel. Fashion companies, such as H&M, Lindex, etc., have joined the clean shipping project. On the other hand, Carrefour initiated a pilot project in 2002 aimed at testing barge transportation. This project allowed a modal shift from road to river of 30 % of textile flow, through a container line. Barge transport took about 3,000 trucks off the roads, representing a reduction of CO_2 emissions of about 130 tons and a cost reduction of 6 %; in 2011, this resulted in 9,000 fewer lorries on the roads and 1,330 fewer tons of CO_2 emitted[24] [16]. Changing freight from air or road to rail and water-borne transport can also significantly reduce the retailer's footprint. Continental Clothing, for example, does not use air freight; items from Turkey are delivered by truck and those from China and India by sea, resulting in a transportation cost of about 2–5 % of the product price ($\sim$5 pence per T-shirt). Its dynamic vendor management inventory (VMI) principle helps it to do well in the marketplace.

Apart from structuring the geographical logistics system and streamlining the routes, cleaner transportation can be encouraged through process innovation, such as increase in vessel size (in maritime transportation), high speed shipping lines, achieving better delivery trip optimization, and higher fill rates of the vehicles—thereby the frequency and cost of deliveries and fuel consumption are decreased [16, 36]. A shift from conventional diesel to alternative fuels or battery powered cars can significantly reduce CO_2 emissions and other harmful pollutants.

At the product design level, innovative packaging has a positive impact on the environment and in most cases this is a very important part of the supply chain. The shape and material have a significant impact on transportation and cargo. Better packaging using recyclable material together with arranged loading patterns can reduce material use, optimize space taken in warehouses and in containers, and reduce the amount of handling required [74].

Further, regarding social issues, stakeholders consider the concern for consumer health and security as important prerequisites for sustainable logistics practices,

[23] http://www.cleanshippingindex.com/

[24] http://carrefour-site.ti.smile.fr/sites/default/files/REDD_49_61_EN.pdf

and these can be achieved through various track and tracing technologies [16]. Mostly this is connected to the traceability of the fashion product along the value chain to ensure that it has no contact with any health hazard. The Clothing Traceability[25] is such a project which "connects the businesses and consumers to a deeper understanding of the impact of the clothing life cycle through documentation and visualization of the supply chain, from fibre through manufacturing and production, the project builds on established tools for supply chain transparency to develop a leading approach to sustainable fashion."

Thereafter, the 3-DCE approach plays a strategic role in effectively coordinating sustainable logistics and transportation solutions in the fashion value chain.

4.4 Design for Sustainability in Retail and Marketing

Rethinking the value creation mechanism is vital at the stages of marketing and retailing when the retailers have the highest potential to create an enjoyable product experience in the mind of the customers [61]. Various mechanisms could be enforced to help consumers evaluate connections between the price, quality, and utility of the product, such as explaining to the customers the environmental benefits of the product, the ethical product values and esthetical longevity, the durability and content of the sustainable materials, etc.

4.4.1 Guaranteeing Long Life and Product Satisfaction

A short life span of fashion apparel is one of the major problems in current industrial systems, resulting in quick, planned obsolescence. Slow fashion in this context is a movement aiming at enhancing the longevity of fashion life span by focusing on a products' use value instead of its exchange value. By ensuring higher quality and ethical values, slow fashion products are expected to deepen and prolong product–customer interaction.

For instance, UK-based brand manufacturer John Smedley is a SAF engaging in producing high quality and classic design knitwear.[26] Together with Better Thinking Inc., John Smedley has developed a sustainable luxury shirt called "Luxury Redefined." FairTrade organic cotton used for the shirt is sourced from Peru because of the lower water footprint and renewable energy; the shirt is in a natural color and no bleach or dyes are used,[27] thus relating customers to the natural environment. For Patagonia,[28] the key elements in its PD are quality,

[25] http://www.clothingtraceability.com

[26] http://www.johnsmedley.com/

[27] http://www.coolhunting.com/style/john-smedley-x.php (February 2014).

[28] http://www.patagonia.com/eu/enSE/home

environmental criteria, and innovation. Quality aspects mainly focus on the multi-functionality of the product adding an environmental benefit, as it allows the customers to consume less [68].

