Wettodry Initiative:

Leading the Way to a Sustainable Fashion Supply Chain through E-Mass Customization

Author:
Helene Bergmann

Supervisor:
Jonas Stray

Examiner:
Jonas Larsson
The saddest aspect of life right now is that science gathers knowledge faster than society gathers wisdom.

- Isaac Asimov
Acknowledgement

I would like to express my deepest thanks to all the people who contributed to the fulfillment of this work, either on a personal or professional level.

Given that this thesis is written in cooperation with the Swedish School of Textiles in Borås, I would like to thank all involved teachers who brought up the research project of the Wet todry Initiative; namely Jonas Larsson, Mats Johansson and Vincent Nierstrasz. My special thanks go to my supervisor Jonas Stray, who provided me with the best possible guidance through the whole writing process for this thesis, as well as the former field study within the Initiative. His high responsibility for the scientific development of assigned students included supporting and motivating ideas, examples and high investment of leisure time. I am very grateful for all his encouragement.

Furthermore, I would also like to mention the company Bivolino.com that was used as a case study example within this thesis to strengthen the research in a practical manner. Herewith, I would like to thank the CEO Michel Byvoet, who took the time to answer my questions significantly.

Last but not least, I would like to thank my wonderful family and Paul, whose emotional support and endless love gave me enough strength to complete my academic career. They always remind me, that the most valuable things in live cannot be measured by numbers. Thank you for that.
Abstract

For this thesis, the concept of e-mass customization, supported through e-commerce and away from mass production is considered as an alternative and sustainable strategy for fashion and textile companies of western markets. Since the need for self actualization and individualization increases among western societies, in addition to sustainably conscious consumption patterns, mass customization is one strategic solution to face current market trends. In accordance to that, it is aimed to find highly flexible supply chain possibilities suitable for this volatile industry sector. This is accompanied by exploring modern and innovative production and information and communication technologies to ease cost, location and risk advantages. The main effort is placed on digital textile printers since this technological integration is regarded as a hub that supports a digital, yet flexible supply chain setup, regardless of point of production. This aim is captured by a two-folded method. First, relevant literature of all targeted and separate academic fields is researched in order to examine its combination potential. Secondly, the state of the art company Bivolino.com is observed to test the application potential practically in order to increase the scientific support. Consequently, it can be concluded that the concept of mass customization leads to a win-win situation for the ecology and economy. Supported through the integration of digital technologies, especially digital textile printers and latest e-commerce possibilities, a new sustainable textile business reality 2.0 is reached. This is realized through an e-mass customized strategy, with an on-demand reversed supply chain setup, in combination with operational improvements that form a digital, fully flexible supply chain management. This outcome makes the thesis significant for all fashion companies that want to respond better to current economic and social changes, by improving its business behavior in financial, strategic, operational and sustainable terms.

Keywords: E-Mass Customization, Digital Technologies, Digital Textile Printer, Sustainability, Supply Chain Management, E-Commerce
# Table of Content

ACKNOWLEDGEMENT ........................................................................................................ II
ABSTRACT .......................................................................................................................... III
TABLE OF CONTENT ....................................................................................................... IV
LIST OF FIGURES ............................................................................................................. VII
LIST OF TABLES ............................................................................................................... VII
LIST OF ABBREVIATIONS ............................................................................................. VIII

1 INTRODUCTION ........................................................................................................ 1

1.1 Background .............................................................................................................. 1
  1.1.1 Key Topic: Mass Customization .................................................................. 2
  1.1.2 Limitation of Literature ............................................................................. 2

1.2 Problem Description ............................................................................................. 3

1.3 Aim and Research Question ............................................................................... 4

1.4 Delimitations ........................................................................................................ 4

1.5 Structure of the Paper ...................................................................................... 4

2 THEORETICAL FRAMEWORK ............................................................................. 6

2.1 Sustainability ....................................................................................................... 6
  2.1.1 Ecological World Footprint ....................................................................... 7
  2.1.2 Impacts of the Textile and Fashion Industry ............................................ 8
  2.1.3 Conclusions on Sustainability Theory ...................................................... 9

2.2 Changing Conditions .......................................................................................... 10
  2.2.1 Conclusion on Changing Condition Theory ............................................. 13

2.3 Mass Customization ............................................................................................ 13
  2.3.1 The Oxymoron within Mass Customization ............................................. 16
  2.3.2 Approaches of Mass Customization ......................................................... 16
  2.3.3 Success Factors of Mass Customization .................................................. 18
  2.3.4 Strengths and Weaknesses of Mass Customization ............................... 18
  2.3.5 Mass Customization as a Driver for Sustainable Development ........... 20
  2.3.6 Conclusion on Mass Customization Theory ............................................. 21
# Table of Content

## 2.4 E-Commerce
- 2.4.1 The Long Tail Economy .......................................................... 23
- 2.4.2 E-Mass Customization ............................................................. 24
- 2.4.3 Conclusion on E-Commerce Theory ....................................... 26

## 2.5 Supply Chain Management
- 2.5.1 Digital Textile Supply Chain Management ............................ 30
- 2.5.2 Flexible Supply Chain Management as a Sustainable Solution ... 31
  - 2.5.2.1 Supply Loops ................................................................. 33
- 2.5.3 Conclusion on Supply Chain Management Theory ................. 35

## 2.6 Digital Technology
- 2.6.1 Direct Digital Textile Printing .................................................. 38
  - 2.6.1.1 Digital Printing Machines ............................................... 40
  - 2.6.1.2 SWOT Analysis for Digital Textile Printing ................... 41
  - 2.6.1.3 Digital Printing as an enabler for Mass Customized Textiles ... 42
- 2.6.2 Other Digital Technologies supporting a Digital Supply Chain Design ........ 43
- 2.6.3 Environmental Aspects of Digital Printing ............................ 46
- 3.6.4 Conclusion on Digital Technology Theory ............................ 47

## 3 CASE STUDY BIVOLINO

### 3.1 Brand History
- 3.1.1 Brand Logo ................................................................. 49
- 3.1.2 The Customized Shirt ...................................................... 50

### 3.2 Bivolino’s Innovative Technology
- 3.2.1 Direct Digital Printing Technology ....................................... 53

### 3.3 Supply Chain Management
- 3.3.1 Open Garments Project .................................................... 56
- 3.3.2 MSEE Project .............................................................. 57

### 3.4 Bivolino and Sustainability .................................................. 58

## 4 RESULTS

## 5 ANALYSIS

### 5.1 Sustainability ........................................................................ 62

### 5.2 Changing Condition ............................................................ 63
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.3 Mass Customization</td>
<td>64</td>
</tr>
<tr>
<td>5.4 E-Commerce</td>
<td>64</td>
</tr>
<tr>
<td>5.5 Supply Chain Management</td>
<td>65</td>
</tr>
<tr>
<td>5.6 Digital Technology</td>
<td>66</td>
</tr>
<tr>
<td>6 CONCLUSION</td>
<td>68</td>
</tr>
<tr>
<td>7 OUTLOOK AND FUTURE RESEARCH</td>
<td>70</td>
</tr>
<tr>
<td>LIST OF REFERENCES</td>
<td>IX</td>
</tr>
<tr>
<td>APPENDIX A</td>
<td>XVII</td>
</tr>
<tr>
<td>APPENDIX B</td>
<td>XXI</td>
</tr>
</tbody>
</table>
List of Figures

Figure 1: Time Line describing developments within the textile and fashion industry 2
Figure 2: Visual Structure of the Paper 5
Figure 3: Three pillars of Sustainable Development 6
Figure 4: Humanity’s Ecological Footprint and Bio capacity through time 7
Figure 5: Maslow’s Hierarchy of needs 11
Figure 6: Four faces of mass customization 17
Figure 7: The Long Tail Economy 23
Figure 8: E-Mass Customization model 25
Figure 9: Customer Order Decoupling Point 28
Figure 10: Economic Implications of Mass Customization 29
Figure 11: Typology of Supply Chains 32
Figure 12: The Full Closed Supply Loop Chain 34
Figure 13: Principle of material systems 35
Figure 14: Mass Production versus Mass Customization Supply Chain 36
Figure 15: Production processes within a mass customized supply chain using digital textile printer 37
Figure 16: Share for Print Technologies 38
Figure 17: Digital Machine Productivities 40
Figure 18: Supply Chain Comparison 43
Figure 19: Digital Technology supported Supply Chain 45
Figure 20: Recent Future Outlook 45
Figure 21: Print/finishing machine 47
Figure 22: Bivolino’s Development 49
Figure 23: Visual Brand Logo Development 50
Figure 24: Women Shirt Design Options 51
Figure 25: Comparison of Mimaki inkjet printer with screen printer 54
Figure 26: Open Garments Network 56
Figure 27: Overview of MSEE Project 57
Figure 28: Bivolino’s development results 61
Figure 29: New Sustainable Textile Business Reality 2.0 69

