Process analysis of an in store production of knitted clothing

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Abstract
In the textile and clothing industry, global value-added networks are widespread for textile and clothing production. As a result of global networking, the value chain is fragmented and a great deal of effort is required to coordinate the production processes [1]. In addition, the planning effort on the quantity and design of the goods is high and risky. Today the fashion industry is facing an increasing customer demand for individual and customizable products in addition to short delivery times [2]. These challenges are passed down to the textile and clothing industry decreasing batch sizes and production times. Conventional clothing production cannot fulfill those demands especially when combined with more and more individual or customizable designs. Hence new production concepts have to be developed.

1. Introduction
The target of every company is to satisfy customer demands. Especially the clothing industry has to serve individual customer requirements. Textile products always have been and still are the defining attributes of people’s appearance. Consumer’s demands towards commercial clothing companies have been changing rapidly during the recent years. Two global megatrends have supported this change: Individualization and digitalization. Individualization created demand for frequent collection changes, while still keeping availability high. Digitalization supported the quick distribution of new trends and forced a higher amount of request during peak periods [3].

Both developments represent a special challenge for the complexity management of global clothing companies. Frequent collection changes have to be managed by supply chain management (SCM). SCM needs to coordinate a growing number of products and suppliers on a global scale. The development of automation in the textile industry has offered alternatives to the distress of growing complexity. Due to the increasing share of intelligent systems within the process chain, textile manufacturers are able to reduce the impact of labor costs. In reaction to the reduced share of labor costs new locations for production facilities have been enabled. Even a production in high-wage countries like Germany and the United States has become imaginable.

In order to evaluate the benefit of agile and flexible production systems a comprehensive must be found and reasonably applied on new and existing production designs. This work evaluates different production systems for the textile industry regarding defined target values of production. In collaboration with the adidas AG, Herzogenaurach, Germany, two production processes have been defined which build the foundation for a textile process analysis method. The results can be used to make decisions on future production systems.

2. Concept description and requirements
Aim of the STOREFACTORY project is the development of an in-store fashion production. Flat knitting is chosen as the main production process, as it offers the possibility to produce clothing
without using joining technics, which is often referred as knit2wear production. As the fashion product
a knitted sweater is selected [4].
The in-store user-experience consists of a body scanner and design stations, where the customer creates their individual fashion products. These processes are supported by a software-system, which transfers the individual body-measurements and the design into the necessary machine data. The production itself takes place on three flat-knitting-machines followed by thermosetting as well as finishing equipment for the statutory labeling. Figure 1 outlines the customer experience in the developed concept.
Using the body scanner, the metric data of the customer is measured. The measurements guarantee a highly individual perfect fit. The metric data then is used in the design station, where the customer can design the patterning and coloring of his product. The colors are limited to the equipped colors on the knitting machines available. One machine can be equipped with up to three different colors, which can be combined in different proportions. When the customer is satisfied with his customization, the design is transferred to the knitting machine with help of the converter unit. The converter unit not only takes into account the shrinkage, but also converts the metric data into machine-data.

![Figure 1. Storefactory customer journey](image)

The methodology needs to include a range of target variables, including companies’ targets of maximized profit, customer satisfaction, etc. A proper evaluation method and visualizing production processes is based on the principle of the value stream. This model has been designed to identify different types of waste within defined production segments: transportation, inventory, motion, waiting, over-processing, over-production and defects. This method captures the comprehensive process of the production and visualizes and rates processes as well as the physical flow. [5, 6]
The analysis is started by detecting the value stream along the production chain. The process steps are separated into value adding, non-value adding and information processes. Value adding means in this context that the condition of the processed good is changed into a more valuable state. Value is defined by the customer. The outcome of the process step will be valuable if the outcome provides a
benefit to the customer. Value adding processes in the textile production are for example: knitting, weaving, mercerizing, dyeing, etc. Non-value adding steps are transportation, waiting, over-production, etc. By evaluating the process steps, problems and constraints can be identified. The identification is supported by KPIs providing a quantitative rating on the current state of the process. The visual implementation of the value stream analysis is achieved with a graphic tool, called the value stream map. Value stream mapping consists of a visual qualitative and quantitative analysis. The qualitative analysis is conducted by a value stream map. The analysis shows the structure of an entire production chain with flow of material, information, processes and process abilities. [7, 8]

Within the project two scenarios were examined. The conventionally product produced in Southeast Asia, is starting with the order from a marketing division, which is processed into a yarn order by the garment producer. After the yarn has arrived the garment is produced and shipped back to the final destination market.

The in-store production starts as described with the measurement and the design selection of the customer, who is then giving the final production order. The customer data on design and size is translated by a manufacturing execution system into a machine readable code. The knitting machines read the code and produce the textile as one piece. Afterwards it is finished during several finishing steps.

3. Findings

The production in-store is located close to the customer. Assumptions and expert interviews indicate that in-store production is more costly than the conventional process, so the profit is lower. The influence of the customer distance of conventional and in-store production is visualized in Figure 2 on the order penetration point (OPP). When facing different customer demands, the production structures have to change as well. The OPP in the work process also defines the type of order processing and affects the manufacturing form. The OPP defines the point of time the order is being processed with specific customer relation.

![Figure 2](image)

**Figure 2.** Order penetration points for the in-store and the conventional production

In the conventional process a product is manufactured on stock and independent to the customer. Most of the work progress is already completed. The finished work process results in delivery times technically close to zero minutes after the customer order because the product is instantly available.
Guidelines support the build-up of capital in form of warehouse inventory. Sometimes the product is not sold directly after arrival in the designated country. The order amount is based on forecasts. If the forecast is wrong, the product won’t be sold for the calculated price. This results in an actual risk that the product will not be sold for the originally estimated price because there may not be an actual demand later. In this case, the product has to be sold with a reduced price.

The value stream analysis shows the differences in production lead time of two knitted products. Both processes have the same starting and ending activity, beginning with the customer order and the customer delivery. For the conventional production, the whole process takes about 289 days. However, the in-store production all in all takes about 175 minutes. Both cycle times are visualized in Figure 3.

![Figure 3. Lead time comparison between conventional and storefactory production](image)

The comparison on the fractions of time used to create value with the product differs a lot, when the conventional and the in-store production are set against each other. Especially the comparison of the transportations as non-value adding time shows how the impact of delivery loyalty between both production designs (Figure 3).

![Figure 4. Process percentage of both production designs](image)

While the in-store production is generating more value adding process time, the production is more expensive.
4. Conclusion
The detected data from the process analysis shows the advantages and disadvantages of an in-store production against a conventional production in Southeast Asia. In order to fulfil customer demands quicker and with lower market risk textile producers must revaluate their business model. Especially with rising labour costs in Southeast Asia production in Europe becomes a more crucial option.
A conventional production process is characterized through high process times, high amount of planning, controlling efforts and risks due to capital commitment in the make-to-stock process. The advantage of this process is low production costs due to low labor costs. A customized in-store production process is characterized through low capital commitment but high delivery times due to the make-to-order process.
Both processes have been analyzed regarding costs and process times in order to define the challenges of a comprehensive textile process analysis. Based on the evaluation of the value stream analysis for both production systems can be evaluated and tested. The tool indicates financial and the temporal impacts of changes in the production specification. A future development would be the further collection of information through “Industrie 4.0” applications on textile production processes in order to evolve usability. The evolution of the value stream analysis can provide a basis on decision-making for future strategically production decisions.

5. Acknowledgement
The authors acknowledge the financial support by the Federal Ministry for Economic Affairs and Energy of Germany (BMWi) in the project STOREFACTORY as part of the “Autonomics for Industry 4.0“ framework”.

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The future of textile production in high wage countries

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Abstract. It is undisputed that smart production in the context of industry 4.0 offers significant potential for industrial production in Germany. Exploiting this potential provides an opportunity to meet the growing competitive pressure for textile production in high-wage Germany. The complete cross-linking of textile mills towards Textile Production 4.0 means substantial savings. However, currently there are still some challenges that have to be overcome on the long way to Textile Production 4.0. This paper initially reflects the particular challenges of textile production in high-wage Germany. Later, the vision of the future of smart textile production will be outlined. In addition, first pilot solutions and current research approaches which pave the way for Textile Production 4.0 are described.

1. Challenges of textile production in high wage countries

Because of the low production costs, the textile production has been relocated to the Asian countries, whereas the production of high-quality and technical textiles is progressively shifted to Europe [1]. The textile industry in high-wage countries is facing numerous challenges. For example, the tendency to small lot sizes requires shorter cycle times and aggravates the economical production of goods [2]. The use of Industry 4.0 in textile machinery and textile production has been examined at the Institute of Textile Technology at RWTH Aachen University [3]. The study on German textile machinery manufacturers and textile producers shows that terms such as Industry 4.0, cyber-physical system or Smart Factory are not yet sufficiently known. The challenges regarding Industry 4.0 also include: standardization, process and work organization, protection of know-how, availability of technology and shortage of skilled workers. Important preconditions for the successful implementation of Industry 4.0 require information gathering, testing technologies, convincing decision-makers in the company and, ultimately, the ability to raise capital [4].

Another challenge for textile production in high wage countries is the average return on sales of around 2.5% [5]. The low profit margins make it difficult for textile producers to accumulate reserves and thus indirectly force major investments. The companies are more focused on conventional production methods and carefully invest in new technologies and developments. This way innovation of textile machine manufacturers meets difficulties on the market, which in turn weakens the innovative strength. Thus, textile production in high wage countries is caught in a vicious circle. Looking at the overall industry environment in those countries, there is an increasing risk of being superseded in terms of technological forefront.

Multi scaling and additive fabrication is a special problem of the textile process chain. The simple way of the textile process chain is to make yarns out of fibers, yarns to surfaces, and textile surfaces to complex textile products (see Figure 1). The whole creation of value of the process chain is rarely done by only one company. Normally products are exchanged between companies for different
processes like spinning and weaving. Every machine is separately equipped and adjusted by the machine operator (see Figure 1). The operator makes decisions based on the information of the semi-finished products and adjusts production and quality parameters.

Figure 1. Example of the typical fragmented textile process chain in high wage countries

This fragmented process chain, where highly specialized companies overtake single production steps is not the only exception in German textile industry. In addition the way of textile production from yarn building to the finish product an ever changing process. Fibres, yarns, textile surfaces and textile products showing heavy varied length scale and weight (see Figure 2). Furthermore, the efficiency varies depending on the production process from line to single production.

Figure 2. Manufacturing character of textile production

The particular features of textile production in high wage countries can be defined by the following:

- fragmented production chain
- switching between continuous production and piece production
- different orders of magnitude
- lack of standardization of communication interfaces
- low return on sales and investment affinity resulting from it

These peculiarities complicate the introduction of cross-process technological innovations such as Industry 4.0. Solving these problems will be the chance for the high wage countries to keep their technical leadership.