4.4.2 Co-Creation, Open Innovation and Crowdsourcing

Co-designing approaches encourage customers to have enhanced personalized experience with the products, offering deeper consumer satisfaction. Several studies (e.g., [57]) have highlighted that these aspects symbolize a deepened product attachment, and emotional bonding which may postpone product replacement—which is sustainable in many cases—to decrease the environmental impacts, thus benefiting from sustainable development [61]. Many sectors have undergone or are undergoing structural changes by systematically looking for strategic innovation outside their organization and inviting more players, big and small, to take their place in innovation processes. Crowdsourcing is such a practice, obtaining the required services, ideas, or content by soliciting contributions from a large group of people, and especially from an online community, rather than from traditional employees or suppliers.[29] Open source fashion is a recent phenomenon and in many ways can lead to SBD.

ModCloth,[30] an online retailer based in San Francisco specializing in vintage and vintage-inspired clothing, uses customer feedback to gauge fashion trends and to determine which ideas to implement. Using controlled design tools, a similar online design company—Threadless[31]—supplies its designers with PD ideas (based on scores from outside selectors/customers, score distribution, and their own sense of fashion aesthetics and style trends) [42]. Increased product satisfaction by changing passive customers into active ones can help fashion businesses accelerate their innovation, cut operating costs (being more demand-driven), and increase return on investment (ROI), thus honing economic viability. Zara, the Spanish retailer, has embraced the customer-based idea selection process over a long period of time by manufacturing small batches of numerous designs and also letting the customers determine the latest trends [42]. Not only does this allow Zara to identify popular items; it also enables the company to cut its losses (less mark-down, less inventory level) quickly when a product flops.

Even though the willingness of fashion businesses to collaborate on sustainability issues with outside organizations and individuals is not new, the most striking thing is the changed strategic role and opportunity which these companies perceive in the online open forums in order to develop viable sustainability solutions. In this context, EDUfashion, was an EU financed project for the development of a collaborative platform for fashion creation and continuous

[29] Crowdsourcing—Definition and More Merriam-Webster.com (February 2014).

[30] http://www.modcloth.com/

[31] https://www.threadless.com/

education emphasizing and oriented toward "ethical" fashion items, meaning no sweatshops, ecologically sustainable, locally produced, and fairly traded apparel, by exploring the forces behind these consumer trends [59]. Initiatives from large international companies such as Unilever's Sustainable Living Lab[32] program, GE's Ecomagination[33] Challenge, etc., have been permanent platforms dedicated to open innovation and to extend and deepen the interactions with external collaborators. In the case of fashion businesses, Nike's Green XChange program similarly capitalizes on public problem solving by sharing intellectual property [19]. This has been economically profitable for Nike during the recent 2008/2009 credit crunch. By adopting the open-innovation platform, through collaboration Nike was able to transform its customers into designers, its sneakers (shoes) into personal fitness consultants, and its intellectual property into free R&D for solving the world's problems. This transition helped Nike to earn a revenue of 19.2 billion USD, with a triumph during the recent crisis [70].

4.4.3 Enhancing Product–Service System

Enhancing the engagement between product and service drives fashion companies to concentrate on satisfying customer needs and, at the same time, have minimalistic impact on the environment. A paramount goal of product–service systems, as highlighted by Mont [56], should be to minimize the environmental impact of consumption by closing material cycles, or reducing consumption through alternative scenarios of product use, or increasing overall resource productivity and dematerialization of PSSs, or providing integrated system solutions with improving resource and functional efficiency of each element. The value-added benefits of such innovative systems would provide an enriched personalized experience to the customers and this can be achieved in several ways, such as by selling the use value of fashion products instead on the basis of the exchange value, changing to a 'leasing society,' by substituting goods by means of service machines, by moving away from a throw-away society to a repair society. and basically changing consumer attitudes from sales to service orientation [6, 56]. For instance, even though the idea of leasing clothing rather than purchasing may seem to be unattractive to many consumers, some clothing and textile products already have leasing as a common practice. For example, leasing formal and evening wear, maternity clothes, school uniforms, sports clothing, linen for restaurants or hotels, uniforms for hotels, protective clothing in industry, wedding clothes, etc. [61]. Leasing is an effective way to use products for more of their potential life and this way of sharing and extending the life cycle of clothing by even just 3 months can

[32] http://www.unilever.com/sustainable-living/?dm_t=0,0,0,0,0 (February 2014).