List of Tables

Table 1: Benefits and risks within Mass Customization 20
Table 2: SWOT for Digital Printers 41
### List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATO</td>
<td>Assemble-to-Order</td>
</tr>
<tr>
<td>B2B</td>
<td>Business to Business</td>
</tr>
<tr>
<td>B2C</td>
<td>Business to Customer</td>
</tr>
<tr>
<td>BTO</td>
<td>Build-to-Order</td>
</tr>
<tr>
<td>CAD</td>
<td>Computer aided Design</td>
</tr>
<tr>
<td>CAM</td>
<td>Computer aided Manufacturing</td>
</tr>
<tr>
<td>CEO</td>
<td>Chief Executive Officer</td>
</tr>
<tr>
<td>CNC</td>
<td>Computer Numerical Control</td>
</tr>
<tr>
<td>CODP Point</td>
<td>Customer Order Decoupling Point</td>
</tr>
<tr>
<td>COO</td>
<td>Chief Operating Officer</td>
</tr>
<tr>
<td>CMYK</td>
<td>Cyan-Magenta-Yellow-Black</td>
</tr>
<tr>
<td>CRM</td>
<td>Customer Relationship Management</td>
</tr>
<tr>
<td>CSCMP</td>
<td>Council for Supply Chain Management Professionals</td>
</tr>
<tr>
<td>CSR</td>
<td>Corporate Social Responsibility</td>
</tr>
<tr>
<td>DBE</td>
<td>Digital Business Ecosystem</td>
</tr>
<tr>
<td>DIY</td>
<td>Do it Yourself</td>
</tr>
<tr>
<td>DOD</td>
<td>Drop on Demand</td>
</tr>
<tr>
<td>DTG</td>
<td>Direct to Garment</td>
</tr>
<tr>
<td>EDI</td>
<td>Electronic Data Interchange</td>
</tr>
<tr>
<td>ERP</td>
<td>Enterprise Resource Planning</td>
</tr>
<tr>
<td>ETO</td>
<td>Engineer-to-Order</td>
</tr>
<tr>
<td>EVA</td>
<td>Ethylene Vinyl Acetate</td>
</tr>
<tr>
<td>FoF</td>
<td>Factory of the Future</td>
</tr>
<tr>
<td>ICT Tools</td>
<td>Information and Communication Tools</td>
</tr>
<tr>
<td>JIT</td>
<td>Just-in-Time</td>
</tr>
<tr>
<td>KPI</td>
<td>Key Performance Indicator</td>
</tr>
<tr>
<td>LOHAS</td>
<td>Lifestyle of Health and Sustainability</td>
</tr>
<tr>
<td>MaaS Systems</td>
<td>Machine Assisted Assembly Systems</td>
</tr>
<tr>
<td>NC</td>
<td>Natural Market Institute</td>
</tr>
<tr>
<td>OI</td>
<td>Open Innovation</td>
</tr>
<tr>
<td>OM</td>
<td>Open Manufacturing</td>
</tr>
<tr>
<td>PLM</td>
<td>Product Lifecycle Management</td>
</tr>
<tr>
<td>QR</td>
<td>Quick Response</td>
</tr>
<tr>
<td>S-MC-S</td>
<td>Sustainable Mass Customization - Mass Customization for Sustainability</td>
</tr>
<tr>
<td>SaaS</td>
<td>Software as a Service</td>
</tr>
<tr>
<td>SCM</td>
<td>Supply Chain Management</td>
</tr>
<tr>
<td>SOA</td>
<td>Service Oriented Architecture</td>
</tr>
<tr>
<td>TBL</td>
<td>Triple Bottom Line</td>
</tr>
<tr>
<td>TCI</td>
<td>Textile and Clothing Industry</td>
</tr>
<tr>
<td>UISS</td>
<td>Uninterrupted Ink Supply System</td>
</tr>
<tr>
<td>3D</td>
<td>3-dimensional</td>
</tr>
<tr>
<td>3D</td>
<td>3-dimensional</td>
</tr>
<tr>
<td>3D</td>
<td>3-dimensional</td>
</tr>
</tbody>
</table>
1 Introduction

This Chapter introduces the reader to the content of this master thesis. The thesis is a part of an initiative at the Swedish School of Textiles that aims to develop and test applications within mass customization business concepts for digital printing on textiles. The initiative is interdisciplinary between design, technology, business and supply chain management.

1.1 Background

Since recent decades, mass customization has become a widely used paradigm in the textile and fashion industry (Senanayake and Little, 2010) by offering opportunities of being closer to market needs and withstand demand volatility which is a typical characteristic within the fashion business. Being able to address a different manufacturing approach compared to mass production which is based on an on-demand fabrication (Piller, 2004), mass customizers can profit from economies of scope and offer customers products according to their unique preferences. The present relevance is further emphasized by the fact that it becomes increasingly attractive for start-up companies and micro businesses to apply this efficient and effective strategy by using merely the online channel (under30ceo.com, 2010). This latest trend is denoted as e-mass customization, which constitutes itself through a combination of e-commerce and customization strategy (Kaplan and Haenlein, 2006), reduces initial business risks and can set new strategic and environmentally friendly opportunities, since it is aimed to minimize returns and in turn reduce waste.

Moreover, current consultation dialogues between the scientific community and entrepreneurs additionally reinforce the need for a sustainable paradigm-shift in society and economics (Carbonaro and Votava, 2009). This progress evolved through the insight that nowadays corporations cannot sustain themselves with a purely profit oriented vision in the market. Therefore, these debates demand the integration of social and ecological aspects into business reality in order to expand economic responsibilities that foster a triple bottom line approach (Zsolnai, 2011). This solution is regarded to set the foundation for sustainable development.

One production possibility provides a vision for a cleaner future that encompasses the evolution of digital clothing supply chains, from design to distribution and an end-of-life supply chain focus. The latest advancements of digital textile printing machines include highly efficient hard- and software devices in order to be competitive with traditional screen printers (Ujiie, 2006). This web-based supply chain is the new approach to realize a more sustainable and efficient apparel industry and global trade (Fralix, 2003), by focusing on e-configurations, digital design and manufacturing toolkits, online dressing facilities and the development of a virtual shopping market. Different types of waste can
be controlled as part of a lean manufacturing within an agile chain, or sustainable project. Technology also plays a role in developing a more sustainable supply chain including computerized sketching, CAD pattern design, digital grading and marker-making, digital direct on textile printing and computer numerical control (CNC) single-ply cutting (Bivolino.com, 2012d). Together with the latest progress on technology, communication and information systems, new production and supply chain potentials pave the way for an innovative business reality within the textile and fashion industry. The dependence on low-labor cost countries within the textile industry may be reduced, which brings back the strength to western markets.

1.1.1 Key Topic: Mass Customization

The observation of an increased need for personalization among citizens leads to the beginning of disintegration of mass markets within the fashion industry. Together with a differentiation of supply and demand, mass production loses its attractiveness and mass customization can be regarded as a megatrend of the 20th century. The changed conditions of diverse areas, namely supply chain management (SCM), technological improvements and market and consumer developments influence and create the model of mass customization. A chronological time line shows these developments in Figure 1.

![Figure 1: Time Line describing developments within the textile and fashion industry](developed by the author)

Therefore, a scientifically deep analysis of mass customization strategies is prioritized, as it has the potential to enter into the presently discussed movement of sustainability.

1.1.2 Limitation of Literature

The concept of mass customization has been reflected thoroughly by, for example, Joseph Pine (1993), Paolo Coletti (2011), Giovani Da Silveira (2001), James Gilmore (1997) or Frank Piller (2003;2004;2012) for the last twenty years. Furthermore, the manufacturing strategy that underlies the conception of mass customization has been revealed as one opportunity to achieve increased sustainable developments. Sutherland (2006) classified the idea of a production setup, based on modular assemblies as one way to reduce waste in global supply chains, whereas Trappey and Wognum (2012) expand a sustainable behavior through a network and supply chain system integration for mass customizers. Besides, a flexible supply chain is regarded as the most suitable strategy for the customization concept (Pan and Holland, 2006) and in addition fulfills sustainable requirements (Shukla et al., 2010). Furthermore, recent improvements in
technology, whether information and communication technology (Anonymous, 2000; McCormack and Kasper, 2002) or digital textile printing machines (Fralix, 2003) have paved the way for achieving highly flexible and digital supply chains among textile industries. These digital technologies set the foundation for e-commerce and extend the concept of mass customization to e-mass customization (Kaplan and Haenlein, 2006). Still, one major link is missing, which is the combination of all four factors, namely sustainability, e-mass customization, digital and flexible SCM and digital textile printing machines. This connection is, according to the author of this thesis, regarded as a future strategic opportunity for the volatile, emotional and saturated textile industry of western markets to come closer to actual market needs and becoming efficient in a sustainable manner. Accordingly, this thesis will examine the relationship between these four factors, and draw conclusions on the out coming effects to modern organizations.

### 1.2 Problem Description

The textile and fashion industry contains severe environmental problems which increase worldwide resource depletion. Notable within this industry is its significant contribution to environmental degradation, regarding enormous water usage for finishing processes, soil degradation through cultivating natural fibers under herbicides and pesticides and CO\(_2\) emissions caused by machinery or long transportation distances based on global production. Another factor that strongly confronts the textile industry is the increasing labor costs within production mills in former low labor cost countries like China. The fact, that the textile industry became highly globalized the last decades, also resulted in a fragmented supply chain, constantly challenging fashion companies in finding efficient strategies that reduce lead times. This pressure is even higher within mass customization firms, since an on-demand production automatically requires shorter lead times. Furthermore, a change within the western consumption society can be observed that shifts towards a more conscious buying behavior where the demand for clean and qualitative products, produced under ethical conditions rises. Besides, an increased personalization movement becomes noticeable by a do-it-yourself (DIY) culture and a growth in mass customized business concepts, both reflecting the craft era. Consequently, it shows that since customers demand unique, personalized and meaningful goods and services, the concept of mass production cannot anymore secure business success. Regarding all these issues with which the textile and fashion industry is currently confronted, the urgency for a paradigm shift increases. Still, instead of concentrating on innovative solutions, most companies hold tight on old business-as-usual frameworks which decrease costs through mass production in low labor cost countries with loose or unclear social and environmental regulations. Without understanding today’s need of capturing the holistic picture, which is accountable for corporate wealth and goes beyond the conventional bottom line approach by considering social and environmental aspects, our world may never experience real, sustainable prosperity.
1.3 Aim and Research Question

This thesis is intended to uncover sustainable solutions out of the mentioned problems in Section 1.2 that confront the textile industry today. Therefore, it is aimed to find alternative, highly flexible supply chain possibilities for the volatile textile and fashion industry. This is combined by exploring modern and innovative production technologies that ease cost, location and risk advantages in order to replace traditional, yet dominating screen printing machines since they are neither regarded as environmentally friendly nor efficient for SME’s requirements. Consequently, it is intended to include newest technology gapless into supply chains and discover the chance of a streamlined, digital SCM. In addition, the described socio-cultural forces within western markets are addressed in this paper, since those behavioral shifts are highly affecting the fashion industry. In order to appeal to current consumer changes, the concept of e-mass customization, away from mass production is considered as an alternative and sustainable strategy. The result should increase the scientific support of the assumption that it is more environmentally sustainable to create and buy garments in a digital form. Moreover, the possibility for the next future trend of going back to local or national production with a local supply chain setup should be supported by the digital solution. It is aimed to verify that ecological and economical targets lead to a win-win situation for companies, the society and the eco-system. Consequently, this thesis has relevance for any textile and fashion corporation that is already involved in customizing products, or wants to change its current business processes in a more sustainable and profitable manner in order to maintain a competitive advantage in the future. Therefore, the following research question is formulated:

*Is the concept of e-mass customization, supported through the supply chain integration of digital technologies an ecologically and economically sustainable solution for the fashion industry?*

1.4 Delimitations

Although the model of sustainability covers the three aspects of social stability (people), ecology (planet) and economy (profit), this thesis places the main effort on ecological and economical relevancies that are revealed from the e-mass customization business strategy. A further focus is placed on the fashion and textile industry within western marketplaces.

