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Improving sustainability in the value chain of the apparel industry empowered with social manufacturing

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Abstract— One of the major contributions of social manufacturing is in the realm of sustainability. The apparel industry is a good example to assess contribution of social manufacturing to improve sustainability in practice. Value chains in the apparel industry are faced with various challenges regarding sustainability issues. Apparel companies pay higher attention to economic sustainability issues, and environmental and social sustainability issues of the apparel industry are often underrated. We realize that the apparel brand owners have the highest impact on improving the sustainability of the apparel industry. Thus, we design a collaborative business model empowered with social manufacturing to join the forces among the brand owners for improving sustainability of the apparel industry throughout the value chain. We chose a case study of shifting from conventional screen-printing to more environmentally sustainable digital textile printing. We suggest that this shift can be accelerated if the brand owners join their forces together to shift from conventional printing to digital printing technology in the apparel industry.

Keywords— Apparel industry, Digital textile printing, Joining forces, Social Manufacturing, Sustainability

I. INTRODUCTION

Sustainability has become an important topic in contemporary business. Meanwhile, Social Manufacturing is a new phenomenon, which is considerably gaining more attention in the recent studies, yet these studies are not extensive (See for instance, Wang, 2012; Wang et al., 2019, Shang et al., 2013; Shang et al., 2017, Shang et al., 2019, Xiong et al., 2014, Xiong et al., 2017, Jiang, et al., 2016, The Economist, 2102, Mohajeri et al., 2014). Hamalainen et al., (2016) provide Principles of social manufacturing as follows

- Inclusive, meaning that private individuals can self-select to cooperate with firms and contribute in all phases of the production value chain, whether in ideation, R&D, design, or fabrication, depending on the business model;

- Dynamic, meaning that the level of contribution between the individual and firm can vary over time to the extent that individuals can change from buyers to sellers; and

- Multilateral, meaning that it might also include individual-firm-individual transactions where individuals buy products through platforms owned by a firm, but also knowing the identity of the individual, who developed the product, and knowing that part of the payment goes to him or her.

In this paper, we resemble apparel brand owners to the “individual” entities in social manufacturing.

According to the principles of social manufacturing, an individual (i.e. brand owner) or firm (i.e. group of brand owners) can participate in the entire value chain. Thus, joining the forces among the entities is one of the major principles of social manufacturing.

In this paper, we design a collaborative business model to join the forces among the brand owners for improving sustainability of the apparel industry in the value chain. This business model is empowered by principle of social manufacturing.

The rest of this paper is organized as follows. Section 2 briefly addresses the sustainability issues in the apparel industry. Section 3 describes the idea of joining forces in the value chain with the environmental and social perspectives. Section 4 explains the case study of shifting from water-intensive screen-printing to waterless digital textile printing technology. Section 5 presents a collaborative business model to join the forces among brand owners to speed up shifting toward digital textile printing. Finally, last section suggests directions and avenues for further research and concludes by summarizing the contributions of this paper.

II. SUSTAINABILITY CHALLENGES IN THE APPAREL INDUSTRY

The apparel industry is the one of the most globalized businesses, which is providing employment to over 60 million workers worldwide (Martin, 2013). The apparel value chain consists of global networks of (input) material suppliers, apparel manufacturers, brand owners and brand sellers. It is a market / buyer driven business, where customer preferences are playing the key role (McNamara, 2008). The characteristics of the apparel business are more or less based on unpredictable seasonal consumer demands in styles, colors and quantities due to different reasons such as variety of market trends, short product life cycles and low barriers to market entry (Gereffi & Memedovic, 2003 ; Ngai et al., 2014). These uncertainties have all made the industry more competitive not only in economical aspect but also in environmental and social aspects. In this regard, sustainability requirements have dramatically influenced the apparel industry.