[33] http://www.ge.com/about-us/ecomagination

reduce the carbon footprint by 8 %, water consumption by 10 %, and waste by 9 %,[34] a concept for 'design for longevity'. This concept of collaborative consumption can make an impact on increasing sustainable buying behavior among consumers, thus enhancing their role in social responsibility. 'Design for longevity' also needs to focus on caring for the garment. Fashion businesses must be clear in instructing consumers in the appropriate way to handle garments. Oxfam's vintage guide produced an information guide to support the care of vintage clothing, by providing tips and advice on general care of garments (this includes, specific instructions for washing, drying, and ironing, storing, etc. [38]. This also includes altering care procedures for garments to achieve lower imprints on the ecology, such as reducing laundering, etc.

4.5 Design for Sustainability in a Closed Loop

Re-manufacturing, recycling, reverse logistics, and redesigning are important aspects of SBD, essential in completing or closing the loop in supply chain operations.

After consumer use, the life of fashion apparel is not yet over. Some clothes and textiles are taken to recycling clothes banks operated, for example, by the Salvation Army (which also has door-to-door collection), Traid, Oxfam, or many other members of the Textile Recycling Association.[35] Of all the collected textiles in the world, about 50 % is reused and 50 % recycled. Using recycled textile material in the manufacturing process can considerably reduce carbon emission in comparison with the fiber production which would otherwise have used virgin materials. A study done by the University of Copenhagen in 2008 revealed several benefits of reuse of textile materials in the production of new textiles. Just 1 kg of recycled clothing can reduce carbon emissions by 3.6 kg, water consumption by 6,000 L, use of fertilizers by 0.3 kg, and pesticide use by 0.2 kg.[36]

An example of this is the Stena Metall Group's[37] research and development projects on recycling of apparel with metal parts, such as jeans with zippers and rivets or a bra with metal bracket. Through pyrolysis, textiles break down into gas which cools and forms oil which can be recovered, while the metal parts are collected as they remain intact. The problem with this process is that it is expensive; moreover, numerous material types and extensive use of fiber blends can produce a significant bottleneck [1]. Even though recycling is a considerable challenge,

[34] http://www.wrap.org.uk/sites/files/wrap/Design%20for%20Longevity%20Report_0.pdf

[35] http://www.textile-recycling.org.uk/

[36] http://www.bir.org/

[37] http://stenarecycling.pl/en/Innovative-recycling/Research-and-Development/

several companies have nevertheless voluntarily chosen to give customers the opportunity to return the garment for reuse and recycling, such as H&M's Garment collecting[38] and Klättermusen's deposit system.[39] H&M's initiative of Garment collecting involves customers gathering leftover clothing from different brands in the 53 markets wherein H&M operates. Any revenue raised from the project will be invested in technology for recycling processes in the textile and social projects. Patagonia, on the other hand, offers a product line of fleece which can be recycled from used PET bottles. Another project in 2009 on recycling favored by EU was textile for textile (T4T),[40] an initiative to guarantee better sorting techniques for upgrading textile recycling. With these process innovations and design aspects, the environmental threat posed by the clothing industry's short life cycle is hoped to become reduce. Recycling also demands technology innovations which may provide a means to extract longer fibers from used textiles (a mode of product design). Similar to this was the 1990 Recycling of Carpet Materials (RECAM) project which has developed a closed loop system for recycling carpet materials and has been a huge technological success; however, it failed to be profitable and hence economically sustainable. However, recycling reduces energy used in production and hence is economically viable. In recycling, the amount of waste from incineration of cotton is significantly lower than the waste generated from the production of electricity to run the recycling operations [1].

Reuse is another way to close the loop. Clothes worth nearly 1 billion USD end up as second-hand clothing every year which is mostly baled and resold in the third world. The second-hand clothes trade in developing countries creates a type of employment, leading to social sustainability [3], incorporating notions of supply chain redesign. There has been a growth in online sales or exchange of garments through retailers such as eBay and Gumtree, which has helped to increase the flow and accessibility of second-hand clothing. A popular event was organized by Marks and Spencer (M&S) in association with Oxfam called 'Shwopping'[41] in 2012, encouraging consumers to donate clothes for reuse or remodeling.