1.5 Structure of the Paper

Starting with a general introduction in Chapter 1, the relevant background information introduces the reader to the main thesis’ topic of mass customization and outlines limitations within existing literature. Current problems with which the textile and fashion industry is confronted are presented and result in several aims regarding the paper. Thereafter, a valid research question is formed that guides the thesis progress. In
order to find convincing answers to the question, the following method is chosen, which consists of a two way approach. First, a theoretical framework, based on comprehensive literature review examines six major scientific fields in Chapter 2, since all these themes deeply influence the topic. After studying each theoretical building block, a conclusion summarizes relevant outcomes which contribute to the thesis’ goal and prepares the reader for the analytical discussion in Chapter 5. Secondly, an observation is done in Chapter 3, which is based on one case study and increases the probability of scientific support. For this case study, one state of the art and worldwide unique business concept within fashion mass customizers, namely from the online company Bivolino.com combines future opportunities to direct new paths within this industry sector. This observation is based on information from the company’s web page, press releases and interviews with the CEO Michel Byvoet. All this combined, leads to results which are summarized in Chapter 4. With respect to these results and the combined findings from the literature review, an analysis is given in Chapter 5 and discussed respectively. This analysis is used in Chapter 6 to construct a conclusion that answers the research question. Finally, a future outlook is added in Chapter 7, which is closed with perspectives for possible future research topics. To visualize this structure, Figure 2 shows the building blocks of the thesis.

![Visual Structure of the Paper](image)

Figure 2: Visual Structure of the Paper (developed by the author)
2 Theoretical Framework

This Chapter outlines required theoretical fields that are necessary for the understanding of this report and define the terms used in the title. Therefore the scope of the thesis is clearly defined in order to use theories that respond to the research question stated in Section 1.3. This builds a framework for the analysis and conclusion.

2.1 Sustainability

An almost forgotten term has been resurrected to give a new meaning to the rising interest in green: Sustainability. The most widely used definition for sustainability refers to the first major articulation that took place in 1987 of the United Nations, known as the Brundtland Commission and its following report `Our Common Future´ (Brundtland, 1987 cited in Edwards, 2005, p.4). In this report sustainable development is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. Even though this short definition does not include economical prosperity, environmental stewardship and social responsibility, those concepts are related to the term sustainability or sustainable development in the scientific community and entrepreneurs (Estes, 2009). The three aspect or pillars of sustainability, namely people, planet, profit are also known as the 3Ps or 3Es: economy, ecology, equity, and need to be addressed using a holistic approach (Edwards, 2005). The correlation between these concepts is visualized in Figure 3.

![Figure 3: Three pillars of Sustainable Development](cskill.org, 2012)

Today, western companies have difficulties increasing their market share in a more and more competitive global market (Estes, 2009). Some consultants (Norman and McDonald, 2003; Altman and Berman, 2011) still hold tight on a single bottom line approach and claim that the most corporate effort should be spent on reducing costs to improve profits and shareholder value, since this implementation automatically leads to social and environmental well-being. One dissident consultant, who already started to research the TBL issue in 1994, is Elkington by including social and ecological terms into
financial statements in order to extend the profit oriented bottom line into a triple bottom line (TBL) approach (The Economist, 2009). The motivation behind this concept is based on the common wisdom that you cannot manage something that you cannot measure (Forbes, 2011). Although aspirations behind the TBL approach are supported by many academicians and businesses, Norman and McDonald (2003) also have considerations about its realization potential since the concept might promise more than it can deliver. This is due to the problem that results when trying to find a common scale to measure an organization’s social and ecological good and bad assets. In addition, it is always not so easy to assess the correct impacts of an action.

2.1.1 Ecological World Footprint

Looking closer at human history the need for sustainable development seems to be a reaction to the industrial revolution in the early 19th century with its technological breakthroughs like John Kay’s flying shuttle in 1733, Watt’s steam engine in 1769, Cartwright’s power loom in 1783 and Eli Whitney’s cotton gin in 1793 (Edwards, 2005). Although these valuable inventions lead to an increased production and economic growth in the textile, iron and steamship industry, they also marked a major turning point in human history (Pierce, 2005). Most notably, average income and population growth began to exhibit unprecedented sustained growth when world’s average per capita income increased over 10-fold, while the world’s population increased over 6-fold in the last two centuries (Maddison, 2003). One way to demonstrate environmental problems based on resource depletion, overproduction, pollution and consumption is the ecological world footprint. It is an effective measure designed to express the world’s nature demand (ecological footprint) used to nurture citizens and the world’s nature supply (bio capacity) in order to meet this demand. The area needed to produce the resources and to absorb the produced wastes is measured in global hectares and compared to the area available on the planet (Global Footprint Network, 2012). The calculation results either in a bio capacity debt or credit. This result reflects how much time the earth needs to renew the resources and absorbs the waste humans are liable for within one year. When the number exceeds the ratio of one, the earth consumes more than it produces and is being utilized with a bio capacity deficit, shown in Figure 4.

![Figure 4: Humanity’s Ecological Footprint and Bio capacity through time (Global Footprint Network, 2012)](image)
The world footprint has been measured since 1960 with the last analysis in 2007. Figure 4 clearly shows the tipping point for unsustainable development in 1980 where the ratio accounted a deficit of 0.06 hectare per capita. Since that time the ratio has resulted in even worse results and so far expressed by a ratio of 1.5 meaning that the earth needs one year and six months to generate what has been used in a year. Furthermore, it can also be recognized that the highest increase happened to greenhouse gases, which results in an excessive carbon footprint. Today, ecological footprints have a large number of applications and can be calculated separately for countries, communities, businesses or single households.

2.1.2 Impacts of the Textile and Fashion Industry

In general, fashion is all about change, fast varying trends and a very emotional market where the goal of being up to date, seeking consumer preference and producing the latest style may displace the involvement in ecological terms (Fletcher, 2008). As a matter of fact, the global fiber demand is rising constantly due to a growing population and economies, higher purchasing power and because of new consumption patterns within the clothing industry. Besides, the clothing industry gets increasingly fast meaning that production cycles become shorter, resulting in shorter product life cycles. This development is described as the process of fast fashion and characterized by rapid production processes with extremely short lead times in order to respond quickly to market needs (Fletcher 2008). The advantage of gaining economies of scale to produce in high amounts at low costs is dominating the clothing market which mostly results in low quality products that are aimed for a short life cycle (Hethorn and Ulasewicz, 2008). This overproduction and overconsumption lead to negative side effects for the environment (Fletcher, 2008). The creation of huge amounts of waste is one of the problems connected to the fast fashion business (Blackburn 2009). According to Hethorn and Ulasewicz (2008), employees who work within the textile industry need to be informed about these side effects in order to be part of the discussion on sustainable issues and processes.

Global textile consumption is so far estimated to be more than thirty million tons a year (Chen and Burns, 2006). Slater (2003) points out that the main environmental harm within textile firms lies in transportation and production, starts with forming the yarn and ends with a ready-made garment. Besides, textile production uses high amounts of energy caused by a high demand of textiles and machinery usage (Slater, 2003).

Another issue is related to textile wet processes, which includes fabric dyeing, printing and finishing in order to create solid colors, patterns and functional characteristics like color fastness. Chen and Burns (2006) mention that although the textile industry is constantly working on recycling and reduction of textile waste, the environmental effects of textile wet processes are still a major concern due to needed chemicals and
Theoretical Framework

dyes. The textile printing industry was once considered to have one of the least ecologically friendly processes due to wet and gaseous effluent discharge (Dawson, 2012). Through the introduction of digital ink-jet printers, an economical advantage due to achieving quick response and short print runs could be measured, in addition to digital printing being a more ecologically friendly process compared to usual screen printers (Dawson, 2012). Still, so far digital printing makes only 1 % of the printing industry (Phillips, 2010).

Another consideration is the water usage during textile production. Approximately 200 billion liters of yearly wastewater effluent is released by textile manufacturing mills (Chen and Burns, 2006). Hoekstra et al. (2011) continue by mentioning that so far companies have little knowledge in science and practice of water management about water consumption and pollution along the whole production and supply chain. Hill (2008) brings up the issue, that the textile industry is a chemically intensive sector and after the agriculture sectors the worst polluter of clean water. Through the need of textile finishing, water is used at every step of the process; this is because chemicals need to be forced through textiles with the help of water and afterwards these textiles need to be washed out from residues before the next step can begin. Polluted water is then released as wastewater into the environment. This hot effluent has an increased pH value and is saturated with dyes, bleaches, detergents, optical brighteners, equalizers and other chemicals such as formaldehyde causing ecological degradation and human illness (Slater, 2003).