The apparel industry in general shows a favorable outlook in terms of the economic sustainability. However, the industry faces significant challenges regarding environmental and social issues (Hill et al., 2012 ; Caniato et al., 2012). The literature on the value chain of the apparel industry shows it is currently fragmented (Gereffi, & Frederick, 2010; Romano & Vinelli, 2001; Ngai et al., 2014). The brand owners in the apparel industry pay attention to the economic sustainability challenges, while the environmental and social sustainability issues of the apparel industry are often undervalued (Luz, 2007; Martin, 2013; Mohajeri et al., 2016). Generally speaking, brand owners in the apparel industry have been increasingly concerned about global environmental and social issues (Kozlowski et al., 2012). Brand owners such as Nike, Levi Strauss, Benetton, Adidas, and C&A have been criticized for environmental and social impact of their suppliers (Seuring & Müller, 2008; Winter & Lasch, 2016).

In order to achieve the environmental and social sustainability outcomes, brand owners should not only apply the sustainable practices in their business, but they must assess the sustainability of the activities of their suppliers throughout the value chain.

III. SUSTAINABILITY CHALLENGES IN THE APPAREL INDUSTRY

As we discussed in the previous section, brand owners should manage their entire value chain to assure that their suppliers and other stakeholders follow sustainability criteria. However, there are several issues in sustainability that cannot be managed by the brand owner alone. Another problem is that sustainability criteria have not been commonly accepted and may be inferred arbitrary between different apparel brand owners. However, there are plenty of examples that corporations within a business sector or industry have joined their forces to resolve a sustainability-related issue.

For example, in the Automotive industry, Toyota Motor Corporation has introduced an LCA system called “Eco-VAS” to join the forces between designers. This system enables an LCA database and an evaluation system that designers are able to use during product design to release the LCA results of all their products (Yamato, 2005). Although in this case LCA is

not required by law to operate the production facility, the designers are encouraged to use this database, because it promotes an environmentally conscious design within the company with reporting appropriate environmental statements to the public voluntarily. As a result of this LCA-based environmental performance information, Toyota can also promote its brand image (Yamato, 2005).

In another case, Intel has formed a campaign in collaboration with other corporations to improve access to quality education. Since 2001, Intel has invested around \$500 million in literacy and education plans around the world, leading to higher social sustainability (Kiron et al., 2015).

In the apparel industry there are well-known collaborations between major brand owners in improving sustainability. One of the most famous alliances happened in Oct. 2015 after in the collapse of Rana plaza in 2013. In this initiative, several well-known apparel brands, retailers, industry groups and humanitarian organizations decided to collaborate to improve working conditions in apparel manufacturing across the world. This collaborative effort was facilitated by the Sustainable Apparel Coalition (SAC). The project aimed to improve the working conditions and the workers’ wellbeing. The project could significantly reduce the amount of money that was spent on duplicated auditing and invest the money saved in improving the situation for the millions of people employed in apparel manufacturing around the world (Gunther, 2016). Despite the controversy about the success of this project, the initiative proves that the major players in apparel industry are able to shift the industry toward a more sustainable path if they are willing to join their forces (Gunther, 2016).

Another example of joining the forces is the bluesign® system. The bluesign® system is the solution for a sustainable textile production to eliminate harmful substances with setting controls standard throughout the manufacturing process from the beginning to the end. These standards not only ensure that the final textile product meets consumer safety requirements internationally but also gives confidence to the consumer to purchase a sustainable product. bluesign® system partners base is constantly growing. There are already well-known names inside this system including Adidas, Nike, Puma, Columbia and etc (bluesign, 2016).

IV. CASE STUDY : SHIFTING FROM CONVENTIONAL SCREEN-PRINTING TO MORE ENVIRONMENTALLY SUSTAINABLE DIGITAL TEXTILE PRINTING

Water scarcity has become increasingly serious in the case of industrial production (Chen et al., 2015). The traditional textile production has a high energy and water consumption. For example, in 2003 the annual water withdrawal of the large- and medium-sized textile and apparel companies in China was 1.3 billion tonnes and the annual effluent discharge was 1.26 billion tonnes (The National Environmental Protection Bureau, 2003). However, after 9 years, in 2012, the volume of effluent discharged by the textile, and apparel industry comprised 23 % (2.37 billion tons) of the total volume of 41 industries in China (Ministry of Environmental Protection of the People’s Republic of China, 2012). Consequently, the water use in apparel production needs to be studied in order to conduct the apparel industry to save water and reduce water pollution.