2. The Vision – Concept of Textile Production 4.0
To be able to continue production of textiles in a highly competitive environment, several factors have to be considered. Cost reductions and efficiency improvements ensure economical production.
However, the individual production processes are already highly automated. Hence it is pretty expensive to archive cost reductions and higher efficiencies via technological enhancements.

To reduce costs and stay competitive Industry 4.0 comes into play. Linking the whole textile process chain (see Figure 3) makes information available everywhere in the process. With use of enhanced machine cognition, those machines become capable to react on changing process- and boundary conditions.

![Figure 3. Concept of Textile Production 4.0](image)

A hallmark of Smart Textile Factory is complete communication of various physical systems [6]. Those from the known boundaries between the individual levels of the company’s automation pyramid have to be destroyed and assembled into a vertical system. Serving as a comprehensive communication platform of the Internet of Things it offers an unrestricted exchange of data on the horizontal plane between all physical systems [7].

Another feature of smart textile factory is inherent machine cognition. The machine recognises itself and the other devices belonging to the same system. In addition, the machine is able to act on changing processes and conditions individually and to make production-related decisions w.r.t. its own abilities. Application of distributed physical information carriers such as RFID tags is another part of Textile Production 4.0. RFID tags support textile production and include either product data or certificates used to retrieve partially sensitive product data over the Internet of Things. In addition to it, the RFID-enabled products are able to control their own processes.

3. Successful example - Self-optimising textile machinery

It was shown in the previous sections how Smart Textile Production of the future may look like. It is obvious that it is a great way to achieve this vision. Successful pilot projects like the smart bobbin using RFID information carriers [4] or the self-optimizing machinery [8] lead to measurable reductions of processing costs. Exemplary the multi-objective self-optimization is described in the upcoming subchapter.

3.1. Cognitive machinery – Self-optimizing weaving loom

A fundamental concept of maintaining competitiveness in high-wage countries is to reduce the manual production effort. In particular, the initial setup of textile production requires substantial amount of
manual work that lead to significant production costs. It is essential to reduce the duration of the manual setup processes in order to reduce these costs.

In addition to manual work, a significant amount of setup time is spent in search for the optimal process parameters. Despite usage of process databases providing initial parameters based on historical data, these parameters are determined by means of the time-consuming Trial & Error principle. In this case, knowledge and experience of the operator play an insignificant role.

A multi-objective self-optimization of the weaving machine was developed at ITA. Self-optimizing systems are defined as "systems [...], which are capable of making changes in their internal state or its structure independently due to changes in input conditions or disorders" [9]. The following objective functions are considered by the multi-objective self-optimization (MOSO) of the weaving process:

- warp tension
- energy consumption of the weaving machine (air- and active power consumption)
- quality of the fabric

The objective functions are optimized according to the following parameters:

- basic warp tension (bwt)
- revolutions per minute (n)
- vertical warp stop motion position (wsmy)

With the MOSO routine, a weaving machine is enabled to automatically find an optimal configuration. Figure 4 shows the concept of the self-optimizing weaving machine.

The MOSO of the weaving process is validated during a long-term test in the laboratory of ITA [6]. To establish industrial conditions, the duration of the long-term test is eight hours, like usual shift duration. A long-term test is carried out using the MOSO against not using the optimization procedure respectively, to examine the influence of MOSO on production figures.

The long-term test is conducted with an air-jet weaving machine OmniPlus 800 by Picanol n.v., Ieper, Belgium. During the long-term test, polyester filament yarn with 330 dtex for warp and weft was used (binding: twill 3/1). The configurations of MOSO used for the long-term test are listed in Table 1. After program execution of MOSO, the algorithm calculates the following optimal parameter settings: $bwt = 3.71 \text{ kN}; n = 522 \text{ RPM}; wsmy = 20 \text{ mm}$.
Table 1. Configuration of MOSO for long-term tests [6]

<table>
<thead>
<tr>
<th>bwt (kN)</th>
<th>n (rpm)</th>
<th>wsmy (mm)</th>
<th>TW warp tension</th>
<th>TW energy consumption</th>
<th>TW quality</th>
<th>Algorithm start point bwt/n/wsmy</th>
</tr>
</thead>
<tbody>
<tr>
<td>min</td>
<td>2</td>
<td>400</td>
<td>0</td>
<td>LOW</td>
<td>LOW</td>
<td>750 rpm / 15 mm</td>
</tr>
<tr>
<td>max</td>
<td>4</td>
<td>900</td>
<td>20</td>
<td>LOW</td>
<td>HIGH</td>
<td></td>
</tr>
</tbody>
</table>

The following settings are used as reference settings coming from an industrial weaving mill that processes the same material as mentioned above: bwt=4 kN; n=900 RPM; wsmy=0 mm. The results of the long-term test using MOSO and reference settings are shown in Table 2.

Table 1. Long-term test results of MOSO weaving machine in comparison to reference settings

<table>
<thead>
<tr>
<th>Recorded data</th>
<th>Unit</th>
<th>Results MOSO</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency (prod. Time / total time)</td>
<td>%</td>
<td>98,60</td>
<td>37,20</td>
</tr>
<tr>
<td>Weft insertions</td>
<td></td>
<td>125157</td>
<td>215982</td>
</tr>
<tr>
<td>Weft meters</td>
<td>m</td>
<td>237798</td>
<td>410365</td>
</tr>
<tr>
<td>Average quality category</td>
<td></td>
<td>0,93</td>
<td>1,55</td>
</tr>
<tr>
<td>Weft defects</td>
<td></td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Quality efficiency</td>
<td>/mio m</td>
<td>8,41</td>
<td>14,62</td>
</tr>
<tr>
<td>Average warp tension</td>
<td>N</td>
<td>1,27</td>
<td>1,49</td>
</tr>
<tr>
<td>Average air consumption</td>
<td>m³/h i. N.</td>
<td>134,23</td>
<td>155,26</td>
</tr>
<tr>
<td>Air consumption efficiency</td>
<td>m³/mio m</td>
<td>564,47</td>
<td>378,35</td>
</tr>
<tr>
<td>Average active power usage</td>
<td>kW</td>
<td>2,49</td>
<td>4,62</td>
</tr>
<tr>
<td>Active power consumption efficiency</td>
<td>kW/mio m</td>
<td>10,47</td>
<td>11,26</td>
</tr>
<tr>
<td>Set-up time</td>
<td>Min</td>
<td>30</td>
<td>120</td>
</tr>
</tbody>
</table>

The program for self-optimization successfully enables the weaving machine to autonomously find an operating point, which improves the targeted objective function compared to conventional (reference) machine settings for at least 14 % [6]. Without MOSO a machine operator needs around 120 min. for the configuration of the weaving machine and to find appropriate settings for the process. The program for self-optimization is concluded in 30 minutes and successfully reduces the set-up time by 75 %.

4. Conclusion and Outlook
The specific properties of textile products and the special characteristics of the textile manufacturing chain may involve a number of challenges that need to be considered on the way to Textile Production 4.0. There already exist various approaches and first pilot projects. Also, the federal governments have recognized the challenges and provide support by several research projects such as Speedfactory, Factory Store and Smart Factory related to development of smart textile production. Nevertheless, the textile industry must increase investments into the research field of Industry 4.0 in order to preserve technological and economical connections.

Acknowledgement
The authors would like to thank the German Research Foundation DFG for the kind support within the Cluster of Excellence “Integrative Production Technology for High-Wage Countries”.

References


Comparative analysis of sustainable consumption and production in Visegrad region - conclusions for textile and clothing sector

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Abstract. Gradual environmental degradation, shrinking of non-renewable resources, and lower quality of life are directly or indirectly arising from snowballing consumption. These unfavorable processes concern increasingly textile and clothing sector and are increasingly being felt in Visegrad (V4) countries. The objective of the article was to access current consumption patterns in V4 countries, identify the factors that influence those patterns and finally to draw the conclusions for more sustainable consumption and production models as well as to make a comparative analysis of the results across V4 countries. A consumer survey was conducted to examine V4 citizens’ attitudes and behaviors in the context of sustainable consumption. To ensure sample size and comparability across countries 2000 randomly-selected V4 citizens, aged 18 and over, were interviewed. To analyze the supply side of the market and legal framework, the desk research was used. The results allowed to give some guidelines for the joint V4 strategy for solving ecological and social problems of V4 countries as well as the conclusions for textile and clothing sector.

1. Introduction

The Visegrad Group (also known as the "Visegrad Four" or "V4") reflects the efforts of the countries of the Central European region (Czech Republic, Hungary, Poland and Slovakia) to work together in a number of fields of common interest (such as education, culture, science, environment, regional development, civil society development, transport, etc.) within the all-European integration. One of this field of this cooperation is also sustainable development and more recently circular economy model.

Gradual environmental degradation, shrinking of non-renewable resources, and lower quality of life are directly or indirectly arising from snowballing consumption. These unfavorable processes concern increasingly textile and clothing sector and are increasingly being felt in Visegrad (V4) countries. They will not stop unless consumption patterns are modified [1]. Therefore, the sustainability agenda has gradually been shifting to include consumption alongside production. Manufacturers may use new designs and technologies to minimize the impact of a product on the environment, but their efforts are pointless if consumers do not buy more sustainable goods and do not
change their consumption habits. Therefore, a change in the attitudes of textile and clothing companies and consumers towards a more responsible behavior is needed. It is a gradual process that needs appropriate knowledge, awareness, and frequently the modification of long-standing habits. These needs and challenges have brought the authors to the objectives of the project „Prospects of the Visegrad cooperation in promoting a sustainable consumption and production models” implemented within the framework of the Visegrad Fund Strategic Grants. The main results of the project are presented in the article.

1.1. The research aims
The objective of this project was to support and strengthen the cohesion of the V4 countries in the efforts to achieve a more sustainable consumption culture and thus more sustainable production models in the selected consumer goods’ markets one of them was textile and clothing market. In order to do that, the project undertook the analysis of immediate connections and influences of: the demand side of the markets (consumers), the supply side of the market (producers), legal framework and cultural impact. An important part of the project was a comparative analysis of the results across V4 countries allowing to give some guidelines for the joint V4 strategy for solving ecological and social problems of V4 countries.

1.2. The research scope and methodology
One of the main objectives of the project was to access current consumption patterns in V4 countries, identify the factors that influence those patterns and finally to draw the conclusions for more sustainable consumption models.