All stated practices use energy and chemicals, consume resources and produce waste resulting in environmental pollution discarded into air, water or land. Still, opportunities in sustainable improvement for textile companies go further with rethinking logistics methods, waste reduction or redesigning packaging (Wackernagel and Rees, 1996).

2.1.3 Conclusions on Sustainability Theory

The essence of sustainability is to find the best strategy that can balance social needs and economic growth with the natural environment in order to prosper and continue for generations, which is required for a more globally acting world. Although one may argue that this TBL approach makes it difficult to convince conventional profit oriented entrepreneurs to engage in social and environmental activities, its significance must be understood based on today’s severe environmental problems. Consequently, it would be easier if ecological and social factors could be measured in monetary terms to provide managers with a financial support, able to point out that all three pillars are not mutually exclusive and can lead to a triple-win situation. Hence, only if enterprises find ways to track their social and environmental impact with key performance indicators (KPI), the idea behind sustainable development can be practically fulfilled. Although, the full costs of, for example, waste water effluent or soil depletion caused by textile dyeing
practices are hard to measure financially, since the cause-effect ratio for that action may need more than a fiscal year, the importance of finding solutions should be considered.

Furthermore, in order to meet the demands of a growing world population, production (using tons of raw material) and consumption (producing tons of waste) goes hand in hand without facing ecological, social and even economical consequences. These consequences express themselves in a degradation of the environment, societal unwell-being, financial crises and other issues confronting the world today. Problems such as global warming, resource depletion, loss of biodiversity or poverty become more pressing and draw humanity closer to its ecological and social limits. This is clearly the result of industrialization and globalization and thus this ratio should be decreased to return to a balanced system.

Since sustainability deals with longevity of products, human resources, finance etc., it seems paradoxical trying to implement a sustainable strategy in the textile and clothing business. A clear unbalance between customer’s needs and actual consumption is created and with that the time from purchase to discard of fabrics. Production waste is created in several stages by the processing of raw materials, in further spinning and fabrication processes and in finishing and cutting procedures. It is a necessary goal to establish efforts for a more environmental friendly production. The full ecological impact of textile products can be broken down into production, maintenance and after-use or disposal, whereas production issues mainly include the renewability of raw materials and toxicity of chemicals for yield treatments, coloration and fastness properties. The fact, that garments are also water intensify goods, which start at the agricultural sector, followed by finishing processes and end at the usage stage where consumers wash textiles periodically with detergents makes the industry liable for environmental degradation. Consequently, the way industry approaches the production of garments and setup of the supply chain directs the resulting ecological footprint. Still, since digital printing embraces an ecologically friendly alternative to screen printing and dyeing, a solution to this problem is aimed to be achieved in this report. Since digital printing accounts to only 1 % of the printing market share, it needs to come closer to the efficiency of screen printing devices.

2.2 Changing Conditions

Western markets and consumer behavior undergo changes that result in increased consumer awareness of the general environmental and social concerns especially in the last decade. The climate crises and the financial crisis in 2008 are regarded as drivers or forces that have pushed consumer awareness (Kirig and Wenzel, 2009).

Increased consciousness for sustainable goods and services was fundamental for several developments within the clothing industry, starting with the first ecological fashion
movements in the seventies which were pushed by socio-political forces (Hethorn and Ulasewicz, 2008). Today, this is fostered with a critical view on the outcomes of the industrial state and societal developments with increased consumption behavior. Since the year 2000 this new development can be stated as the high eco-fashion phase, emerged through a new consumer group called LOHAS (Lifestyle of Health and Sustainability) that represent a luxury consumer class characterized by a sustainable way of living (Hethorn and Ulasewicz, 2008). The new ethical code of LOHAS combines certain values, namely loyalty, awareness, criticism or responsible behavior in their consumerism (Diekamp and Koch 2010). Environmental factors and social concerns became more important than being trendy or buying the latest innovative products (Lynn, 2002). This consumer group is open for innovative ideas and benefits of new technology as long as it leads to progress in a good sense, they use new media like internet, blogs and social communities to spread their ideas and seek for a meaningful life ahead of mass consumption (Kirig and Wenzel, 2009).

The hierarchy of needs by Maslow explains these recent developments as natural outcomes of a high developed society that fulfills basic needs situated on the bottom by which it can afford the luxury of self-actualization and individualization (Figure 5).

![Maslow's Hierarchy of needs](image)

**Figure 5:** Maslow’s Hierarchy of needs  
(Chapman, 2001-2004)

It means that only if one need, starting from the bottom of the pyramid can be fulfilled, a person can focus on the next need above. Consequently, since the broad western society can be regarded as a wealthy, highly developed civilization in a free and peaceful economy, the sensitivity for self actualization, personal growth and fulfillment is increased. Therefore, modern individuals in western economies place their effort in setting themselves apart from other citizens by focusing on individualized and value-based distinctions (Larsen, 2006). According to Larsen (2006), this individualization comes combined with a need for social growth based on more intrinsic values that sustain real happiness and a meaningful life in the long term.
Carbonaro and Votava (2009) also observed a change within old established consumer behavior. They add that the environmental and financial crises lead the way to private crises in western cultures where concerns about living standard, pensions and job security are increased by the loss of traditional gender roles and family models. Therefore, consumers have reinterpreted the meaning of luxury as a private item with increased value through being “unique, clean, fair, good [...] something that makes sense and is able to tell the story of its tradition and origin” (Carbonaro and Votava, 2009 p.36). Carbonaro and Votava (2009) demand an ethical design of business and consumption models to achieve a new intrinsic oriented prosperity and sustainable growth especially in crisis-driven times like today. Pointing out that in western society people’s aspiration is presently shifting from a material oriented economy to one based on well-being and happiness, where the most expensive goods are not the most valued ones, but the goods that have a significant meaning, are not exchangeable, replaceable or reproducible. Those socio-cultural forces are values of security, peace, friendship, time, culture, knowledge or honesty and those needs can form the basis for a future economy. They continue to suggest a sustainable way out of the current economic system by demanding a new design of economic and political systems and cultural models that can change people’s attitude and behavior (Carbonaro and Votava, 2009).

Hethorn and Ulasewicz (2008) created another term; the eco-savvy consumer, which is characterized by means of responsible actions towards environmental and social concerns in combination with a fashionable sense of style and trends. These consumers are also highly critical and aim for a change in the fashion industry, which results in purchasing decisions based on a company’s sustainable actions. Another behavioral aspect that can be stated is a difference between the attitude of a consumer and the actual buying behavior. Fletcher (2008) recognized that a high amount of consumers are concerned about the environmental impact of fashion, but mostly this does not lead to a change in consumer’s every-day purchasing habits.

The value change also integrated the term of corporate social responsibility (CSR) into business reality. CSR, as the ethical and social responsible code of companies gained evermore importance in the global economy over the last ten years (Weybrecht, 2010). Engagements usually focused on sports, arts or charity projects expanded further with a takeover of social and environmental responsibilities as serious elements within a company’s corporate culture. Since stakeholders demand a synthesis of market-based actions and sustainable thinking within corporations, CSR is tried to show that both approaches are not mutually exclusive. Scientists are speaking of a green economy as Greenomics that describe the new eco-economy as a development out of problems connected to climate change or the financial crisis in 2008 (Wenzel et al., 2008). The Natural Market Institute (NMI) estimates the Greenomics market potential in 2010 to be around $ 424 billion and by 2015 this amount is supposed to double. Clear moral, social
Theoretical Framework

and ecological themes fortunately become part of the economy. Meanwhile, it can be considered that it is possible to establish a flourishing business through green technology and processes (Wenzel, Kirig and Rauch, 2008).

2.2.1 Conclusion on Changing Condition Theory

Behavioral shifts to a more conscious consumption, that value quality rather than quantity and the small and simple things in life, combined with a strong individualization is today’s answer to live a meaningful life. In employing LOHAS, mass production is regarded as a waste of resources, human and financial capital, where the culture of buying to be happy is replaced by a culture of being to be happy with values shifting to an intrinsic satisfaction and self-actualization. This disillusion of previous life styles from western citizens supported through material, extrinsic values based on consumption can no longer be a reasonable answer facing the current global problems. The present economic illusion of unlimited material growth and senseless wealth accumulation need to be reshaped in more realistic patterns of responsible citizens and economy, based on true and sustainable quality that strives toward a better life and push sustainable growth, science, knowledge, craftsmanship, experience and wisdom. Hence the need for personalization in the western culture is one consequence of people’s social behavioral change. These contemporary movements, impregnated by environmental and social concerns are rising and show high popularity leading to influences of recent trends and markets. What is more important is that all named developments illustrate the demand of the broad society to see economy and ecology as a closed system, able to profit from each other and not on costs of each other.

2.3 Mass Customization

Mass customization has emerged into one of the most lucrative business trends for manufacturing and service industries since the 90’s (Pine, 1993). One essential idea of mass customization is to translate customer’s heterogeneous needs into unique products or services that have the opportunity to create value (Piller, 2003). Nowadays, companies need to face severe pressure throughout the supply chain with suppliers and partners who want to make a good profit and customers who demand lowest possible prices (Gattorna, 2010). However, in the course of increased global competition, costs have to decrease as much as possible (Pine, 1993a). This cost pressure is further fostered through rapid technological changes and reduced product life cycles for fashion goods that consequently increase business risks and lead to an uncertain and vulnerable marketplace. In addition, Pine (1993b) observed early, that mass production based on forecasting does not lead to efficiency in volatile marketplaces and therefore he emphasized that companies show more interest in customizing their goods and services in co-operation with customers according to their unique specifications at relatively low costs.
Mass Customization is a strategy by which products and services are personalized for individual customers at a mass production price where a company should “mass-customize as much as necessary and as little as possible” (Davis, 1994 p.180). The term mass customization arose in 1987 for the first time and was developed by the famous business visionary and consultant Stanley Davis. Davis speaks of mass customization when “the same large number of customers can be reached as in mass markets of the industrial economy, and simultaneously [...] be treated individually as in the customized markets of preindustrial economies” (Davis, 1987 p. 169). In his book Future Perfect, Davis predicted a perfect future for end consumers with unlimited choices of products and at the same time an unsecure future for managers. Many examples are given of how goods and services will develop due to technological innovations which lead to improvements in speed, convenience and selection. Based on today’s knowledge Davis’ definition might be regarded as visionary rather than strategic because of a broader conceptualization of mass customization. A focused and practical description of mass customization is to interpret it as a system that implements information and communication technology (ICT), flexible and agile processes and organizational structures, to provide a wide variety of products and services that fulfill specific needs of individual customers (Da Silveira et al., 2001).