Reverse logistics from a green perspective also manages the flow of products intended for remanufacturing, recycling, or disposal, and utilizes resources more effectively [36]. More and more companies are starting to become involved in the issue of reverse logistics, as it not only provides a positive environmental impact, but also economic benefits [74]. This calls for process and supply chain designing perspectives to devise the remanufacturing processes of reusable parts in reverse logistics [40]. This incorporates the ideas of vehicle routing for re-cycling of end-of-life (EOL) goods to ensure extended product responsibility (EPR).

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[38] http://about.hm.com/en/About/Sustainability/Commitments/Reduce-Reuse-Recycle/Garment-Collecting.html

[39] http://www.klattermusen.se/companysoul.php?id=5&lang=EN

[40] http://textiles4textiles.eu/

[41] http://www.marksandspencer.com/s/plan-a-shwopping

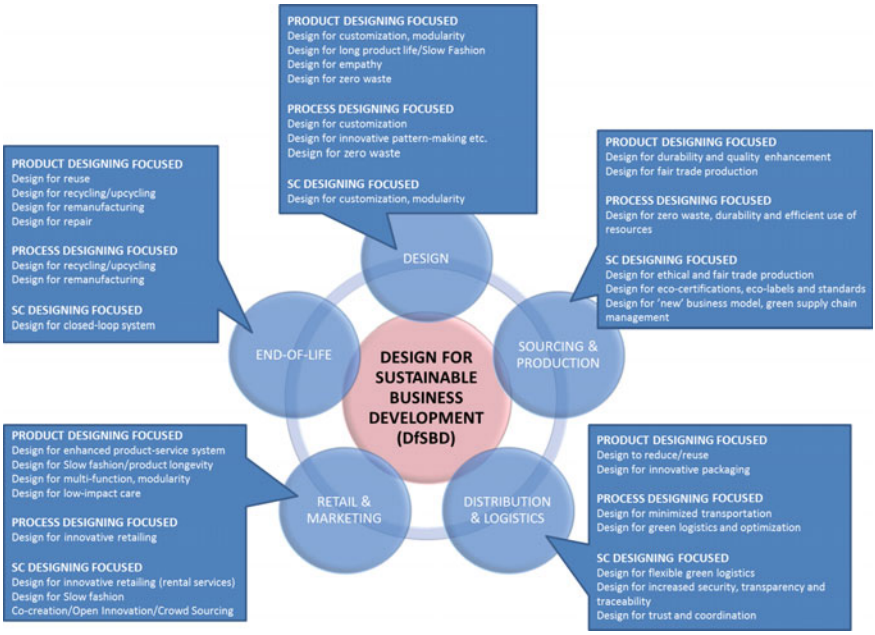

Fig. 3 Model for design for sustainable business development (DfSBD)

The new strategy of upcycling has also seen prospective growth and business opportunities in the case of smaller fashion labels. Co-designing of garments by consulting the wearers can open up the design innovation process to lead to a greater input in remanufacturing, as was done by London-based fashion designer label Queenie and Ted.[42] This approach provides strong economic and environmental viability as upcycling means upgrading and adding value to a product which may otherwise have been discarded. This calls for 'new' product designing perspectives. Till now, upcycling in the fashion apparel industry has been mainly specific to couture garment designers, as this specializes in small runs of products.

Overall, there are several ways to construct a closed loop value chain and align the fashion industry towards a more sustainable one. These approaches can be by simple repairing worn garments to reuse them, by advanced recycling of wastes and discarded apparel, or by altering the clothing to upgrade it. From a designing aspect, this not only includes product design perspectives but also covers designing simple processes for reconsidering 'how to upgrade garments' which might otherwise be discarded.

[42] http://www.queenieandted.co.uk/Queenie_and_Ted/Home.html

5 Concluding Remarks

Some of the conclusions derived from this work are summarized below:

- SBD in the case of fashion businesses requires a holistic design approach, based on designing products, processes, and supply chains both independently and concurrently
- Such designing calls for applying a 3-DCE approach along all the value chain activities of forward loop: design and product development, sourcing and production, distribution and logistics, retail and marketing, and backward loop: recycling, remanufacturing, reverse logistics, and reusing
- An SBD model is supposed to lead to 'triple bottom line' sustainability within economic, environmental, and social perspectives
- An SBD loop does not have a beginning or an end. It contributes towards development of a circular business economy
- DfS along all the value chain activities contribute towards a DfSBD model (cf. Fig. 3).

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