From the total amount of water use, the manufacturing, dyeing, and printing processes together consisted of 80% of water use and effluent discharge (Zhang, 2010). However, it is highly probable that the amount of water used and effluent will increase in the coming years since the variety of consumer requirements for textile and apparel, such as the color and printing pattern of textiles are becoming richer, demanding to higher water use and effluent produced by dyeing and printing products (Chen et al., 2015).

Currently, rotary or roller screen-printing is the main technology applied in the apparel manufacturing industry (Chen et al., 2015). Screen-printing has important shortcomings such as high water consumption and high effluent discharge. Digital textile printing is an alternative technology to screen-printing. Digital textile printing technology has become increasingly popular in the textile industry in the recent years (Chen et al., 2015).

Digital printing machines apply dye directly onto the fabric instead of using a mass of water to dissolve dye, which reduces water use and pollution at the dyeing and printing processes with significant amount (Li et al., 2011). The characteristic of conventional screen-printing is “print-to-stock” production whereas digital printing has “print-on-demand” capability. The benefit is that in theory the textile prints could be produced only when sold, which could avoid storing, discounting and possibly dumping of unsold products. Because of high set-up costs in screen-printing, 1 meter costs the same as 1000 meters of digital printed textile. The digital printing technology is also more effective both in product R&D iterative sampling and producing sale samples, as the work and cost of stencils and screen is not needed. Only 40-60% of sampled prints go to mass production. Cheap storage of digital files and “print-on-demand” is believed to become the of future of textile printing (Cie, 2015; Campbell, 2008).

The digital printing is seen as a versatile technology for textile modification. Any type of substrate can be used, and substrate and fabric can be changed easily and quickly. Some companies have changed from hybrid mill to pure digital mill. As the digital printing machinery needs only fraction floor space needed compared to rotary screen printing, companies can replace one roller printing production line with several digital printing machines. They have calculated that it is more cost-effective to run more digital printing machines than to operate both technologies (Campbell, 2008).

In addition to printing color, digital printing can be used to add other properties such as antimicrobial and bacteriostatic properties to the textile. One evolving application of digital printing is printed electronics on textile surfaces (Paul, 2015; Karanikas et al., 2013).

V. COLLOBATIVE BUSINESS MODEL TO JOIN THE FORCES BETWEEN BRAND OWNERS TO SHIFT TO DIGITAL TEXTILE PRINTING

As described in the previous section, digital textile printing includes plenty of benefits in terms of sustainability compared to conventional textile printing. In this section, we analyze the value chain of the apparel industry and find out the brand owners are the key player to drive this change towards digital textile printing. We suggest a collaborative business model to

join the forces between brand owners to shift towards digital textile printing.

Generally speaking, the value chain of the apparel industry consists of six distinct value-adding activities (Gereffi & Frederick, 2010, Fukunishi et al., 2012):

- Fiber production
- Yarn production
- Textile production and component production
- Garment production
- Distribution
- Marketing, branding and selling (wholesale and retail)

Figure 1 illustrates the activities from yarn production to ready-made garment. The distribution, marketing and selling activities as well as design and product R&D are excluded from the figure. Those illustrated activities are traditionally subcontracted whereas excluded activities are typically owned by the brand owner. The aim of the figure is to point out the three main stages (yarn manufacturing, textile manufacturing and garment manufacturing) added with their usage resources in each activity. The figure indicates that all three stages use electricity, but they differ in the usage of water and chemicals. Waste management happens along the entire value chain. The fiber yarn production, processing, and textile finishing consume so much water and chemicals in their processes. Thus, highest environmental improvements could be done in these stages (Gereffi & Frederick, 2010, Fukunishi et al., 2012).