This concept was then further developed by Joseph Pine (1993b) in his book Mass Customization - The New Frontier in Business Competition. Pine mentioned that “today I define Mass Customization as the low-cost, high-volume, efficient production of individually customized offerings” (1993b). Both Pine (1993b) and Da Silveira et al. (2001) define mass customization as the ability to supply products tailored to individual customer’s wishes on a large scale by using flexible processes, similar or close to mass production efficiency, whereas Pine extends the definition by mentioning that the focal point is the creation of “[...] variety and customization through flexibility and responsiveness” (1993b).

Duray et al. (2000) continue by demanding the inclusion of two dimensions into the concept of mass customization, which is customer involvement and modularity. They classify different stages of mass customizers based on modularity type and point of customer involvement. Customer involvement plays a central role in mass customization since it determines the degree of uniqueness of the end product. Meaning that the earlier a company integrates customers in the design and production process, the more customized items become. The other dimension of mass customization is modularity through ensuring pre-engineered assemblies. These common assemblies are essential to gain economies of scale in production since customized goods should still be offered at a low price. Hence, Duray’s et al. (2000) view of customization is similar with the make-to-order, engineer-to-order and assemble-to-order range used in traditional supply chain management configuration which will be explained more detailed in Section 2.5.
Additionally, Pine (1993b) critically points out that the concept of mass customization does not necessarily mean that every module of a product can be reconfigured in unlimited ways, as this leads to high uneconomic costs. Moreover, companies select a predetermined range of possible varieties out of which customer can assemble individual products. According to Lee and Feitzinger (1996), products that can be designed and assembled according to pre-engineered modules into the end product are required for a successful implementation of mass customization, since final assembly is postponed to the very latest stage within the chain. A more pragmatic explanation is given by Tseng and Jiao, since the term relates to “the technologies and systems to deliver goods and services that meet individual customer’s needs with near mass production efficiency” (Tseng and Jiao, 2001 p. 658). Frank Piller, professor at the German RWTH University and co-director of MIT Smart Customization Group is a well-known researcher on value co-creation between customer and business and has published findings about mass customization. Piller’s (2003) definition brings the term to the point, by declaring it as a perfect bridge for connecting cost pressures and customer-specific requirements by combining customized products and services in compliance with the efficiency of mass production. Piller (2004) later continues to point out limits of this strategy, since not every flexible operations system or customer centric product design can be directly regarded as mass customization.

It can be recognized that much research evolved around the field of mass customization the last centuries and still continues. Mentioning Davis again, the pioneer of the early developments, his definition of mass customization also evolved over the years. Davis (2007) speaks of mass customization 2.0 as a reflection of the web 2.0, where the old theory had a top-down perspective with the producer or provider who wanted to enable consumers with mass customized goods. Now, in the 2.0 world the perspective has changed to a bottom-up view where consumers increasingly co-create goods and services according to their preferences. Besides, Duray et al. mention after a profound literature review that “extant literature has not established good conceptual boundaries for mass customization” (2000 p. 606). Anderson (2011) also points out, that meanwhile many professions agree on the benefits of mass customization over mass production, especially for businesses that have to deal with volatile markets, product variety, inaccurate forecasts, overstock or high response time. Still, Anderson points out one missing link that hinders companies to truly embrace success from this strategy, which is “knowing how to actually design and build mass-customized products” (2011 p. 32). For that reason, Anderson (2011) suggests to change production, supply chain, design and marketing strategy in such a manner that any product family can be produced on demand through highly flexible processes.

To summarize it, Piller makes clear that the wide field of mass customization should not suffer from a definition debate and need to “capture the uniqueness of mass
Theoretical Framework

Customization with its own distinctive properties” (2004 p. 314). By comparing different delineation of mass customization, it is obvious that individual and customized products or services as well as the efficiency of modern production, information and communication technology are the elements that make up the definition of mass customization.

2.3.1 The Oxymoron within Mass Customization

Looking at the previous definitions for mass customization, the concept represents a paradox for general manufacturing industries, namely from the term itself. This expression is a combination of the word ‘mass’ which derives from mass production and the word “customization” which originated from the craft era. Usually, customization and low cost production have been mutually exclusive (Thomas and Fouweather, 2009). Given the fact that businesses were either set up to produce customized and crafted goods at higher costs in high variety to gain economies of scope, or mass produced and standard goods at lower costs at high volumes to gain economies of scale. But Pine (1993b) and Davis (1987) introduce this new paradigm shift for manufacturing industries where a specific product can be produced according to customer’s wishes without disposing of the scale economy. According to Duray et al. (2002) this contemporary phenomenon is made possible due to new interactive technologies that let customers interact with companies and automated manufacturing systems that are linked through technology within the chain and provide quick manufacturing.

2.3.2 Approaches of Mass Customization

Meanwhile there exist different approaches with regard to characterizing customized products and services. According to Aichner and Coletti, the following aspects of customer’s needs can be considered for being customized (2011 p. 3-4):

- Aesthetics - represent social power and richness
- Technology – enhance an object’s utility
- Personal utility – enhance an object’s utility for the owner (custom made)
- Personal aesthetics – value of aesthetics and being recognized for that (status)
- Research – if conventional technological solutions are satisfying

In today’s range of customized products and services the aspects above mirror typical quality characteristics that can be selected to personalize items. Still, this approach fails to determine any type of customization, so Gilmore and Pine (1997) created a framework for mass customizers in which they worked out four distinct “faces” to customization, namely collaborative, adaptive, cosmetic and transparent. This framework should assist in applying the right customization strategy and avoid unnecessary production steps, as well as reduce process complexity during the implementation:
Theoretical Framework

- **Collaborative customizers** – companies classify the offering that fulfills customer’s needs, and both work together to make a customized product with needed design adjustments. It is defined as the highest form of customization where functionality and visual appearance of products are changed.

- **Adaptive customizers** – companies let customers create the product themselves according to their specific and different performance needs. Neither the functionality nor the visual appearance of the product is changed and customers basically assembles the final product to their requirements.

- **Cosmetic Customizers** – companies sell a final product differently depending on the customer group. The functionality of the product stays always the same but the visual appearance (package, design) changes due to customer preferences.

- **Transparent customizers** – companies shape their products due to customer’s requirements so that the functionality is changed, but without changing the design or visual appearance of the product (Gilmore and Pine, 1997)

Although Gilmore’s and Pine’s approach of mass customization is just one example to discover the paradigm of this strategy, it is chosen for this thesis since it is an established business model that can be applied in any type of business and also fits the requirements of this thesis. To visualize this framework, Larsson (2011) created a model to present examples of Gilmore’s and Pine’s four faces of mass customization. Those approaches can be achieved apart from each other or in a combination depending on the chosen design of a product, process or business unit (Figure 6).

![Figure 6: Four faces of mass customization](Larsson, 2011 p. 23)
2.3.3 Success Factors of Mass Customization

Da Silveira et al. (2001) summarized six internal and external factors from a rigorous literature review that are prerequisite for successful mass customizers. These factors can assist companies in order to find out whether mass customization is an appropriate strategy for their business models (Da Silveira et al., 2001 p.4):

- **Customer demand for variety and customization must exist**
  The success of mass customization is bound to the willingness of customers to respond to severity for a customized product (such as waiting time) as well as company’s ability to offer the mass customized service

- **Market conditions must be appropriate**
  An early implementation of mass customization contributes to company’s competitive position, for example an establishment of a reputation as innovative and customer driven. Thus, the success of mass customization is dependent on the timing of this development

- **Value chain should be ready**
  In order to be successful, companies need to consider their supply chain network and adjust its processes as required with all involved partners. Every link in the chain should be ready to fulfill the new conditions since mass customization is a strategy based on value chain performance

- **Technology must be available**
  An optimal integration of ICT and process flexibility technologies is necessary. The implementation of superior manufacturing technologies is fundamental

- **Product should be customizable**
  If a product can be modularized, is versatile and can be reconfigured it accomplishes necessities for being customized, although it is not necessary to fulfill all characteristics. Moreover, fast product development and innovation capabilities increase the success of the customization process

- **Knowledge must be shared**
  Company’s cultures should foster knowledge creation and distribution across the value chain due to the dynamic of the mass customization strategy as well as the fulfillment of customer’s demand to new products and services

2.3.4 Strengths and Weaknesses of Mass Customization

As any other business strategy, the concept of mass customization is also accompanied with benefits and risks that have to be clarified before any operational or strategic changes are decided (Table 1).
## Benefits