For this purpose, the primary research study was used. A consumer survey was conducted to examine V4 citizens’ attitudes and behaviors in the context of sustainable consumption. In particular, the survey examined following aspects of consumers’ behavior: environmental knowledge and concern, perceived consumer effectiveness (PCE) and perceived marketplace influence, environmental actions undertaken within last twelve months, barriers and buying behavior (PMI). To ensure sample size and comparability across countries 2000 randomly-selected V4 citizens, aged 18 and over, were interviewed. The interviews were carried out via Computer Assisted Web Interviewing (CAWI). To determine if there are statistically significant differences across the V4 countries, the Kruskal-Wallis H test (one-way ANOVA on ranks) was used. To analyse the supply side of the market and legal framework, the desk research was used - analyze of the available survey results, reports and statistical data. In this part we concentrated on the following aspects: sustainable production prospects (in the context of social and ethical as well as economic determinants), development of sustainable products markets in Poland, sustainable patterns of production in business operations, the main barriers and challenges of sustainable production.

2. Research results
In the first step we concentrated on the demand side of the market represented by consumers, their values and attitudes.

2.1. Demand, values, attitudes, cultural impact – differences and similarities
To access the level of respondents’ environmental knowledge they were asked how much they agree or disagree with the three statements (‘When I am a choosing a product, I very often pay attention to environmental or social labelling before deciding to buy’, ‘I don’t feel I have enough knowledge to choice more sustainable products with less environmental and/or social impact’, ‘I often read articles or news about environmental and/or social impact of products I buy’). A Kruskal-Wallis H test showed that there was a statistically significant difference in case of all the statements between the V4 countries. The value of the mean rank as well as the the distribution of answers suggest that the country whose respondents access their environmental knowledge lowest is Slovakia. It is also worth to outline that in all countries we can observe relatively high proportion of uncertain answers „neither
agree or disagree”. This may suggest that respondents had some problems with clear understanding the right meaning of the questions concerning environmental knowledge, or that the issue was not so important for them.

Another very important factor influencing sustainable consumption is environmental sensitivity. The knowledge itself very often is not enough. What we need is a combination of knowledge, the awareness resulting from it, and the individual predisposition of a particular person which produces a category referred to as concern [1]. Together they can lead to seeking and purchasing sustainable products. Generally, the results indicate that, compared with environmental knowledge, the respondents in all V4 countries represent a higher level of environmental sensitivity. Most people from the V4 countries think that “we are approaching a disaster and politicians make little effort to protect the environment”. However, there are some differences between the countries. People from Poland, the Czech Republic and Slovakia showed a similar level of concern about environmental conditions for future generations. In contrast, the respondents form Hungary differed from the other V4 countries in these area, as a higher percentage of them agreed that they were afraid when they are thinking about environmental conditions for future generations and that we are approaching an environmental disaster if we continue our current style of living. At the same time the highest percentage of them disagreed (“strongly” or “rather”) that environmental problems were greatly exaggerated by the opponents of the environmental movement. Therefore, we could conclude that (at least at the level of declarations), the Hungarians represent slightly higher environmental sensitivity then the citizens of other three Visegrad countries.

As far as sustainable products are concerned the influence of the so called perceived consumer effectiveness PCE is attributed a grave importance. The PCE is understood as a measure of the subject’s judgment in the ability of individual consumers to affect environmental resource problems [2]. A significant impact of PCE on sustainable consumption was also confirmed in the literature [3,4]. The concept of perceived marketplace influence - PMI is similar to PCE in nature, however, rather than solely looking at whether someone feels their actions are individually making a difference in environmental problems, it captures an individual's belief that their actions are actively influencing the behaviour of other marketplace actors – consumers or organizations [5]. The survey prompted consumers with four statements to see how strongly they believe they can make a difference in solving environmental problems and influence other consumers or companies. The results showed that generally Polish consumers had a slightly stronger feeling that they can influence other members of their community, companies’ performance and the solution of environmental problems than the citizens of other V4 countries.

We also asked the consumers how often, if at all, they undertook concreate actions. Three of the questions related to the before purchase phrase: looking for information, avoiding the purchase of unethical products and buying sustainable products. The remaining five questions concerned the post purchase behaviour: rationalization of the laundry process, and proceeding with used products: repairing them, passing and swapping, segregating and composting. Despite some differences between particular countries generally we could conclude that V4 consumers are more active in the after purchase phrase and also in those activities that do not require a lot of knowledge and engagement but additionally can bring some economic reward. We could say that the most frequent activities, were those activities that we could call “every day practices”, that are well known, do not require additional knowledge or engagement. More engaging activities, like making compost with the food waste at home turned out to be far less popular among V4 consumers.

Another important aim of the survey was to identify the main barriers to introducing more sustainable consumption patterns and therefore development of “eco market”. Despite those differences we could conclude that in all V4 countries the most important barriers were: insufficient availability of sustainable products, too high price of sustainable products and lack of confidence in eco-labels, in different order, depending on the country. The least important barrier, in all countries, turned out to be unsatisfactory attractiveness of sustainable products. Additionally, a high percentage of neutral/uncertain answers “neither agree nor disagree” given to questions relating
to sustainable options/products may suggest that respondents in all countries were somehow confused about the terms “environmentally friendly” and “harmful” products.

It was also important to see to what extent Visegrad consumers manifest unreasonably high consumption level known as consumerism. The results indicate that despite some differences between countries a large majority of V4 respondents manifests a rather non-consumerist attitude, declaring that they buy things only when they really need them, that they rather not shop just for the pleasure of shopping, that they do not frequently buy things that they hardly use, and that they buy things only when they really need them. However, this may arise not so much from a conscious opposition to consumerism but rather from economic limitations.

2.2. Supply, legal framework – differences and similarities across V4 countries
In this part of the project we tried to to answer the question: “How could the existing niche markets for sustainable products be extended to mass markets?” Important aspects in this area are ethics and social attitudes, manifested to a large extent on trust, social and human capital. One of the key factors shaping the attitudes and social capital of a country is trust. It applies to the relationships between individual human beings, between companies being represented by them, as well as between sectors and communities. According to the European Social Survey (ESS) [6], in terms of the general level of trust all V4 countries occupy the last four places among the European countries. V4 respondents think that people in their countries mostly look out for themselves and are not helpful, most people can not be trusted and most people try to get advantage of others rather then to be fair.

Another of the analyzed indicators was the the ‘resource productivity”, which is calculated by dividing GDP (gross domestic product) deflated by DMG (domestic material consumption), is used to monitor the relationship between resource use and economic growth. Improving resource productivity and ensuring a sustainable resource and materials management building on the principle of the 3Rs (reduce, reuse, recycle) is a central element of green growth policies. It helps to improve the environment by reducing the amount of resources that the economy requires and diminishing the associated environmental impacts, and sustains economic growth by securing adequate supplies of materials and improving competitiveness [7]. The Eurostat data shows that values of resource productivity (measured in purchasing power standards [PPS] per kg) are lowest in Poland. However, we could conclude that resource productivity generally is not high in Visegrad Region [8].

Another important indicator is eco-innovation index, which refers to the development of new or significantly improved products (goods and services) or organisational practices that reduce the use of natural resources and decrease the release of harmful substances throughout the entire life cycle. It plays an important role in addressing environmental challenges without compromising economic and social objectives. Besides its environmental benefits, eco-innovation brings new products to the market, contributing to economic activity and job creation [9]. The EU eco-innovation index shows how well individual Member States perform in eco-innovation compared with the EU average. The only V4 country that in 2015 had the European Eco-Innovation Scoreboard at the level of the EU average was the Czech Republic. The country with the lowest score in almost all years during the period 2010-2015 was Poland.

In the EU the top priority is to prevent and minimize waste. It is followed by treatment methods, such as reuse and recycling, energy recovery through incineration and, lastly, disposal in the form of landfilling [9]. Since recycling and composting reduce the amount of waste that needs to be disposed of and reduce demand for raw materials, leading to the reduction in primary resource extraction, those ways of waste treating are assumed to be most environmentally friendly and therefore desirable. Analysis the Eurostat data on total waste recycled in the EU-28 in 2012 showed that Poland recycled over 50% and Czech Republic almost 50% of its total waste. Lower percentage can be observed in the case of Slovakia (37%) and Hungary (36%). However, we can consider whether the total waste indicator is the best one in the analyses of the general trend in waste generation and comparative analyses. A more rational indicator seems to be landfill rate of waste, excluding major mineral wastes. Looking at this indicator, we can see that Poland, together with the Czech Republic, is slightly below
the EU average, with 30% landfill rate of waste. It is a much better result than in the case of the other two V4 countries, Slovakia and Hungary.

Another important area that we analyzed was environmental certification and labelling. One of the voluntary European implemented to encourage different organizations (companies, plants, institutions, etc.) to keep improving their environmental performance is the Eco-management and Audit Scheme (EMAS). The Eurostat data showed that the number of EMAS-registered organisations and sites across the European countries is highly differentiated. All V4 countries lag far behind the EU leaders, which are Germany, with 1991 sites, Italy, with 1771 sites and Greece, with 1292 sites. However, we can notice that Poland has made big progress when it comes to the number of organisations and sites with eco-management and audit scheme (EMAS). There was a sharp rise of the organisations and sites with EMAS in Poland in the last few years (an increase from 33 sites in 2012 to 122 in 2015). That makes Poland the indisputable leader among the V4 countries [8].

The ISO 14000 environmental management standards aim to help organizations minimize the way in which their operations (processes, etc.) negatively affect the environment (i.e. cause adverse changes to air, water, or land), comply with applicable laws, regulations, and other environmentally oriented requirements, and continually improve in the above. According to Eurostat data, all V4 countries, again, stay behind the EU leaders when it comes to the ISO 14001 certified companies. This time, unlike the EMAS registration, the indisputable V4 leader is the Czech Republic, with 6629 companies. Poland ranks third, just behind Hungary, with 1793 companies [8].

The EU Ecolabel is a voluntary scheme established in 1992 to encourage businesses to market products and services that are more sustainable. The Ecolabel helps to promote and identify products and services that have a reduced environmental impact throughout their life cycle, from the extraction of raw material through to production, use and disposal. According to Eurostat data in 2016 the largest number of EU Eco label licences was awarded in France (26%), Italy (18%), and Germany (12%). The V4 countries again lag far behind the EU leaders. However, we can observe an upward trend in all V4 countries except Slovakia. The number of Ecolabel licences has increased gradually since 2005 [8].

### 3. Conclusions for textile and clothing sector

Based on the survey results we could conclude that despite the declared environmental sensitivity, consumers in V4 countries still do not have enough knowledge allowing them to reach more rational decisions, make conscious choices and exhibit more sustainable behaviours. Therefore, it is desirable to introduce system solutions in education, taking into account the issues related to sustainable development in textile and clothing industry starting from pre-school education. Despite some differences between particular countries, the V4 consumers are more active in the after purchase phrase and also in the activities that do not require a lot of knowledge and engagement but can additionally bring some economic reward. The increased activity of the NGOs and the media in raising environmental knowledge and awareness in the field of textile and clothing as well as in shaping the public opinion in V4 countries is necessary.