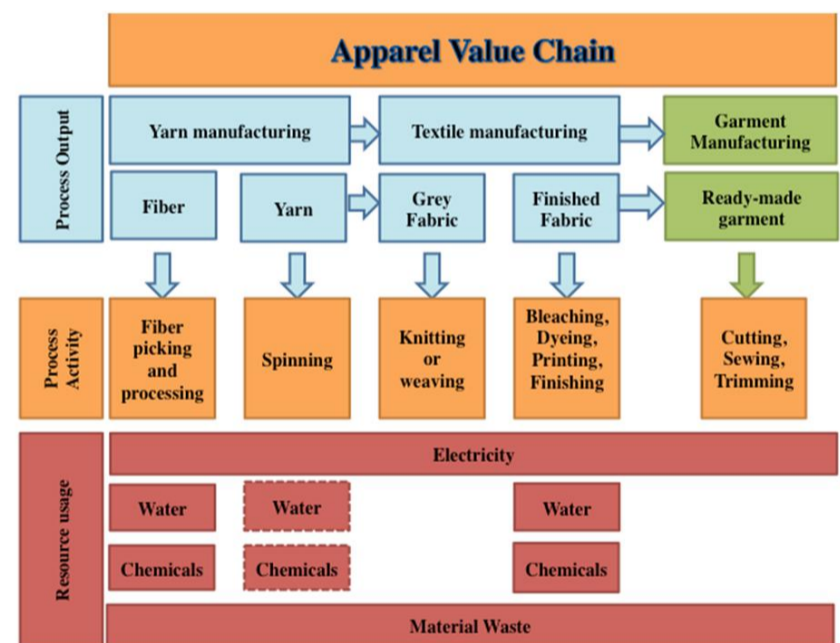


Figure 1-Description of apparel value chain segments without transportation and retailing segments adopted from (Gereffi & Frederick, 2010, Fukunishi et al., 2012, Martin, 2013).

The profit in value chain is generated in product creation (R&D and design), marketing and sales. Production “only” produces products based on product specification made by brand owner. The most important decisions are made before and after production. This means manufacturing companies usually are not the decision maker. The most important decisions are already set in all other stages (Fernandez-Stark et

al., 2011). These other stages (developing, purchasing and selling) are most likely owned and thus controlled by apparel brands owners. This implies that the brand owner is the decision-maker in the value chain of the apparel industry.

The brand owner and their R&D and design teams define how sustainable the product could become. The understanding and knowledge about technologies and materials to be used, and the impacts of those selections to the whole chain are essential in order to make sustainable decisions. Because the apparel manufacturing is taking place more or less in developing countries, the brand owner needs to give input, push and support, possibly even in financially to the manufacturing supplier to make investments to the sustainable technologies and processes. Thus, it is always the brand owner directly, who can lead the technological and product development for the more sustainable direction.

Figure 2 illustrates the decisive role of brand owners in the value chain of the apparel industry.