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Each individual customer need can be fulfilled which leads to customer satisfaction</td>
<td>Choosing the wrong approach of mass customization, not adjusting internal processes or even being not enough qualified yet is one of the biggest risks</td>
</tr>
<tr>
<td>Value added services can be increased due to mass customization</td>
<td>Mass customization fails if there is no potential market for customized products</td>
</tr>
<tr>
<td>Through satisfied services and need fulfillment, customer loyalty can be raised</td>
<td>Lacking of required flexible ICT, as well as manufacturing technology within the chain limits the success of the concept</td>
</tr>
<tr>
<td>Improved customer relationship management (CRM) through customer co-creation and faster market trend adaption</td>
<td>Although customization may lead to price reduction, the same customized product is still cheaper if it were produced within mass production principles (Zipkin, 2001)</td>
</tr>
<tr>
<td>Less risks of forecasting errors since demand is pulled through the chain</td>
<td>The unit costs for mass customized products rise exponentially due to product output since production of variety cause a loss of scale economies (Bergmann, 2012)</td>
</tr>
<tr>
<td>Mass customization is able to reduce unit costs and lead-time which results in higher profit margins as shown in Tseng and Jiao findings in Section 2.5</td>
<td>Delivery times are more critical within Assemble-to-order (ATO) production. Even if customers are willing to accept a longer waiting time compared to standard goods, they are still critical when deliveries exceed the promised time (Blecker and Friedrich, 2007)</td>
</tr>
<tr>
<td>Customer’s willingness to pay a slightly higher price for customized goods can lead to a company's increased cash flow</td>
<td>Variety can be regarded as a benefit for customers, but variety also leaves the risks of becoming overwhelmed and refuse and product selection. Studies from Schwartz (2004) or Huffman and Khan (1998) confirm that variety rich environments might increase the difficulty of choice for customers</td>
</tr>
<tr>
<td>Since no forecasts are needed and inventory space can be reduced less waste is in the system (for instance, no obsolete inventory), resource utilization can be improved and expenses decreased</td>
<td>Companies have to find the right balance of added customer value from customization and related process complexity, since too much customization might lead to complex management and operations processes, whereas too little customization looses the added value for customers (Heiskala et al., 2005)</td>
</tr>
</tbody>
</table>
Through mass customization niches can be served that accumulate a steady profit compared to hits (Anderson, 2006) Successful information and communication transfer might be a big challenge since both flows increase for mass customizers (Piller et al., 2004; Zipkin, 2001).

Efficiency improves since end products are not associated with inventory costs as a result of their value addition through customer involvement (Blecker and Friedrich, 2007).

Since mass customization only produces features which customers need and require, useless and hence costly product configurations are avoided. Both Pine and Gilmore (1999) and Blecker and Friedrich (2007) consequently mention that this fact might also lead to a price reduction for customers.

Table 1: Benefits and risks within Mass Customization (developed by the author)

2.3.5 Mass Customization as a Driver for Sustainable Development

Sustainable production and consumption provides the foundation for sustainable developments. Besides this conventional wisdom, all manufacturers need to consider the usage of materials with low environmental pollution that enable clean production, avoiding hazardous and toxic chemicals and using technologies that consume less energy in production (Emmet and Sood, 2010).

According to a three year research project started in 2010, which is called S-MC-S (2012), Sustainable mass customization – Mass customization for sustainability, the positive effects of a more sustainable production are researched. This research already revealed sustainability advantages of the customized business strategy. Since products are produced on demand and when necessary according to customer specifications, it reduces waste, inventory, energy consumption and cuts manufacturing costs (S-MC-S, 2012). Therefore, this strategy changes the general push approach of production to a more sustainable pull strategy which is flexible and closer to market needs. This is also supported by Sutherland (2007), who claims that manufacturers need to learn how to adopt necessary survival skills in order to sustain themselves in current market situations. Sutherland continues with the notion on global trends and claims that the concept that lies within mass customization is one strategy that captures the market trend of increased personalization, plus doing so, it offers more sustainable production practices. Accordingly, he argues that the design strategy of product modularity is one
reason for achieving more environmental conscious manufacturing, due to the fact that
“modular products offer significant benefits in terms of reparability and upgrading”
(Sutherland, 2007 p.19) which might increase a product life-cycle.

2.3.6 Conclusion on Mass Customization Theory

The term mass customization became a known buzzword where no clear definition or
universal understanding has developed. Nevertheless, the implementation of mass
customization becomes even more essential for fashion companies since it provides
strategic benefit and economic value due to the ability of gaining a competitive
advantage in today’s volatile fashion marketplace. This advantage depends on how well
consumer’s individual needs are anticipated by textile companies and in what manner
business strategies incorporate innovative and new technologies in order to respond to
those wants. Since control of the market is hard to obtain in such volatility, where
customers’ demand can no longer be forecasted, it is unlikely to gain an efficient
production through economies of scale resulting from mass production. Becoming
aware of this fact, mass customization seems to be an alternative business strategy. As a
matter of fact, the one size fits all theory of traditional mass production is replaced by
the concept of mass customization.

Where producers usually had to balance trade-offs between time, variety and costs it
might seem that the strategy of mass customization brakes this conventional rule of
thumb, since mass customizers offer personalized products at low costs, high variety
and mass produced efficiency. Since customization can arise in different levels of the
value chain depending on the degree of customization, the customer order decoupling
point (CODP) should be thoroughly considered by any company due to the supply
chain’s capability to cope with this new business strategy. As a result, mass
customization shifts away from being a paradox and rather becomes a new strategic
opportunity were trade-offs between cost and customization are nearly resolved.

Furthermore, the model of mass customization is one strategy that has potential to
address some environmental issues, because it provides the basis to integrate the TBL
aspects of sustainability due to producing precisely what customers want (people). In
that way the life cycle of a certain product might be extended which decreases disposal
to landfills (planet) while also being more profitable (profit). For that reason,
organizations need to evaluate their behavior towards processes, product design and
product end-of-life in order to come closer to a green and sustainable future. Therefore
it is preliminary to establish a green supply chain first, with sustainable and lean
manufacturing processes able to avoid waste and using less energy.
2.4 E-Commerce

The steady growth of electronic commerce can be noticed within many organizations that change to brick and click business or new enterprises that establish a pure online or click platform (Al-Mashari, 2002). E-commerce can be defined as:

“The use of electronic transmission mediums (telecommunications) to engage in the exchange, including buying and selling, of products and services requiring transportation, either physically or digitally, from location to location” (Greenstein and Feinman, 2000 p.2).

A similar but more complete definition comes from Lallana et al. (2000 p.2):

“E-commerce is the use of electronic communications and digital information processing technology in business transactions to create, transform, and redefine relationships for value creation between or among organizations, and between organizations and individuals”.

originally, e-commerce has its starting point through commercial transactions by using electronic technology such as electronic data interchange (EDI) in the late 70's (Hayes, 2002). It was first introduced in the food industry as a pilot project and later General Motors and other organizations required their chain partners to use EDI technologies to send commercial documents like invoices electronically. The 90’s brought enterprise resource planning (ERP) systems, data mining and data warehousing to e-commerce and Tim Berners-Lee invented the World Wide Web browser with the communication system internet which established business-to-consumer (B2C) e-commerce (Hayes, 2002). By the end of 2000, many European and American business companies offered their services through the World Wide Web and for the last twelve years internet changed the way goods and services are bought and sold. According to Roos (2008), a study revealed that in 2007 nearly 66 % of people with internet access have purchased something online and around 93 % informed themselves about products online without buying anything.

Jarvis (2009), the author of What Would Google Do, mentions the importance of the internet since it teaches a new, modern and appropriate way to manage abundance by entering a post-scarcity economy. Jarvis continues that in former times of industrialization, which was based on efficiency and economies of scale, companies built their value on scarcity. This system was all about control where businesses could demand any prices because supply was less than demand. But the internet and e-commerce changed the rules of this outdated business-as-usual game, given the fact that there is, for example, no limited shelf availability like with “brick and mortar” stores. Without these “brick and mortar” shops a company’s cash flow remains higher
since no capital is tied up in shops or inventory and no sales staff needs to be hired to fill
the shops (Bergmann, 2012). Now, a company can sell to anyone in the world by going
online where “the internet has changed the speed, the rhythm, and the process of
business” (Jarvis, 2009 p. 107).

2.4.1 The Long Tail Economy

The Long Tail concept was made popular in the beginning of the 21st century by Chris
Anderson who picked up that term in a Wired magazine article in 2004 and continued to
elaborate this new business concept in his book The Long Tail: Why the Future of
Business Is Selling Less of More and The Long Tail: How Endless Choice is Creating
Unlimited Demand (Longtail.com, 2012). The concept of the long tail economy first
appeared in the music and book industry. Since the internet became an important
and revolutionary technology in the Web 2.0 age, it brought out new methods of doing
business, away from conventional paths. The fact that online music stores like iTunes
and Spotify or other free music downloads made it convenient for customers to have
access to a broader selection of goods, turned record labels and music stores down since
huge profits became seldom to make (Anderson, 2006). In general, the Long Tail
illustrates a retail strategy where a large number of few unique goods or services are
sold all the way down the tail, in comparison to selling fewer popular commodity
products in large quantities (Anderson, 2006). These few unique sales can be classified
as niche products in the tail in relation to popular items known as hits in the head of the
distribution curve. Looking at this distribution curve of Figure 7, it can be recognized that
the classical allocation of the Pareto law with its widely valid 80/20 rule is still fulfilled,
meaning that roughly 20% of products contribute to 80% of sales (Reh, 2012).

![Figure 7: The Long Tail Economy](Victor, 2011)

However, for a classic Long Tail retailer this distribution slightly changes since online
companies can carry unlimited virtual capacity of inventory at lower cost on the web by
which “the margin for non-hits can be far higher in Long Tail markets than in traditional
bricks-and-mortar” (Anderson, 2006 p. 133). According to Anderson, the distribution in the Long Tail business is even more complex due to many more niche products where around 90% of the products make 25% of the sales and due to low inventory holding cost these items generate 33% of the profit. Although critics like Schwartz (2004) claim that too many choices of niche goods lead to more customer confusion and distract the customers from buying, the possible profit margin proves another reality. To relate to the dilemma of having too many choices, Anderson (2006) opposes to leaving the task of product selection to companies, before a consumer can choose their preference.