According to survey results, the biggest barriers to sustainable consumption for V4 consumers were: insufficient availability of the sustainable products, too high price and lack of confidence in eco-labels. The least important barrier turned out to be unsatisfactory attractiveness of sustainable products. The government and, primarily, enterprises should therefore focus on expanding distribution channels, enhancing the visibility of sustainable options in the stores, introducing better differentiation strategies and creating incentives to buy sustainable products. Continuous education in this area is necessary to build consumer confidence. Effectiveness of those activities depends on consistency, transparency and fairness of actions and declarations. Additionally, success, growth and profits in textile industry in the Europe must be grounded in two critical components: excellence in life cycle performance and sustainability coupled with disruptive innovation in the transformational process; hence creating new green space in textiles.

Important factors that stimulate the implementation of eco-innovations in the V4 countries are the legal requirements and expected changes in EU legislation (environmental regulations that already
exist, as well as these expected in the future). Furthermore, relatively low level of social trust in the V4 companies, indicates the need for further education and training in order to build skills to implement ethical values and attitudes. It is necessary to create space and mechanisms to increase the exchange of practices and to build confidence and trust throughout the clothing supply chain. In the V4 countries still the decisive motivation for more sustainable behaviour are economic stimuli [10]. Despite some differences between countries, national initiatives and regulations in the area of sustainability are a direct consequence of the implementation of mandatory EU targets on environmental protection and combating climate change. The necessity to meet these regulations is often the primary, if not the only, factor motivating consumers and businesses to change their behaviour.

Acknowledgments
The article was prepared in the framework of the project “Prospects of the Visegrad cooperation in promoting a sustainable consumption and production model “. The project is supported by the International Visegrad Fund http://visegradfund.org/

References
Simulation modelling of central order processing system under resource sharing strategy in demand-driven garment supply chains

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Abstract. In this paper we proposed a central order processing system under resource sharing strategy for demand-driven garment supply chains to increase supply chain performances. We examined this system by using simulation technology. Simulation results showed that significant improvement in various performance indicators was obtained in new collaborative model with proposed system.

1. Introduction
In recent years, the trend of customization and personalization is increasing tremendously in garment industry. Instead of traditional ready-to-wear garments, customers are seeking to wear customized clothes fitting individual preference and body shape with distinctive materials, styles, pattern or colours. Therefore, the demand of small-series production and quick response become more and more important in today’s garment supply chain. To meet this raising trend, demand-driven supply chain (see figure 1) is developed and employed nowadays. According to Verdouw, C.N et al. [1], a demand-driven chain is defined as “a supply chain in which all actors involved are sensitive and responsive to demand information of the end customer and meet those varied and variable demands in a timely and cost-effective manner”. In demand-driven supply chains, only products and services corresponding to customers’ demands are produced and it forces stakeholders in the supply chain to collaborate with each other [2]. However, there are still a lot of potentials to improve current demand-driven supply chain, e.g. long lead time and high cost.

![Figure 1. (a) Information flow and (b) material flow in demand-driven garment supply chains](image-url)
As the increasing of complexity and flexibility in today’s supply chain, inter-organizational collaboration between different supply chain echelons becomes an important issue. Companies are tending to find suitable partners to improve supply chain performance as a whole, so that to achieve mutual benefits together. Supply chain collaboration (SCC) becomes a hot research topic in supply chain field. Most of researches concentrated on joint decision making [3], [4], incentive alignment contract [5], [6] or information sharing [7], [8], which are all common strategies employed in vertical SCC. Collaboration in a demand-driven supply chain mainly focused on vertical collaboration as well. In previous research, horizontal collaborations were less addressed in either SCC research or demand-driven supply chain. Therefore, we are thinking to implement horizontal collaboration into current demand-driven garment supply chains, so that to combine vertical collaboration and horizontal collaboration together. Resource sharing (RS) is also a common SCC strategy and it was utilized more frequently in horizontal collaboration. The principle of RS is that resources or assets, e.g. machines and techniques, could be shared and leveraged among supply chain partners [9]. To the best of our knowledge, no previous research considered or discussed RS in garment supply chain. So, in this study, we explored the application of RS for horizontal collaboration in a four-echelon demand-driven garment supply chain. We compared a traditional demand-driven garment supply chain model to a new collaborative supply chain model with a central order processing system under designed RS strategy. We used simulation technology to see whether the whole supply chain can obtain significant performance improvement in the new model by applying proposed novel system.

2. Methodology

2.1 Conceptual model

As shown in figure 1, in a demand-driven garment supply chain, garment retailer or customer places a demand to a garment manufacturer, then garment manufacturer calculates material (dyed fabric) it needs for the production and send corresponding order to its supplier. Dyeing workshop estimates number of fabrics needed based on this demand and sends another order for fabric production to its fabric supplier. Although this model has advantages such as decreasing wasteful overproduction of garments, it still has several defects, such as long lead-time or delay between two echelons of supply chain.

![Figure 2. Information flow of central order processing system under RS strategy](image)

We designed a central order processing system (COPS) in this study as shown in figure 2. Instead of fixed one-to-one or multiple-to-one relationships between suppliers from different echelons in a traditional demand-driven supply chain, collaborative relationships between suppliers are dynamic in our collaborative model with COPS. All members in COPS are potential collaborative partners with each other; no matter they are from the same echelon or different echelons. Production capacity status of each supplier for different types of products is updated in the system. Resources could be shared among suppliers from the same echelon in supply chain (horizontal collaboration). COPS is responsible for all demand estimation and order distribution to suitable suppliers, starting from raw material to final garment product. In our collaborative model, end consumers make a request of
garments to the system. COPS would calculate raw materials (fabrics) needed for production and create an order. The status of all fabric manufacturers would be checked in the system and the order would be delivered to the first fabric manufacturer with idle resource. Once the fabric production finished, fabric manufacturer would inform COPS, COPS would create another order for fabric dyeing and check capacity status of all dyeing workshops. Once a dyeing workshop has idle resource, then COPS would inform fabric manufacturer to transport the fabrics for corresponding dyeing workshop. Same principle is applied to the garment production stage. A suitable garment manufacturer would be selected for fabric cutting and sewing process and it would deliver final products to corresponding garment retailer or customer.

2.2 Simulation model
As it is impossible to run the experiment on our designed system in real-world system, also considering the complexity and stochastic nature of supply chain model discussed in this study, traditional analytical method, e.g. mathematical modelling, is not feasible. Therefore, we employed discrete-event simulation (DES) technology to evaluate RS model in this study. DES concern the modelling of a system as it evolves over time by a representation in which the state variables change instantaneously at separate points in time [10]. In this study, SIMIO (SImulation Modelling framework based on Intelligent Objects) was utilized as the simulation engine for building our simulation model. We initially developed a simulation model based on the traditional demand-driven garment supply chain model shown in figure 1. As mentioned previously, we simulated four echelons in garment supply chains, including fabric manufacturer, dyeing workshop, garment manufacturer and garment retailer. In each echelon, three individual small and medium-sized companies were available and could provide same service. Therefore, in total of twelve companies and three separate garment supply chains were modelled. Garment retailer demanded three types of garments, viz. dress, trousers and jacket. Input parameters (order size, order type, processing time etc.) were collected based on one-year historical data provided by a garment manufacturer and also through interviewing professionals in garment industry or reading relevant literatures [11], [12].

Then we created COPS in the simulation model. In general, three main functions were realized in COPS: (1) production capacity update and check, (2) order reception, creation, monitor and distribution, and (3) supplier selection for each supply chain echelon. They were respectively set and programmed in the simulation model. Production capacity of each process (general scripts in Simio: MachineX.Capacity.Remaining) was updated and checked during working hours in COPS. COPS received garment production orders from all three garment retailers. It also created corresponding orders for each echelon in supply chain. Once an order was completed in certain supplier, corresponding products were stored in the warehouse of supplier (wait process in Simio). COPS would monitor the status of each created order and is responsible for its distribution. Each order has three potential suppliers in next echelon in this model; COPS determined the selection of supplier responsible for the order. Once there is available capacity in supplier of next stage (general scripts in Simio: MachineX.Capacity.Remaining>0), COPS would send this order to selected supplier and also send signal (fire process in Simio) to current supplier holing raw material for delivering them to selected supplier (assign specific path to true, others to false in Simio).

3. Results
Two simulation scenarios (traditional demand-driven supply chain and supply chain with COPS under RS) were run for a duration of 20 weeks with 50 replications respectively. Average value of several supply chain performance indicators were checked, including order completion rate (number of completed order/number of all received order), facility utilization (machine run time/total working time), lead time (average time from receiving an order to order completion) and productivity (throughput of garments per day). They were compared between two models as shown in table 1. All checked indicators were improved in terms of their average value of 50 replications. Independent samples T-test (confidence interval = 95%) was performed to output data to verify whether there is a significant difference of each performance indicator between two models, as shown in table 2.
Significant improvements were obtained in terms of productivity, order completion rate and facility utilization respectively. Therefore, the experiment results can reflect the improvement of these three performance indicators of the model. COPS can bring overall benefits to companies operating in the system.

### Table 1. Comparison of checked performance indicators

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Number of replications</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Productivity (pieces/day)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional</td>
<td>50</td>
<td>1195.10</td>
<td>27.0748</td>
</tr>
<tr>
<td>New</td>
<td>50</td>
<td>1222.52</td>
<td>29.7452</td>
</tr>
<tr>
<td><strong>Lead Time (days)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional</td>
<td>50</td>
<td>15.29</td>
<td>1.4018</td>
</tr>
<tr>
<td>New</td>
<td>50</td>
<td>14.86</td>
<td>2.5470</td>
</tr>
<tr>
<td><strong>Order Completion Rate</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional</td>
<td>50</td>
<td>83.38%</td>
<td>0.0256</td>
</tr>
<tr>
<td>New</td>
<td>50</td>
<td>87.01%</td>
<td>0.0318</td>
</tr>
<tr>
<td><strong>Facility Utilization</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional</td>
<td>50</td>
<td>82.86%</td>
<td>0.0</td>
</tr>
<tr>
<td>New</td>
<td>50</td>
<td>84.79%</td>
<td>0.0201</td>
</tr>
</tbody>
</table>

### Table 2. T-test results

<table>
<thead>
<tr>
<th></th>
<th>T value</th>
<th>Degree of freedom</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Difference percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Productivity</strong></td>
<td>-4.821</td>
<td>97.145</td>
<td>0.000</td>
<td>27.4204</td>
<td>2.29%</td>
</tr>
<tr>
<td><strong>Lead Time</strong></td>
<td>1.032</td>
<td>98</td>
<td>0.305</td>
<td>-0.4243</td>
<td>-2.78%</td>
</tr>
<tr>
<td><strong>Order Completion Rate</strong></td>
<td>-6.276</td>
<td>93.775</td>
<td>0.000</td>
<td>0.0363</td>
<td>4.35%</td>
</tr>
<tr>
<td><strong>Facility Utilization</strong></td>
<td>-5.331</td>
<td>92.925</td>
<td>0.000</td>
<td>0.0193</td>
<td>2.33%</td>
</tr>
</tbody>
</table>

### 4. Conclusion

In this study, we proposed COPS for garment supply chains. RS strategy was employed in the system, which is a less researched but important domain in supply chain collaboration. Simulation experiment results showed that, compared to traditional demand-driven supply chain model, the new proposed model with COPS got significant improvements in multiple supply chain performance indicators. COPS could help collaborative partners gain more benefits as a whole, converting so-called competitors to collaborators in garment supply chains. The system provided a platform for small and medium-sized companies in garment industry to increase their competences while facing the trend of customization and small-series production. This new model also could be a potential direction for solving current issues in small-series production, e.g. long lead-time or delay between two supply chain echelons, in other industries with similar supply chain process. It is expected to have more researches on this direction in future.