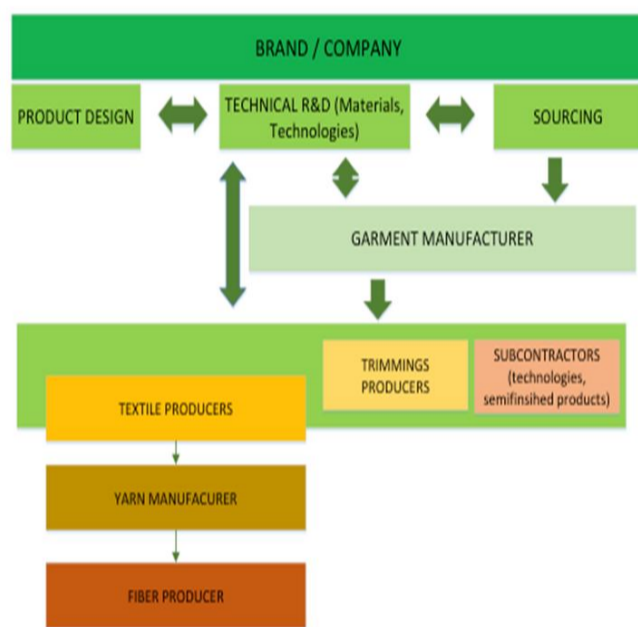


Figure 2- role of the brand owner in the value chain of the apparel industry.

Thus, we realize brand owners are the main driver of shift towards sustainable technologies such as digital textile printing in the value chain of the apparel industry. Likewise, pressures and incentives from brand owners could trigger “Other Brand Owners”, to follow this shift.

Since, we suggest applying digital textile printing by some brand owners (with pooling their resources) will most likely provoke the other brand owners to follow this shift. This shift might eventually results discontinuation of using the conventional water-intensive screen-printing technology in apparel production.

The brand company is directly in contact to suppliers (fabric, Component and technology supplier) in their value chain network. This is the way to improve the transparency of the value chain, which again enables brand owner to guide, support and even push the suppliers towards more sustainable choices in the production phases. Thus, brand owners require obtaining strong knowledge and skills about material, textile , clothing technologies and processes so they would specify the product, material properties and technologies to be used in the entire value chain. This means in order to make environmentally right choices, all processes and technologies

in the area of apparel manufacturing must be known by the brand owner.

For the case of digital textile printing, the brand owner has a challenging role as solid knowledge of each industry sector (fiber, yarn, textile and garment) is required in order to implement this change toward digital textile printing. To assist the brand owner to obtain these requirements, we suggest a model to pool the resources among brand owners of the apparel industry. As the focal decision makers, the brand owners could join their forces to form a pool, which has an aim to support the development to shift to more resource saving technologies and specifically digital textile printing. This model especially enables also smaller brand owners to have more power to these shifting actions, without being only the largest brand owners’ privilege.

We define the pool in this paper as follows: *A coalition to share the knowledge about sustainable issues between brand owners.* The brand owners who join the pool commit to apply technologies and process in order to speed up shift to more sustainable production. The concept of pool does not imply to any anti-competitive collation where the brand owners set the agreement to hamper competition. But the decisions made in the pool are in line with all legislation and they cannot be anti-competitive.

The positive economic and environmental impacts of shifting from conventional water intensive screen-printing to waterless digital textile printing, with applying the concept of pool, are illustrated in Figure 3. This figure illustrates our suggested collaborative business model based on the idea of pool of apparel brand, which is aligned with principle of social manufacturing as discussed before.