The Long Tail economy consists of three forces that are drivers in order to enable the demand down the tail and are classified by Anderson (2006) as:

- **Democratizing tools of production** (through content editing software, blog tools)  
  In fashion business, companies have interfaces available to connect with customer who can customize products
- **Democratizing tools of distribution** (through Amazon, eBay, iTunes, DaWanda)  
  Access supply is easier since online distribution is free and consumers can be reached. Through the internet anyone can cheaply distribute items
- **Connecting supply and demand** (through Google, blogs, online ads)  
  Makes use of filters for technologies that shift through a collection of choices in order to give consumers the products that are most suitable

According to a research project at the University of Textiles in Borås, there are people who have problems in finding the right fit in the head of the tail or just feel a need for individualizing garments according to their unique preferences (Larsson, 2010). Here, the concept of mass customization appeared from the Long Tail economy, because consumer demand moves away from mainstream or standardized products and flattens the shape of the distribution curve which, in turn, lengthens the tail.

### 2.4.2 E-Mass Customization

Section 2.3 provides a general definition of mass customization, where rapid developments in ICT lead to different stages within this business strategy. And as stated in Section 2.4, only through these recent improvements in manufacturing and information and communication technology, such as the internet or EDI, the possibilities within this field could be extended. According to Piller (2012), the first stage appeared in the early 90’s through the possibilities of flexible manufacturing technology. In these times, the concept was developed offline in traditional “brick and mortar” surroundings and although examples like Levi Strauss had a huge potential, it showed that customers were not prepared yet. The second stage evolved with the dot-com era around 2000, when start-ups, as well as matured businesses discovered the potential within customization over the internet. Through rapid developments of online configurations,
Theoretical Framework

the concept of customizing goods and services flourished and businesses matured over time. Here many of today’s successful companies had their starting point (Piller, 2012). Jarvis (2009) points out that through the internet numerous online companies emerged where goods and services are selected again through customers, commerce and media itself. Still, the most groundbreaking progress can be seen today; the reason being that mass customization platforms break the conventional routes of design, manufacturing and retail capacity, in turn, due to tools being available today that enable anyone “to create and distribute goods” (Jarvis, 2009 p. 63) through media with infinite choices. According to Piller, those platforms combine “the eBay idea of very easily selling things over the internet with the customization model of robust fulfillment processes” (2012). This shows that through the appearance of the internet and graphical World Wide Web interfaces a turning point within mass customization occurred, which is classified as e-mass customization. A dialogue with customers can be ensured through these interfaces in an automatic, faster and less costly manner (Bergmann, 2012).

Coletti and Aichner (2011) defined the three dimensions of e-mass customization through modifying the model of e-commerce from Choi, Stahl and Whinston (1997). As can be seen in Figure 8, the three dimensions consider product, meaning how digital the product is, then player as one dimension, which “defines the way the buyer interacts with the producer and the process dimension which distinguishes different ways for controlling the production process” (Coletti and Aichner, 2011 p. 30).

![Figure 8: E-Mass Customization model (Coletti & Aichner, 2011)](image)

A traditional mass customization concept within the textile industry would assemble a physical item (dress, pant, blouse) with direct interaction within the supplier to physical processes based on customers’ needs that evolved also from direct communication. As soon as each of these dimensions can be transformed digitally, it can be called pure e-mass customization.
Kaplan and Haenlein followed the mentioned developments and inspired by Coletti’s and Aichner’s (2011) findings they came up with a definition for classical e-mass customization, known as:

“Electronic mass customization is a strategy that creates value by some form of company–customer interaction at the fabrication/assembly stage of the operations level to create customized products with production cost and monetary price similar to those of mass-produced products, where at least one of the three market dimensions—player, product, and process—is digital” (2006 p. 178).

2.4.3 Conclusion on E-Commerce Theory

Since the study in 2007 revealed that nearly 66% of people have purchased something online and around 93% use the internet as an information tool, e-mass customization shows a huge potential of generating profits online. Not only can the Long Tail economy be observed in music or book industry, but also in the fashion market where a growing number of small online shops and fashion blogs move the demand of products down the tail. Companies like Spreadshirt, Bivolino, StoffSchmie.de or You tailor are just a few examples who profit from mass customized niche products and open the boundaries within the value chain by involving customers and suppliers into business processes. Based on Colletti’s and Aichner’s e-mass customization model in Figure 8, one can argue whether such a pure digitalization concept is possible for the fashion industry, since a physical product is at least needed at the end. While music can be stored within a digital file, or books can be created into e-books, clothes are different since they need to appear physically at the very latest stage. However, the design stage could be fulfilled digitally, since measurement of customers can be taken through 3D body scanners, from where patterns are constructed using CAD interfaces. The final garment can be assembled online as well and visualized by using avatars that mirror a customer’s body shape virtually. However, as soon as those garment patterns are printed and cut, the digital product becomes physical. Still, the other two dimensions, namely processes and players are realizable, since customer’s preference is gathered through communication interfaces and product assembly is fully automated. Accordingly, based on the model displayed on Figure 8, today’s fashion mass customizers process needed technologies and process capabilities to succeed within the e-mass customized area.

2.5 Supply Chain Management

A supply chain starts with generic commodities that are transformed to an end product for consumers and after usage these goods are returned to the place of origin, recycled or disposed. According to Colin et al. (2011), a supply chain consists of material flows from raw material to the final product and related information flows all the way upstream and downstream the chain. In that order, supply chain management (SCM)
Theoretical Framework

involves managing the entire chain of aligned processes such as sourcing raw materials, manufacturing, packaging, distribution to the end consumer and returns management (Harrison and van Hoek, 2011).

Among academicians, several definitions of SCM exist (Ericsson, 2011). For the reason that this report has its focus on mass customization, which means that the starting point for chain processes comes from the demand side with the final end consumer, a definition is given from the Council of SCM Professionals (CSCMP):

“Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies” (2012)

Today, there exist several main strategies in how a supply chain can be designed, which depends on the alignment of a focal company’s business strategy. Basically, it can be said that the approach in supply chains changed from working on operational efficiency to focus more on strategic positioning (Porter, 1996) where the end customer’s needs are essential (Christopher and Holweg, 2011), resulting in a focus on mass customization instead of mass production. Speaking of different supply chain strategies, one mostly distinguishes between lean, agile and a combination of both, known as leagile supply chain management. Starting with lean, a production concept that emerged in the early 80’s from the philosophies of the Toyota Production Systems, the idea of leanness is to do more with less by eliminating eight types of wastes (Harrison and van Hoek, 2011). Those wastes can be classified as non-value added activities and include overproduction, excess inventory, unnecessary defects, transport, movement and waiting time, over processing and unused employee’s creativity (Liker, 2004). Lean thinking is also referred to the philosophy of Just-in-Time (JIT), six-sigma quality control and total quality management where the two later concepts improve quality in all related business processes (Harrison and van Hoek, 2011). According to Christopher and Towill (2000), lean supply chains are thus product driven with a supply focus. As times changed, supply chains had to be more market driven since markets in the 90’s became more matured which automatically increased competition and pressure for companies in order to compete against each other and react in a flexible manner.

Therefore, the idea of agility is expressed as a company’s ability to respond flexibly to unknown problems and involve organizational structures, information systems and supply chain processes (Gattorna, 2010). Christopher and Towill (2000) continue that
Theoretical Framework

the goal to reach a flexible manufacturing has been originally tried through automation that could make a rapid change possible as well as achieving greater responsiveness to product changes. Here production is pulled upstream from consumers instead of pushing goods downstream the chain (Gattorna, 2010). According to Gattorna, the agile supply chain matches with goods of shorter product life cycles, since they change or innovative rapidly. Hence, agile chains need to reduce its process complexity as well as possible in order to make the required quick response (QR). To ensure a seamless flow, supply chain integration of processes and collaboration within the focal company and partners are needed. That is why agility is better expressed as a supply chain network instead of a chain due to achieving common goals collectively (Ericsson, 2011). Mostly, this is followed by processes that are more transparent since demand information is frequently shared between partners. According to Harrison and van Hoek (2011), this creates information based virtual supply chains rather than a chain based on inventory.

Although agility and leanness both demand high levels of product quality and minimum total lead-time from order making to distribution, the difference between lean and agile chains “is that service is the critical factor calling for agility whilst cost, and hence the sales price, is clearly linked to leanness” (Christopher and Towill, 2000 p. 208). Since both concepts have their advantages the solution to finding the best supply chain for ones company is to configure the right location of the customer order decoupling point (CODP) for material and information flow which is known as hybrid supply chain strategy. By that a company can combine a lean, hence efficient supply upstream the chain and an agile, hence effective supply downstream the chain, which is known as leagile supply chain (Gattorna, 2011). Since this thesis needs to deal with sustainable supply chain design for mass customizers and includes digital technology, the location of the CODP for material and information flow needs to be further evaluated in Figure 9.

![Figure 9: Customer Order Decoupling Point](Verein netzwerk Logistik, 2012)

As seen in Figure 9, this CODP determines the push-pull boundaries. It means that upstream the CODP the supply chain is operated based on demand forecasts, known as
push strategy and vice versa downstream the CODP, the chain operations are rather driven by customer’s needs, known as a pull strategy (Joeng, 2011). According to Rudberg and Winkner (2004), the decoupling point determines the decision about form, design and quantity of a product. Based on Harrison and van Hoek (2011) the different points can be defined as followed:

- **Make-to-stock (MTS)** – a full push principle where customers buy available inventory straight from the retail shelf; principles based on mass production
- **Assemble-to-order (ATO)** – CODP shifts upstream where final assembly of pre-manufactured modules is done after customer placed an order
- **Make-to-order (MTO)** – CODP is at design stage with a customer involvement
- **Engineer-to-order (ETO) or Build-to-order (BTO)** – customers are involved from the beginning and design the product in alliance; highest form of customization

According to Childerhouse and Towill (2000) and Gupta and Benjafaar (2004) each company needs to consider whether such a postponement strategy suits their business processes, as it might also lead to higher costs due to storing more materials because more variety modules are needed. Still, as mentioned in Section 2.3, a successful mass customization strategy can be as efficient as mass production. Furthermore, Tseng and Jiao (1996) mention the economy of scale as one important element that influences the balance of a mass customization production system and identified the economical implications of mass customization as useful for any company as shown in Figure 10.