### Acknowledgments

This work is supported by the joint doctorate programme “Sustainable Management and Design for Textiles” which is funded by the European Commission’s Erasmus Mundus programme.

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Operations management tools to be applied for textile

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Abstract. In this paper, basic concepts of process analysis such as flow time, inventory, bottleneck, labour cost and utilization are illustrated first. The effect of bottleneck on the results of a business are especially emphasized. In the next section, tools on productivity measurement; KPI (Key Performance Indicators) Tree, OEE (Overall Equipment Effectiveness) and Takt Time are introduced and exemplified. KPI tree is a diagram on which we can visualize all the variables of an operation which are driving financial results through cost and profit. OEE is a tool to measure a potential extra capacity of an equipment or an employee. Takt time is a tool to determine the process flow rate according to the customer demand. KPI tree is studied through the whole process while OEE is exemplified for a stenter frame machine which is the most important machine (and usually the bottleneck) and the most expensive investment in a finishing plant. Takt time is exemplified for the quality control department. Finally quality tools, six sigma, control charts and jidoka are introduced. Six sigma is a tool to measure process capability and by the way probability of a defect. Control chart is a powerful tool to monitor the process. The idea of jidoka (detect, stop and alert) is about alerting the people that there is a problem in the process.

1. Basic concepts

Every business has the aim to maximize profits. Operations management tools are applicable for any business and any industry in order to help to maximize profits by means of both high productivity and high quality. In this paper, several operations management tools are introduced and applied for a finishing plant to measure operational performance. By the way, an effective toolset, serving scientific management, is provided for the managers of textile operations.

To start with, basic concepts of process analysis are illustrated following which operations management tries to improve results of these:

Flow time: The time needed for a unit of product or service to be produced. By the way, this is the time from the start to the end of the process for one unit.
Flow rate: Units to be produced per certain time. The reciprocal (1/x) of flow time.
Inventory: The total amount of units in a process. Raw, semi or final products are considered.
Bottleneck: The work station which has the least capacity. Having least capacity, the bottleneck is the step driving the production. By the way, the capacity of the process, maybe even the capacity of the business, is the same of the capacity of the bottleneck. In a finishing plant, the bottleneck is usually the stenter frame machines. So in this paper, these machines would be mentioned more frequently.
Direct labor cost: The cost of directly workers’ pay for the production of one unit.
Utilization: The percentage of working time over the total time paid for.
2. Operations management tools for textiles

Strategic initiatives allow companies to shine in their respective arenas. These include (a) business process reengineering, (b) just-in-time manufacturing and purchasing systems, (c) time-based competition, and (d) competing quality [1].

Efficient production of goods and services requires effective applications of the concepts, tools and techniques of operations management. Productivity and quality are two legs of a business running together. Operations management serves many tools on productivity and quality in a process. In this paper is exemplified six different tools, three of which is in service of productivity mostly, while the other three is quality biased. It should never be neglected that any tool helps also the other side to go forward. These tools are KPI (Key Performance Indicators) tree, Overall Equipment Effectiveness and Takt Time for productivity and six sigma and process capability, control charts and jidoka for quality. Many more are available and can be adopted textile business.

2.1. KPI tree

KPI tree, where KPI stands for “key performance indicators”, is a tool that visualizes the relationship between operational variables and financial variables. Profit, being one of the most important numbers in a business, is the main branch of the KPI tree in figure 1. It is executed from the difference of the revenue and the costs. The revenue is driven by the flow rate multiplied by the price ($/meter). The flow rate would be the minimum of the demand and the capacity. The flow rate would be equal to the capacity of the plant when demand exceeds the capacity and the capacity of the plant would be equal to the capacity of the bottleneck where the bottleneck is generally the stenter frames in a finishing plant. On the other hand, costs are the sum of fixed and variable costs accumulated by the flow rate multiplied by the operating costs of workstations added up.

![Figure 1. A KPI tree for a finishing plant.](image)

A KPI tree visualizes the relationship between the operational and financial variables from branches to the leaves. Figure 1 shows an example of a KPI tree. Leaves of the tree are easier to treat but have less impact on the results while the branches are harder to treat but have more impact. A KPI tree is a good start point for sensitivity analysis to see which operational variables yield the biggest financial improvements [2].
2.2. *Overall Equipment Effectiveness (OEE)*

Companies purchase expensive machines for example stenter frames. Such machines should be fully utilized in order to pay back. But unfortunately, a stenter frame machine might be utilized less than 50%. Overall Equipment Effectiveness (OEE) is a powerful tool that helps to analyze the utilization and downtime of a machine and to see the potential for productivity improvement.

Through a ‘working hours’ spreadsheet of a machine, OEE diagram can be prepared. The diagram shows the effective time of the machine and downtime reasons dramatically. By the diagram of a machine, managers see where improvements can be provided faster and easier and more results are obtained. Different machines can also be compared to set a start point.

In figure 2 is an OEE diagram of a stenter frame machine. Time losses are shown in order of downtime losses, speed losses and quality losses. By adding on, total time loss is 43% and true value add time is 57% of total planned time. It means there is an extra 43% potential capacity.

![Figure 2. An OEE diagram of a stenter frame machine.](image)

2.3. *Takt time*

Due to market instability and the frequent introduction of innovations in processes and technologies, operating managers are facing the need to continuously adapt the system architecture and the operational parameters to meet profitable operating conditions and remain competitive in the global market [3]. Changing even hourly in some industries, demand changes seasonally in textiles. The same company can produce one million meters of fabric in September, half million in December. Thus, company should make resource planning by months in order to reduce direct labor costs and increase the utilization.

Takt time is a concept telling the time period during which a unit has to be produced according to the demand. When one worker is needed for takt time 5 minutes, then 5 workers would be needed for takt time is 1 minute. The shorter the takt time is, the faster the production should be. This is possible by leveling the production first and then employing “staff to demand”.

Having leveled the production, the quality control department of a finishing plant should inspect one thousand meter fabric in 43.2 minutes for one million meters in a month, in 86.4 minutes for half million. Takt time is 43.2 and 86.4 minutes for September and December respectively. In order to employ the staff to the demand, the number of inspectors for that month can be calculated accordingly (Figure 3).
2.4. Six Sigma and Process Capability

The term “Six Sigma - 6σ” refers to a quality level where specification limits are between ± 6 standard deviations. It means %99.9999998 of the production is in specification and just 2 defects are produced per billion. This is a rational objective such industries as aerospace, health. However, most manufacturing companies aim 3 sigma level rationally.

Besides, process capability increases as the sigma level increases. The capability index (C_p) of a process is the assessment of whether the natural tolerance (6σ) of a process is within the specification limits. When upper and lower specification limits (USL – LSL) and standard deviation known, capability index (C_p) can be calculated as:

\[
C_p = \frac{\text{allowable process spread}}{\text{actual process spread}}
\]

\[
C_p = \frac{\text{USL} - \text{LSL}}{6\sigma}
\]  \hspace{1cm} (1)

**Table 1.** Sigma levels, process capability and related defect probabilities and defect numbers per million.

<table>
<thead>
<tr>
<th>zσ</th>
<th>C_p</th>
<th>(P{\text{defect}})</th>
<th>ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1σ</td>
<td>0.33</td>
<td>0.317</td>
<td>317,000</td>
</tr>
<tr>
<td>2σ</td>
<td>0.67</td>
<td>0.0455</td>
<td>45,500</td>
</tr>
<tr>
<td>3σ</td>
<td>1.00</td>
<td>0.0027</td>
<td>2,700</td>
</tr>
<tr>
<td>4σ</td>
<td>1.33</td>
<td>0.0001</td>
<td>63</td>
</tr>
<tr>
<td>5σ</td>
<td>1.67</td>
<td>0.0000006</td>
<td>0.6</td>
</tr>
<tr>
<td>6σ</td>
<td>2.00</td>
<td>2x10^-9</td>
<td>0.00</td>
</tr>
</tbody>
</table>

A C_p of 1.0 indicates that process is judged to be “capable”. This is ±3σ level. [4]

*An example on process capability:* Consider that USL = 141.0 cm and LSL = 139.0 cm for a fabric width where average width and standard deviation are 140.4 and 0.6 respectively.
Cp was calculated by equation (1) and found 0.56 which is less than 2σ for this specification. Being the average 140.4 not the middle of upper and lower specification limits, it can be calculated –thanks Excel- that 15.9% of the production would exceed 141.0 cm and 1.0% would go below 139.0. Due to the high defect probability, such a deal might not be profitable for marketing.

2.5. Control charts
Control charts are powerful tools for statistical process control. A finishing plant could monitor many process and product parameters by control charts and catch any problems about machine settings and product specifications. It is as easy as plotting measured data on a graph and add on.

On the control chart in figure 4, besides upper and lower specification limits from the example above, upper and lower control limits are set using equations following [5].

\[
\text{Upper Control Limit (UCL)} = \bar{x} + z\sigma \\
\text{Lower Control Limit (LCL)} = \bar{x} - z\sigma
\]

(2) (3)

Figure 4. Control chart of the width mentioned in the previous section. Each data is the average of five samples.

Control charts help the operations managers to trace the defects and causes of the defects. They also show trends when a specification goes upwards or downwards in a period of time. It means the specification would exceed upper or lower limits soon. Another utilization of control charts is the visualization –roughly- of the process capability within specification limits.

2.6. Jidoka
Catching defects is critical for especially two reasons: Defects lead to further defects and secondly when defects reach the bottleneck the capacity of the plant is wasted. Finishing plants occasionally experience those.

Toyota Motor Company have introduced a detect-stop-alert system called jidoka. The basic steps of jidoka are to: (1) detect the problem, (2) stop the process, (3) restore the process to proper function, (4) investigate the root cause of the problem, and (5) install countermeasures. Each worker at Toyota is empowered to stop the assembly line [6]. This quality tool have still been used in Toyota plants all over the world via an andon cord accompanying the assembly line. When a worker catches a defect,
he/she pulls the cord to stop and alert whole plant. Plant stops. Managers, engineers and workers come to the incidence scene —gemba in Japanese. The plant would only run after the problem is solved and root causes are eliminated in order not to experience such a defect again.