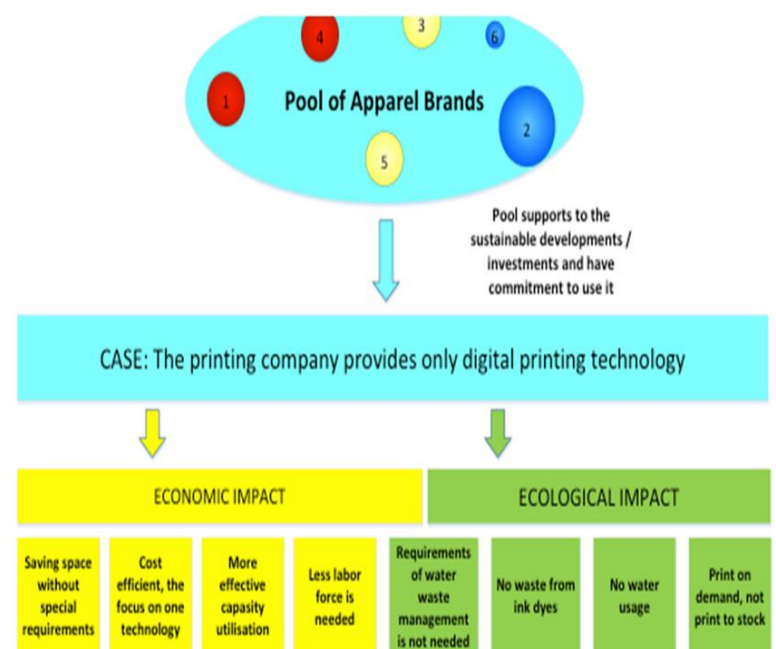


Figure 3- the collaborative business model based on the idea of pool of apparel brands.

This business model does not require high capital investments, but it would mean that the companies decide together to use that new eco-friendly technology instead of other alternatives. Relying on this shift being organized by the brand owners, the suppliers of the brand owners required to cease using of the resource-intensive technologies without losing their business. It is worth considering the companies cooperating in this pool might be competitors. Cooperating does not decrease their competitiveness. On the contrary, the advantage of cooperating is investing on sustainability, which increases the brand value of every brand owner. This course of

action could likely to promote and differentiate the companies inside the pool, creating a motivation for other brand owners to join.

VI. CONCLUSIONS AND FUTURE RESEACHES

Sustainability has become an important issue in contemporary business. Social manufacturing is also an evolving phenomenon in the recent years. The apparel industry is a good example for assessing the possible contribution of social manufacturing to improve sustainability in practice. The apparel industry has been faced with several sustainability issues. In the recent years, the apparel brand owners as well as customers have started to pay closer attention to sustainability. The apparel industry shows promising results in terms of economic sustainability.

Environmental and social sustainability in the apparel industry exhibit significant shortcomings. In this paper, we analyzed the value chain of the apparel industry. We chose the case study of the shift from conventional water-intensive screen-printing technology to waterless digital textile printing technologies. The textile manufacturing is very water and chemicals intensive processes. Dry and waterless processes such as dry spinning and dyeing as well as dry textile printing and finishing processes could be environmental-friendly technological solutions for having savings in usage in water, energy and dyestuff. The savings are significant only if it saves the resources as a whole. Therefore, a shift from conventional water-intensive screen-printing technology to digital textile printing technology makes a significant contribution to improving sustainability of the apparel industry.

In order to perform the shift from conventional water-intensive screen-printing technology to waterless digital textile printing technologies, we analyzed the role and influence of the players in the entire value chain of the apparel industry. We found that brand owners play a pivotal role in directing the apparel industry toward further sustainability. Accordingly, we suggested a model empowered with social manufacturing in which the brand owners can join their forces to support the implementation and development of the digital printing as the standard in the apparel industry.

The model proposed in this paper could be assessed with empirical case studies in future researches. Quantifying the saving would be another good approach in future researches. Joining the forces can be used to resolve other environmental issues such as waste management. The same approach shall be considered in the front-end part of the value chain in the apparel industry, i.e., marketing, distribution and selling. Another case could be the shift from fluorocarbon based textile repellent finishes to biodegradable eco-finishes. If more companies would decide only to use ecological textile finishes, the chemical companies could concentrate to develop only the ecological repellent finishes and effort for developing fluorocarbons would not be needed.

In recap, this paper proposes a new way to discard environmentally harmful technologies, i.e. conventional water-intensive technology, in the apparel industry, from the point of view of social manufacturing. We believe the proposed way and insights offered in this paper would accelerate the shift

towards more sustainable technologies in the apparel industry in the future.