The system had been developed initially for weaving looms of Toyota before Toyota was a motor company. Weaving machines have still got those lights to alert people when stop due to a defect.

3. Conclusion
There is so fierce competition in textile industry as every business. The one and only way of success is “scientific management” in a highly competitive business world.

This paper shows that a finishing plant can employ practically at least six effective tools in order to serve scientific management and measurable operations instead of rule of thumb. These tools and more tools alike can be applied simply and easily by textile managers. Some of them like control charts and *jidoka* could even be applied by workers. Harmony, cooperation, high efficiency and maximum output would take place by such an operations management.

References
Competitive strategies in fashion industries: Portuguese footwear industry

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Abstract. Portugal is an important player in the European fashion industry. The Portuguese footwear industry, “low-tech” and traditional industry, dominated by SMEs and located in two main clusters, is a success case in the Portuguese economy. After a long period of decline until 2009, the footwear companies prepared new strategies that made big changes in the image and performance achieved. Since 2009, exports have increased more than 55% and the Portuguese footwear has grown in almost all the most important foreign markets. The competitive strategies followed by the Portuguese footwear companies are different and they can be clearly identified according Porter’s three generic competitive strategies: cost leadership, differentiation and focus strategy. This paper had analysed seven Portuguese footwear companies (seven cases, case study strategy) and the results obtained shows how important is to have the right approach to the markets, according the internal and external resources that each firm has available. The footwear clusters in Portugal and the sectorial organizations are also very important in this competitive performance achieved by the companies. Last years the Portuguese governments recognize this increasing importance of the fashion industries and prepared several programs to promote these industries in Europe and other continents.

1. Introduction
Portugal is an important player in the European fashion industry, regardless of whether you are talking about textiles, clothing, furniture or footwear. The Portuguese footwear industry, “low-tech” and traditional industry, dominated by SMEs and located in two main clusters, is a success case in the Portuguese economy. After a long period of decline until 2009, the footwear companies prepared new strategies that made big changes in the image and performance achieved. This industry had in the last six years a remarkable performance in several indicators, a reference in the Portuguese industry [1]. In 2016, Portugal exported more than 81 million pairs of shoes, an amount of more than 1 923 million euros, a growth of 3.2% over 2015. Leather footwear are the main category of Portuguese footwear exports, that gives the 10th position in the international context (value of 1 840 million of USD in 2015 and a World Share of 3.4% - Table 1). As a result of an unprecedented investment in international markets, Portugal now exports more than 95% of its production to 152 countries on five continents [1].

These research fulfil the lack of empirical knowledge in the linkage between competitive strategies, innovation and own brands in “low-tech” industries. Moreover, as fashion industry, footwear, apparel and textile are strategic for the national authorities. The European Framework for Research and Innovation – Horizon 2020, is assumed as a main instrument to the companies became more competitive. But the financial resources and internal skills has to be focused in the right strategic direction. Both footwear clusters are very committed to cooperate and to take a chance to increase his position in news markets, mainly outside of Europe.
Table 1: Top 10 Exporters of Leather Footwear 2015

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>USD Million</th>
<th>World Share</th>
<th>Pairs Millions</th>
<th>World Share</th>
<th>Average Price $</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>China</td>
<td>10,922</td>
<td>20.5%</td>
<td>725</td>
<td>33.1%</td>
<td>15.05</td>
</tr>
<tr>
<td>2</td>
<td>Italy</td>
<td>7,695</td>
<td>14.4%</td>
<td>125</td>
<td>5.7%</td>
<td>61.50</td>
</tr>
<tr>
<td>3</td>
<td>Vietnam</td>
<td>5,965</td>
<td>11.2%</td>
<td>293</td>
<td>13.4%</td>
<td>20.37</td>
</tr>
<tr>
<td>4</td>
<td>Hong Kong</td>
<td>2,455</td>
<td>4.6%</td>
<td>90</td>
<td>4.1%</td>
<td>27.34</td>
</tr>
<tr>
<td>5</td>
<td>Germany</td>
<td>2,392</td>
<td>4.5%</td>
<td>69</td>
<td>3.1%</td>
<td>34.74</td>
</tr>
<tr>
<td>6</td>
<td>Indonesia</td>
<td>2,233</td>
<td>4.2%</td>
<td>95</td>
<td>4.3%</td>
<td>23.48</td>
</tr>
<tr>
<td>7</td>
<td>Spain</td>
<td>2,132</td>
<td>4.0%</td>
<td>57</td>
<td>2.6%</td>
<td>37.46</td>
</tr>
<tr>
<td>8</td>
<td>Belgium</td>
<td>1,968</td>
<td>3.7%</td>
<td>71</td>
<td>3.2%</td>
<td>27.86</td>
</tr>
<tr>
<td>9</td>
<td>India</td>
<td>1,923</td>
<td>3.6%</td>
<td>115</td>
<td>5.3%</td>
<td>16.72</td>
</tr>
<tr>
<td>10</td>
<td>Portugal</td>
<td>1,840</td>
<td>3.4%</td>
<td>59</td>
<td>2.7%</td>
<td>31.00</td>
</tr>
</tbody>
</table>

Portugal exports more than 85% of his footwear production to the European markets. The five more important Portuguese footwear markets and trade partners are all European: France, Germany, Netherlands, Spain and United Kingdom and they import more than 70% in value (Table 2).

Table 2: Main trade partners 2015 (Exports)

<table>
<thead>
<tr>
<th>Export Markets</th>
<th>USD Millions</th>
<th>Value Share</th>
<th>Pairs Millions</th>
<th>Quantity Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>454</td>
<td>22%</td>
<td>16</td>
<td>20%</td>
</tr>
<tr>
<td>Germany</td>
<td>381</td>
<td>18%</td>
<td>13</td>
<td>17%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>297</td>
<td>14%</td>
<td>10</td>
<td>13%</td>
</tr>
<tr>
<td>Spain</td>
<td>209</td>
<td>10%</td>
<td>14</td>
<td>17%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>148</td>
<td>7%</td>
<td>9</td>
<td>7%</td>
</tr>
</tbody>
</table>

2. Methodology
The research was done with an active participation of the sectorial organizations, helping in definition of the sample of innovative footwear companies (a short list of twelve innovative companies were used). The research methodology was qualitative and the strategy for data collection was the multiple case studies [2]. To select the seven innovative companies were used the intentional sampling. The logic and the power of purposeful or intentional sampling are based on the selection of cases that are rich in information for in-depth study of a particular phenomenon, central to the purpose of the investigation [3]. The companies selected were: FELMINI, SAVANA, CENTENÁRIO, PROCALÇADO, KYAIA, SOZÉ/DKODE and ACO. All of them are located in the two Portuguese footwear clusters. Regarding the number of cases considered appropriate, some authors [4] say that a number between four and ten works normally well. Other author [5] considers that although numerous cases diluting the overall analysis, the researcher typically chooses "no more than four or five cases". There are several strategies to select the innovative footwear companies using the intentional sampling. The maximum variation strategy and the sampling with criteria was the most appropriate to the research, as suggested by sectorial organizations APICCAPS and CTCP. To obtain the data, the investigators made eleven semi-structured interviews during more than five months (in four companies were made interviews to more than one person). They visited the seven footwear companies several times and all the interviews were digital recording and after transcribed to text. A questionnaire was completed by the companies to gather and connect dispersed data and to
make links between some concepts and results. Sometimes the interviews at a cluster company were
decisive in approaching other companies, some of them suppliers or partners in previous research
projects and others are yet in common research projects.
The MAXQDA software was used to make the qualitative analysis of data gathered and to prepare
some conceptual models.

3. Results and discussion
Throughout the investigation, have been formulated several hypothesis. The competitive strategies
followed by companies are identified by their owners, CEOs and administrators, and lead to better
results and a differentiated competitive positioning. This hypothesis was formulated in the beginning
of the research and was clearly validated during the research. Figure 1 shows a “planetary model” that
highlights this assumption. The generic competitive strategies, as proposed by Michael Porter in 1980
[6], are clearly identified in this research. Cost leadership, differentiation and focus strategy are the
Porter’s competitive generic strategies and the focus strategy can be divided in “focus on costs” or
“focus on differentiation”.

Conclusions about competitive strategies and competitiveness of the footwear companies were very
simple to obtain and they are very clear. Even if the owners or administrators does not know the
Porter’s designation to the competitive strategies, they can describe the principles that they are based
on and recognize if their company is following one or the other. Table 3 shows the results obtained
during the research (Table 3).

<table>
<thead>
<tr>
<th>Felmini</th>
<th>Savana</th>
<th>Centenário</th>
<th>Procalçado</th>
<th>Kyaia</th>
<th>Soze/Dkode</th>
<th>ACO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turnover (million €)</td>
<td>13.4</td>
<td>8.9</td>
<td>9.2</td>
<td>21</td>
<td>56</td>
<td>10</td>
</tr>
<tr>
<td>Nº workers</td>
<td>183</td>
<td>142</td>
<td>74</td>
<td>296</td>
<td>620</td>
<td>160</td>
</tr>
<tr>
<td>Turnv/Wrk (€/Worker)</td>
<td>73 460</td>
<td>63 050</td>
<td>124 150</td>
<td>70 950</td>
<td>90 320</td>
<td>62 500</td>
</tr>
<tr>
<td>Exportation Value (million €)</td>
<td>13</td>
<td>7.9</td>
<td>9.1</td>
<td>10.5</td>
<td>50</td>
<td>9</td>
</tr>
<tr>
<td>Own Brand (%)</td>
<td>100%</td>
<td>10%</td>
<td>0%</td>
<td>60%</td>
<td>90%</td>
<td>60%</td>
</tr>
<tr>
<td>Competitive Strategy Innovation (Oslo Manual)</td>
<td>B.D</td>
<td>A</td>
<td>C</td>
<td>B</td>
<td>B.D,E</td>
<td>B.D</td>
</tr>
<tr>
<td>Cooperation with Cluster (1 to 5)</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

Notes: A – Cost leadership
B – Differentiation
C – Focus strategy
D – Quick Response
E - Synergy

Cost leadership is followed by two companies: ACO and Savana. ACO is the biggest company
analysed with 740 workers and with a turnover of 33.5 million euros in 2013. Both work mainly in
private label regime, with a low percentage of own brand products. These two companies have others factories that belongs to the same main company, working in some process operations: cutting, sewing and assembling. ACO has one factory in Cabo Verde (Africa) with 260 workers and other one in Ponte de Lima (Portugal) with 100 workers. Quality control is done in the main factory, before to be sent to the final customers or clients (private label regime). Savana has a small company in Baião (Portugal) with 30 workers. These smaller companies belongs to the same owners and are located in the same region (footwear cluster in the north of Portugal)

Differentiation strategy is followed by four footwear companies: Felmini, Procalçado, Kyaia and Sozé/Dkode. They have own brands, with own products and footwear collections. The percentage of own brand products is higher than 60% in all the cases, remaining a percentage of production to the private label. Quick Response strategy is followed and identified by three companies, which joins the differentiation strategy already indicated above. The synergy strategy proposed by Aaker [7] is assumed only by one company: Kyaia. Aaker’s synergy definition corresponds to the capacity that two or more entities or companies have to jointly generate more value, which is greater than that achieved separately by each one. Kyaia participates frequently in research projects, being mostly of the times project leader.