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REFERENCES

- [1] Bluesign., (2016) Welcome to the Bluesign® system, online available at <http://www.bluesign.com>, Accessed (30 september.2016).
- [2] Campbell, J. R. (2008). Digital printing of textiles for improved apparel production. *Advances in Apparel Production*, Woodhead Publishing, 69, 222-49.
- [3] Caniato, F., Caridi, M., Crippa, L., & Moretto, A. (2012). Environmental sustainability in fashion supply chains: An exploratory case based research. *International journal of production economics*, 135(2), 659-670.
- [4] Cie, C. (2015). *Ink Jet Textile Printing, 2015*, Woodhead Publishing, Elsevier Chapter 9, Washing ink jet printed textiles, (pp 111 -123)
- [5] Cie,C. (2015). *Ink jet textile printing*, Woodhead Publishing, Elsevier , Chapter 11, The effect of ink jet on the textile printing industry (pp 139-152)
- [6] Chen, L., Ding, X., & Wu, X. (2015). Water Management Tool of Industrial Products: A case study of screen printing fabric and digital printing fabric. *Ecological Indicators*, 58, 86-94.
- [7] Fernandez-Stark, K., Gereffi, G., & Frederick, S. (2011). *The Apparel Global Value Chain: Economic Upgrading and Workforce Development* online available at http://www.cggc.duke.edu/pdfs/2011-11-11_CGGC_Apparel-Global-Value-Chain.pdf Accessed (10 September 2016)
- [8] Fukunishi, T., Goto, K., & Yamagata, T. (2013). Aid for trade and value chains in textiles and apparel. World Trade Organization, IDE-JETRO and the OECD, Paris.
- [9] Jiang, P., Ding, K., & Leng, J. (2016). Towards a cyber-physical-social-connected and service-oriented manufacturing paradigm: Social Manufacturing. *Manufacturing Letters*, 7, 15-21.
- [10] Gereffi, G., & Memedovic, O. (2003). *The global apparel value chain: What prospects for upgrading by developing countries* (pp. 1-40). Vienna: United Nations Industrial Development Organization.
- [11] Gereffi, G., & Frederick, S. (2010). *The global apparel value chain, trade and the crisis: challenges and opportunities for developing countries*. World Bank Policy Research Working Paper Series.
- [12] Gunther, M. (2016). Despite the Sustainable Apparel Coalition, there's a lot you don't know about that T-shirt, online available at <https://www.theguardian.com/sustainable-business/2016/jun/14/sustainable-apparel-coalition-factory-environment-water-textiles>, Accessed (1 October 2016)
- [13] Hamalainen, M., Mohajeri, B., & Nyberg, T. (2018). Removing barriers to sustainability research on personal fabrication and social manufacturing. *Journal of cleaner production*, 180, 666-681
- [14] Hill, J., & Lee, H. H. (2012). Young generation Y consumers' perceptions of sustainability in the apparel industry. *Journal of Fashion Marketing and Management: An International Journal*, 16(4), 477-491.
- [15] Karanikas, E. K., Nikolaidis, N. F., & Tsatsaroni, E. G. (2013). Preparation of novel ink-jet inks with antimicrobial and bacteriostatic properties to be used for digital printing of polyester and polyamide fibers. *Progress in Organic Coatings*, 76(7), 1112-1118.
- [16] Kiron, D., Kruschwitz, N., Haanaes, K., Reeves, M., Fuisz-Kehrbach, S. K., & Kell, G. (2015). Joining forces: collaboration and leadership for sustainability. *MIT Sloan Management Review*, 56(3), 1-32.

- [17] Li, M., Zhang, Q., Yinan, Y.U., (2011). Present state and developing trend of digital printing. *Dyestuffs Coloration* 48 (December (6)), 32–34.
- [18] McNamara, K. (2008). The global textile and garment industry: The role of information and communication technologies (ICTs) in exploiting the value chain, infoDev publication (Washington DC, World Bank).
- [19] Martin, M. (2013). Creating Sustainable Apparel Value Chains: A Primer on Industry Transformation, *Impact Economy*, online at: http://www.impacteconomy.com/papers/IE_PRIMER_DECEMBER2013_EN.pdf, Accessed [29.9.2015].
- [20] Mohajeri, B., Nyberg, T., Karjalainen, J., Tukiainen, T., Nelson, M., Shang, X., & Xiong, G. (2014). The impact of Social Manufacturing on the value chain model in the apparel industry. In *Service Operations and Logistics, and Informatics (SOLI)*, 2014 IEEE International Conference on (pp. 378-381). IEEE.
- [21] Ngai, E. W. T., Peng, S., Alexander, P., & Moon, K. K. (2014). Decision support and intelligent systems in the textile and apparel supply chain: An academic review of research articles. *Expert Systems with Applications*, 41(1), 81-91.
- [22] National Bureau of Statistics of China, (2003) online available at <http://data.stats.gov.cn> Accessed (20 June 2016).
- [23] Newman, D. (2014). The Omni-Channel Experience: Marketing Meets Ubiquity, online available at <http://www.forbes.com/sites/danielnewman/2014/07/22/the-omni-channel-experience-marketing-meets-ubiquity/> Accessed [3.3.2015].
- [24] Paul, R. (Ed.). (2015). *Denim: Manufacture, Finishing and Applications*. Woodhead Publishing, Elsevier
- [25] Romano, P., & Vinelli, A. (2001). Quality management in a supply chain perspective: strategic and operative choices in a textile-apparel network. *International Journal of Operations & Production Management*, 21(4), 446-460.
- [26] Seuring, S., & Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. *Journal of cleaner production*, 16(15), 1699-1710.
- [27] Shang, X., Liu, X., Xiong, G., Cheng, C., Ma, Y., & Nyberg, T. R. (2013, July). Social Manufacturing cloud service platform for the mass customization in apparel industry. In *Service Operations and Logistics, and Informatics (SOLI)*, 2013 IEEE International Conference (pp. 220-224). IEEE.
- [28] Shang, X., Xiong, G., Nyberg, T. R., Wang, F., & Cheng, C. (2017). Social manufacturing cloud for high-end apparel customization. *Acta Automatica Sinica*, 42(1), 1-12.
- [29] Shang, X., Shen, Z., Xiong, G., Wang, F. Y., Liu, S., Nyberg, T. R., ... & Guo, C. (2019). Moving from mass customization to social manufacturing: a footwear industry case study. *International Journal of Computer Integrated Manufacturing*, 32(2), 194-205.
- [30] The Economist. (2012). A third industrial revolution, online available at: <http://www.economist.com/node/21552901> Accessed [21.05.2014].
- [31] Yamato, M. (2005). Eco-vehicle assessment system (Eco-VAS): a comprehensive environmental impact assessment system for the entire development process. *Toyota Technical Review*, 54(1), 80.
- [32] Wang, F.-Y. (2012). From social calculation to Social Manufacturing: one coming industrial revolution. *Bulletin of Chinese Academy of Sciences*, 27(6): pp. 658-669.
- [33] Wang, F. Y., Shang, X., Qin, R., Xiong, G., & Nyberg, T. R. (2019). Social Manufacturing: A Paradigm Shift for Smart Prosumers in the Era of Societies 5.0. *IEEE Transactions on Computational Social Systems*, 6(5), 822-829.
- [34] Winter, S., & Lasch, R. (2016). Environmental and social criteria in supplier evaluation—Lessons from the fashion and apparel industry. *Journal of Cleaner Production*, 139, 175-190.
- [35] Xiong, G., Chen, Y., Shang, X., Liu, X., & Nyberg, T. (2014). AHP Fuzzy Comprehensive Method of Supplier Evaluation in Social Manufacturing Mode. The 11th World Congress on Intelligent Control and Automation
- [36] Xiong, G., Wang, F. Y., Nyberg, T. R., Shang, X., Zhou, M., Shen, Z., ... & Guo, C. (2017). From mind to products: towards social manufacturing and service. *IEEE/CAA Journal of Automatica Sinica*, 5(1), 47-57.
- [37] Zhang, J., (2010). Development and application of new types of pretreatment auxiliaries suited to requirements of low-carbon economy (I). *China Textile Leader* (7), 97–98.