Being close to the retail and the final consumer is a common feature of the differentiation strategy option and “to move consumers’ involvement from low to high” [8] with brands’ linkage. Focus strategy is clearly followed by Centenário. Production process is very peculiar and with a high value added (Goodyear production system) with a complex system that requires skills and competences not easily available in other countries. The shoes are produced with special leathers and skins of exotic animals (alligator, skin snake, Brazilian fishes, etc.), in private label regime. The company is preparing a new product line to the American market: golf footwear in high quality leather and exotic skins. The company has own brand, prepares own products without a collection, but it represents a small share. It is important to keep the quality level of the company and to test some techniques and production improvements.

![Figure 1: Competitive strategies in innovative footwear companies](image-url)
The cooperation with the cluster occurs in different levels. Some companies, usually more innovative and with “Innovation in Products” and “Innovation in Marketing”, and with strong brands, have a very good cooperation in the cluster. They are frequent partners in innovation projects, involving also equipment producers and software houses. High Speed Shoe Factory was a project led by Kyaia that had involved several sectoral partners, including machinery producers, software house, footwear companies and technological centers.

This analysis fits in previous studies already done in the Portuguese industry [9]. Traditional industries are important if they have the right competitive strategy and if they can compete against the main international players. The clusters play a very important role, mainly if they can collaborate in innovation processes and creating competitiveness inside the cluster[10].

4. Conclusions

There is a link between the category of innovation followed by the innovative firms (according Oslo Manual - OECD) [11] and the competitive strategy adopted in these companies [6]. This conclusion is very clear in this research and recognized by the sectorial players. Differentiation strategy is followed by the same companies that have “Innovation in Products” and “Innovation in Marketing”, according Oslo Manual classification.

The ratio “Turnover/worker” of the footwear companies is related with the strategy followed. Centenario has the highest ratio “Turnover/Worker” with a value of 124,150 euros/worker and the strategy followed is “Focus Strategy”. On the other hand, ACO follows a “Cost Leadership” strategy and has the lowest ratio “Turnover/Worker” with a value of 45,200 euros/worker. If Portugal wants to continue to be more competitive in traditional sectors, with a very positive trade balance as it happens with footwear, clothing and textile, then the companies need to take advantage of the this EC Framework HORIZON 2020. They have to prepare competitive strategies to entry in new markets, with products more sophisticated, with good design, own brands and with high quality. Portuguese footwear quality is already recognized by the international markets, mainly in leather products category. The experience and know-how obtained in private label regime by the Portuguese footwear, textile and apparel industries were very important to the quality levels that these industries are showing nowadays. Own products, own collections, own brands and innovation are elements that contribute for these results, even if these companies are mainly SME’s [12] as it happens in the Portuguese fashion industry. The Spanish Group Inditex has in Portugal an important supplier to their fast fashion products [13]. In textile and clothing industries, Spain is the main commercial partner with Portugal (exports and imports) [14]. The high qualification of human resources and workers, the technological upgrade and the entry in sophisticated markets are helping to keep this competitive performance.

The road ahead is long and difficult but it is the only way to remain competitive in global markets. Cooperation between partners and good decisions are critical to keep the road open. Future research should enhance the strategic options of companies in these important and traditional sectors of the Portuguese economy.

5. References

Acknowledgments:
“This work is financed by FEDER funds through the Competitivy Factors Operational Programme - COMPETE and by national funds through FCT – Foundation for Science and Technology within the scope of the project POCI-01-0145-FEDER-007136”.

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Sustainable value creation through new industrial supply chains in apparel and fashion

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Abstract This paper explores the inter-organizational value creation, in apparel supply chain context, through circularity and digitalization for sustainability, by gathering evidences from vivid research experiences. It can be highlighted that inter-organizational value creation in both circular- and digital- apparel supply chains largely builds upon a variety of collaborative initiatives, and among a range of included members. Knowledge co-evolvement and business co-development, end-to-end integration and information transfer, and open networks are crucial to such collaborations – making development of new supply chain structures a meta-capability of apparel firms in the changing industrial landscape.

1. Introduction
Apparel and fashion industries are increasingly striving for a systemic change towards being more sustainable in near future. This is driven by a transition from being cost and labor intensive in a linear economic context towards a digitally-driven one in an emerging circular economy. In light of this transition towards sustainability, various new technologies and business models have already started disrupting the apparel and fashion industries, in order to join the bandwagon of the macro industrial trends of digitalization and circularity [1, 2]. Various technological advances, e.g. from virtualization of customer interfaces to 3D printing for apparel manufacturing have started to digitalize the apparel value chains, and have been complemented by new business models, like open manufacturing, co-creation etc. The trend towards circularity equally has led to advances in new technologies, e.g. for tracing and tracking to recycling, which is increasingly appropriated by companies through advent of new business models aimed at slowing, closing or narrowing the value chains (or loops) in terms of material and energy flows [3]. However, new digitalization- and circularity- enabling technologies and business models even though have captured the attention among both practitioners as well as academics in terms of how they manifest sustainable value creation, the focus has been mostly at the technological process- or intra-organizational- levels. Such value creation requires a wider attention as it is generated along a complex industrial chain (or loop) as in the case of apparel and fashion, and thus spans over multiple processes and organizational boundaries. Thus an inter-organizational focus on value creation is essential, but has not been discussed explicitly so far, despite the obvious importance and rationale behind it. Given this, the goal of the paper is, therefore, to explore inter-organizational value creation, in a supply chain context, through circularity and digitalization for sustainability in apparel and fashion. In the paper, we reason that inter-organizational focus essentially leads to new industrial structures required to create sustainable value for multiple stakeholders. In order to exemplify these ‘new’ industrial structures, an evidence-based analysis is conducted in supply chain context [4]. Evidences gathered from extensive research experiences, are obtained from the apparel and fashion industries and from some successful ongoing initiatives to exemplify the key underpinnings. It is to be noted that in this viewpoint paper, neither the literature review nor the empirical evidences of the cases should be considered to be strictly exhaustive or always best practice. But the empirics merely serve as a lens for putting forward authors’ personal view of the evolution of apparel and fashion supply chains in a changing landscape. This implies by no means a value judgement about the superiority or emergence of one worldview over another. It does, however, allow, for a focused exposition of an opinion, i.e. a forum piece.
2. On the sustainable value creation concept

Value creation in the supply chain context generally refers to the economic implications of any process or activity performed to create a product/service that a customer is willing to pay. However, the notion of value has emerged to be much wider than just economic implications, and can include environmental, social and other value types created for diverse stakeholders, such as environment, and society at large [5]. Sustainable value creation, in this context, refers to the approach that creates long-term value for stakeholder(s) by generating all types of values associated with economic, environmental and social developments, without compromising with one at the cost of the other. Keeping in mind the multi-stakeholder perspective of different value types, these multiple benefits can be generated internally in a focal firm, but also externally, i.e. jointly with other engaged actors by bringing in complementary resources, skill sets and knowhow. The benefits of such jointly created value spills over the boundaries of the firms and are generally greater than the individual share for each involved actor. Within the scope of this paper, however, we do not focus on differentiating between the diverse value types (e.g. economic, environmental, image) as prescribed in Schenkel et al. [6], but explore inter-organizationally created value for overall industrial sustainability at an aggregate level.

3. ‘New’ industrial supply chain structures in apparel and fashion

3.1. Circular supply chain

In contrast to today’s linear ‘take, make, waste’ industrial economic model, the concept of creating ‘value from waste’ is underpinned by the idea of restoration rather than disposability, by designing and optimizing products and materials flow for multiple cycles of disassembly and reuse [7]. This further corroborates the idea of “slowing the resource loop” through design of long-life products, multiple-life of products and product-life extension [3]. Several examples of circular supply chains and associated product recovery based business models underpin the central notion of circularity; these are: cradle-to-cradle, reuse, recycle, remanufacture, sharing and collaborative consumption, etc. The concept of circular supply chain thus is underpinned by five major underlying models [8]: (i) circular supplies – that provides fully renewable, recyclable or biodegradable resource inputs that underpin circular production and consumption systems, (ii) resource recovery – that enables a company to eliminate material leakage and maximize the economic value of product return flows, (iii) product life extension – that allows companies to extend the lifecycle of products and assets through recovery options, such as repair, upgrade, remanufacture, (iv) sharing platform (peer-to-peer) – that promotes a platform for collaboration among product users, either individuals or organizations, and (v) product as a service – that provides an alternative to the traditional model of “buy and own” through leasing or pay-for-use arrangement. Circular apparel supply chains – being a multi-actor network (consisting of profit-makers, e.g. fashion retailers, commercial recyclers, traders and sorters; public institutions, e.g. municipalities, universities; non-profit organizations, e.g. charities, research institutes) – are however highly fragmented and are fraught with a wide range of challenges related to lack of well-functioning reverse logistics, conflict of stakeholder interest, ownership confusion, and lack of formal legislation and regulation such as extended producer responsibility [9] – that hinders joint value creation.

3.2. Digital supply chain

Digitalization and information technology (IT) innovation underpins the biggest opportunity for many industrial supply chains. Coined in Hines (2007) [10], digital supply chains are where goods or services that had previously been supplied in physical form (in analogue supply chains) are digitized as information replaces inventory to remove time, distance and cost in order to improve supply chain performance. Specific to apparel and fashion supply chains, this is increasingly driven by the emergence of customer-focused products and processes, wherein demand is elicited through specifications from customers to initiate the design and production of customized products using systems and tools to support customer involvement [11]. Such customer-driven supply chains are influenced by digitalization of the customer-retailer interface, and is enabled by virtual collaborative
design, purchase decision support, online distribution channels, along with knowledge of customers’ preferences [11]. In relation several virtual reality and/or fitting technologies such as 3D scanning, web-based collaborative design tools and product visualization tools have gained prominence in the recent years [12], while for sales and distribution online sales is quickly replacing traditional formats. Role of digital tools, IT and advanced manufacturing technologies (AMTs) have equally been emphasized in the production side of the digital supply chains for ensuring flexibility, responsiveness and innovativeness [13, 14]. Mechanization of manufacturing processes and supply chains through flexible manufacturing systems based on AMTs such as computer-aided design (CAD), robotics, and computer integrated manufacturing (CIM) etc. supported by complementary business practices can have a significant impact on supply chain performance [13]. However, often the integration and information flow suffers due to increase in product variety (due to high demands on customization, agility, short-series manufacturing, etc.) or lack of integrated knowledge-base and digital technology platforms. This results in inaccuracy in such digital supply chains which in turn increases the production and product costs. Critical in such context, is complete digital integration (end-to-end) through integrated product design structure and production routings [15, 16]. Such end-to-end information transfer largely depends upon the existence of a computerized manufacturing environment and determines the success of a digital supply chains for customized products [16], by enhancing various aspects such as traceability, transparency, trust and security.

4. Evidences on inter-organizational value creation through circular supply chains

Management of used clothes flow in most western economies is recognized as a multi-actor system, however most participating actors tend to play a significant role in handling and treating them single-handedly. However, a clear benefit can be spotted through joint efforts and increased collaboration for achieving higher value-added product recovery, and also leading to new industrial supply chains and business models. Such collaboration has been emerging at various product recovery stages and across options, e.g. for collection and take-back of used clothes, for managing textile wastes, or for subsequent value-added recovery. Many branded fashion retailers, like H&M, Marks & Spencer, have started collaborating with global sorting groups like SOEX and Boer to initiate in-store collection of used clothes, via a system called take-back scheme. Under the scheme, the retailers are predominantly involved in organizing the collection through their stores, which is then handed over to the collaborating for-profit broker/Sorter who takes the used clothes through the next reverse logistics and product recovery stages beyond collection, such as sorting, shredding, recycling, even reselling.

Collaborative agreement in such take-back schemes is based upon contract such that the retailers earn revenue from the sales of the used clothes to the broker/Sorter, paid per kilo of collected volume, and in turn all collection-related costs are borne by them. These globally operating firms have also ventured out for collaborating with charities and non-profit organizations – a relation based upon improving price point for the charities while access to higher volume for the global operators (e.g. between Human Bridge a Swedish charity run organization and Boer Group, or between Myronna – a Swedish second-hand retailer and Freitex International – both subsidiary of Salvation Army). In the textile waste management (TWM) system, a common form of collaboration is between academic and research actors with the industry members (retailers, charities, sorting firms, etc.) and governmental institutions (e.g. municipalities). Such collaboration aim at developing new technologies and business innovations, for instance, in areas were commercially viable options are yet not available or are market ready. In fact, to this date there is no commercially viable separation, sorting and recycling technology for materials such as cotton and polyester blends. In order to improve their expertise in this area, and ability to scan and evaluate new research and technologies, H&M has partnered with the Hong Kong Research Institute of Textiles and Apparel (HKRITA) over a four year project. While the new technology and innovation can affect the components of an existing business model and how they interact, it can also create completely new business opportunities in uncontested market space, as in the above case exploit new recycled materials in the production chain. Such collaboration can also be seen at the sorting stage, for higher value added and demand-driven product recovery options. Few exemplary cases are Recovertex – an initiative by Ferre Company in Spain and Wargón Innovation – in the region of West Sweden, for establishing sorting facility aimed at recovering used textiles to
recycled materials for many life-cycles. Potential partners in such initiatives are charities, municipalities and other collecting organizations, research institutes for leading necessary research, demonstration and business development through optimized sorting processes, new technologies and feasible business models. Benefits are immense for miscellaneous industry sectors as end users, with the output as garments, textiles, polymers, composites, non-woven, etc. Some interdisciplinary projects, e.g. Mistra Future Fashion, Trash2Cash, Resyntex have exemplified such collaborative pan-European initiatives to strive for overcoming the design, technological and management challenges posed to achieve textile circularity. Trash2Cash, for instance, is a consortium of partners representing universities and research institutes, commercial companies, e.g. design firms, sorters, etc. aimed at regenerating fibers through chemical recycling of textile waste.

What is common to such initiatives is the inter-organizational collaboration (IoC) for creating circular apparel and fashion systems – though consisting of diverse members with different goals. But for developing and managing circular supplies, flows and associated knowledge, for effective and efficient closing, slowing and/or narrowing of the resource loops, these IoCs are essential to secure material sustainability and enhanced industry-wide extended responsibility.

A key driver of such IoCs is trust. It is an important enabler and requirement of partners’ collaboration, which can be built through open communication and knowledge sharing among partners. This is built upon an advanced and comprehensive understanding of each other’s work and core values. For instance, actors like research institutes and charities act under different formats and strive towards different goals, and this might lead to unanticipated challenges when it comes to setting normative orientations in the IoCs, such as for development of a new technology despite their common interest and support for the idea. Similarly in take-back schemes, the retailers and sorters have slightly different focus towards expected value gains and this requires a trusted cost-neutral arrangement for successful functioning.

Governmental legislation (voluntary or mandatory) is another key driver for encouraging collaborative actions among the actors involved in circular supply chains, either within their own organizational structure (e.g. incorporate circular material supplies as a starting point for new production, adopt more servitization schemes to extend their responsibility and stewardship, the charities and retailers utilized the logistics facilities of the private collectors, while the collectors in order to export their collected textiles utilized the charities’ exporting channels, etc.), as well as motivating them to have collaboration beyond their organizational boundaries by taking financial risks.

5. Evidences on inter-organizational value creation through digital supply chains
Digital supply chains permit the realization of direct connections and interactions between diverse actors, such as fashion designers, textile and apparel producers, brands and retailers, IT developing firms, and other concerned professionals – across both business-to-business (B2B) and business-to-consumer (B2C) interfaces. Even though a large number of digital solutions have emerged in the apparel supply chains, they are still not fully connected and lack an integrated knowledge-base. Recent industry level initiatives, such as Apparel made for you (AM4U) and Reshoring Initiative in the United States, for example, have developed various production technologies to create a local textile and apparel production but the digitalization does not include the business-to-consumer (B2C) digital interface. On the other hand, LEAPFROG has developed 3D garment prototyping processes. For setting the direction towards a more holistic inter-organizational focus in digital supply chains, two recently concluded pan-European projects, Open Garments and fromRolltoBag, lay the foundation.

At the business-to-business (B2B) side, open manufacturing based upon the open innovation concept, lays foundation for such collaborative supply chain structure where the production of customized individual garments is realized by a flexible network of production units ranging in size from micro enterprises to SMEs. While mass customization and rapid manufacturing for fast and flexible fulfillment of small size orders is crucial and is typically achieved through AMTs and virtualization, the most critical factor is the collaboration between enterprises and customers within the individual product-service innovation process. Such new industrial structure through integrated design,
production and sales of consumer designed and configured garments, involve a range of stakeholders, such as designers, manufacturing firms, and manufacturing service providers, where all actors in the value chain contribute and share knowledge. This new industrialization 4.0 structure based on digitalization is not just use of new technologies but more open digital integration among various players involved in the apparel supply chain for seamless information transfer, supporting new manufacturing and design models based upon open networks of flexible, demand-driven mini-factory lines with the know-how of making customized orders of different brands and deliver to the consumer; the brands would log into a cloud-based service portal perhaps run by an e-commerce service provider who organizes such manufacturing networks, operating on service charge basis.

Consumer-drive is another necessity for such customized digitized apparel and fashion supply chains, as diverse digital technologies such as virtual reality and 3D rendering at the customer-retailer interface, and digital pattern and fitting tools at the product design and development stage, are crucial. This is supported by the development and integration of AMTs and digitally-enabled processes based on utilization of existing technologies and/or new technical innovations in an emerging Industry 4.0 context. Examples could be digital printing, cutting, and garment-making techniques (such as bonding techniques). By achieving higher digital integration among various supply chain actors for seamless information transfer, to support the open and distributed manufacturing network of value chain processes are more transparent, integrated, flexible and agile to handle small-series niche volumes thus matching the Industry 4.0 perspective.

Further such integrated digital supply chains and marketplaces act as resource for the regional apparel industries to establish supply chains networks aiming for more seamless integration and fits well with the strategic directions prescribed under Regional Strategies for Smart Specialization (RIS3) – aimed at creating job regionally leading to regional competitiveness and social sustainability.

The above mentioned initiatives suggest that even though digitalization of supply chains has become a core necessity in apparel and fashion industries, critical to its success in a high-cost setting is end-to-end system integration and information transfer based upon an open and distributed network model. This not only renders higher degree of coordination along the digitally integrated supply chain but is required to gain full transparency among all actors. To support this on one side, B2C communication provides scope for agile reorganization and flexible adaptation of the manufacturing processes, through constant exchange of information required to support small batches and high system complexity. On the other, advanced ICT systems and methods of communication and virtualization can render end-to-end digital integration by connecting the front-end to the back-end manufacturing and delivery used by companies for pricing, design and production planning.

6. Concluding remarks
In context to the systemic transition that the European apparel and fashion industries are going through towards a sustainable future, this paper elaborates on two pivotal antecedents to it – circularity and digitalization. As a means to attain sustainable value through the development of new industrial supply chain structures based on these antecedents, the paper argues that beyond technological process- or intra-organizational- focus on value creation, inter-organizational focus is equally crucial.

By drawing inferences from a limited yet vivid set of evidences, this viewpoint paper explores and resonates upon the key drivers/aspects of inter-organizational value creation in circular- and digital-apparel supply chains. In circular apparel supply chains, predominantly where multiples actor types are involved, clear benefits are observed in terms of higher value addition through joint business development efforts through IoCs in the product recovery processes (e.g. in take-back collection schemes, or in technology-based TWM). Key drivers of such IoCs are viewed to be trust and legislative governance. On the other hand, in digital apparel supply chains, IoCs are identified in the form of more open networks structures (e.g. open manufacturing) for knowledge access and co-evolvement, and end-to-end digital integration for seamless information transfer and transparency. Altogether they lead to a new Industry 4.0 setting for inter-organizational value creation.

In particular, it can be highlighted that inter-organizational value creation in both circular- and digital-apparel supply chains seem to a large extent be built upon collaborative initiatives (a dynamic capability in itself), where firms either open up their activities, or couple with diverse actors (from...
both primary value chains and secondary actors such as research organizations, etc.), or induce more seamless integration. Therefore, developing new industrial supply chain structures can be perceived to be a meta-capability of firms in the changing industrial landscape. This opens up scope for conducting deeper studies on supply chain structures utilizing multiple theoretical lenses. By understanding these key areas of inter-organizational focus for value creation in circular- and digital-industrial supply chains, the paper prescribes the first step towards devising decision support framework on how and where to devote effort as a means to create higher degrees of sustainable value in apparel and fashion industries. In addition, the paper has discussed circularity and digitalization as two different strands leading to sustainability in the apparel sector; whereas it is worth investigating through further research, how if they reinforce one another.

References