![Figure 10: Economic Implications of Mass Customization](Tseng and Jiao, 1996)

Figure 10 illustrates advantages of mass customization at low to medium volume production. The cost curve is nearly stable or similar at any production outcome which is not the case for mass production. Therefore value is added at low and medium production volumes, in addition to customers’ willingness to pay more for individualized goods which enables an economy of scope. Moreover, secure intranet systems and
business-to-business (B2B) e-commerce platforms have changed the focus to improve information management by integrating internal systems with external partners that form strong, virtual supply chain networks (Ericsson, 2011).

2.5.1 Digital Textile Supply Chain Management

Today’s digital economy changed supply chains to huge virtual networks with interconnected activities and strong relationships across chain partners (McCormack and Casper, 2002). According to McCormack and Kasper, these “inter-connected supply chain webs are the new business-to-business configuration and the key competitive levers in the economy” (2002, p.133). Moreover, a company’s success in the web 2.0 era is more determined by how information is managed and used. One reason for that is accurate information which streamlined chain processes and through the replacement of human involvement and automated processes, the risk of inaccuracies decrease (Briant, 2000). Briant continues that tools like EDI and a web access reduce the number of “resources required for day-to-day operation” (2000 p. 64), saves material and overhead costs and give companies a competitive advantage. And these faster, responsive and customer driven supply chains are needed in volatile markets like the textile industry where end consumers become more powerful with higher expectations on goods at lower costs (Gattorna, 2010). Still, a research that was carried out in 2001 by the EIU and Meritus Consulting Group (EIU, 2001), made clear that although companies are aware about digital developments within the chain and know about its importance, many firms are not able to integrate e-technology or reduce cycle-time. According to the survey, one essential success factor is to achieve the highest level of seamless supply chain process integration from customers to suppliers, able to perform as a single entity no matter how many nodes and links can be found within the chain.

According to Fralix, the entire textile production process, from yarn formation to finishing “is already under digital process control and many of the processes can be integrated with digital product development” (2003). Only the sewing process remains highly labor intensive and in the case of mass customizers, a company’s goal should be to delay this digital-to-physical conversion point as close as possible downstream the demand side. Based on Fralix, this is exactly the challenge of the total digital textile supply chain and hence, if products are designed digitally but are not able to be converted at the very latest stage, these products should be manufactured in low wage countries. But in the case of using a digital textile printer for coloring garments on demand and ready to assemble pattern shapes, the digital to physical conversion point is as downstream as possible. In addition, textile digital printing has always been connected to a flexible supply chain that is able to respond quickly to market demand changes within very short timescales (Tyler, 2005). One specific garment can be made efficiently on the digital printing machine (economies of scale are not relevant), where these products have been designed digitally, patterns were constructed digitally on the
computer, as well as digital markers and a lay plan. Then the garments can be digitally
printed and in this case, products become physical as soon as automated cutting
machines cut the fabric into pattern pieces. These manufacturing process steps result in
fully automated process steps which, according to Fralix (2003), are not sensitive to low
level of production output and digital processes, where products can be reconfigured
easily. This fact is also highlighted by Ujiie (2006), who says that digital technology
enable manufacturing processes to be fully automated and any needed reconfigurations
can be easily managed since modifications on production requirements or product
characteristics are not complicated.

Making mass customization attractive from a supply chain perspective, it can be said
that concepts like QR, JIT and lean manufacturing, as well as newest ICT, flexible
automation and team-based short-cycle manufacturing are all realized within the
customized business concept (Goldman 1997). Furthermore, due to trends like
producing smaller batch sizes and minimum order quantities, product differentiation
and affordable single item production, the concept of e-mass customization is very
attractive (Ujiie, 2006). Ujiie claims that product development management packages
“will contain patterns, cost sheets, bills of material, manufacturing specifications, fabric
specifications, quality standards, and in some cases, color specifications and printing
instructions that can drive digital printing machines” (2006, p. 309). The entire available
data can be distributed and used worldwide without any physical boundaries.
Consequently, using digital technologies result in a more responsive supply chain that
permits consumers to order customized products which are “distributed digitally and
converted locally within very short time frames” (Ujiie, 2006, p. 310).

2.5.2 Flexible Supply Chain Management as a Sustainable Solution

The need for flexible supply chains occurred due to increased global competition among
all industries and resulted in outsourcing non-value added activities which automatically
led to an increased number of supply chain partners. This fact is accompanied by at least
two necessities. First of all, the huge global network of supply chain partners need to be
constantly controlled by the focal firm in order to attain the firm’s required standards.
Second of all, the management of such a supply chain network resulted in more flexible
or agile supply chain capabilities that have to be highly responsive to customer demands
in order to obtain a high service level, quick delivery and customization. Since
sustainability has caught severe interest from businesses (Siegel, 2009; Closs et al.,
2010), a resume of flexible supply chains is valuable to highlight its opportunities of an
ecologically sustainable chain solution. Due to increasing threats resulting from global
warming or climate change, supply chains need to become more ecologically friendly
since the way chain actions like manufacturing or transportation are designed, might
lead to a negative ecological footprint (Weybrecht, 2010).
According to Shukla et al. (2010), flexibility and sustainability go hand in hand and do not have to contradict each other. Shukla et al. continue that those supply chains that are capable of achieving the highest form of flexibility, but not on the expense of environmental sustainability are the most competitive supply chains. Together, they developed a matrix based on flexible and sustainable criteria and classified four different supply chain possibilities (Figure 11).

![Figure 11: Typology of Supply Chains (Shukla, 2010)]

It can be seen that the traditional attempt of supply chains is based on low levels of flexibility and sustainability. According to Shukla et al. (2010), these supply chains can be found in monopolistic situations where market volatility is rather low. Whereas not-for-profit organizations are situated in the 2nd category of the matrix, demanding a high level of sustainability over flexibility, the most supply chains are situated in the 4th category. Those highly responsive and agile chain practices demand flexibility and are primarily driven by profits without any considerations for sustainability. This is the so-called dilemma of modern supply chains according to Shukla et al. (2010), where the textile and apparel industry is a good example. Respectively, the desired category for any supply chain combines both practices and balances the trade-offs of flexibility and sustainability to be highly efficient and effective.

This fact is also supported by Closs et al., who say that managing a company’s supply chain by focusing on the triple bottom line “will lead to improved efficiency and profitability over the long term” (2010, p. 102). Dixon and Gorecki (2010) point out that the solution for achieving sustainable supply chain processes lie in flexible, agile process designs. Therefore, Dixon and Gorecki married sustainability and agile supply chains together and formed a new term, named Sustainagility which is defined as:
Theoretical Framework

“the ability to solve complex sustainability challenges in a profitable way, with rapidly evolving business innovations, applications, methods, products and processes, adapted to changing situations” (2010 p. IV).

For Dixon and Gorecki (2010), agile SCM is able to adapt to changing market forces by ensuring enough contingencies and being ready to apply the most suited strategy. Finally, logistics and transportation have been classified as one of the most environmentally harmful processes within supply chains which limit sustainable performance (Closs et al., 2009). This is due to the fact that logistics processes and transportation cover the management of movement of goods and services through the entire supply chain and include freight transport, storage, inventory management and material handling. From an environmental point of view logistics is mainly associated with air pollution, climate change or noise pollution. According to Swallow (2009), logistics belongs to the top priority activities for making supply chains more sustainable, for the reason that transportation is the highest contributor of greenhouse gas. In addition, Weybrecht (2010) and Emmet and Sood (2010) reveal, that one first step into a more sustainable direction is to close supply loops through reverse logistics.

2.5.2.1 Supply Loops

The term supply loop describes actions of supply chains which recycle or reuse materials, products or by-products from the same or another chain. Supply loops always contain a forward and backward or reverse supply chain. There are different loops in industrial supply chains, such as manufacturing supply loop, where the output from one process is used as the input for another process, or the reversed logistics supply loop which is the aftermarket customer service and deals with end of life management and recycling issues (Emmet and Sood, 2010). According to Hawks (2006), reverse logistics is:

“the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal. More precisely reverse logistic is the process of moving goods from their typical final destination for the purpose of capturing value or proper disposal”

Nevertheless, all supply loops have the goal to protect the environment from harmful pollution and increased usage of its resources. Supply chains, from the design stage to the disposal phase of a product show a linear form which needs to be loosened in order to achieve a more sustainable way of production (Dyckhoff and Souren, 2008). This can be achieved by closing the loops through remanufacturing, refurbishing, reprocessing, repairing, reusing or recycling. Reverse logistics and avoidance of extra waste within a focal company and across key partners of the supply chains can close supply loops (Dale
et al., 2002). Today more companies start to measure the effectiveness and efficiency of their backward operations with the same effort as for their forward logistics activities (Terreri, 2010). According to Harrison and van Hoek (2011), reverse logistics captures two important components, namely a service factor that includes maintenance and recalls and an environmental element due to enabling recycling of end-of-life products. Consequently return management is the enabler for closed loop supply chains that can capture additional value to the business and furthermore integrates all supply chain activities gapless (Harrison et al., 2003). Based on this assumption a full circle scheme can be created as visualized in Figure 12.

As can be seen in Figure 12, the alternative supply chain closes the chain through an additional End-of-Life return process by recycling materials. Although other processes like remanufacturing or repairing are also considered, these steps are not relevant for this thesis. Dale et al. (2002) have grouped returns into five distinctive areas, namely consumer, marketing, assets, product and environmental returns (for closer information, see Bergmann, 2012).

According to Winkler (2011), a single focal company cannot realize, run and control such a closed supply chain loop as seen on Figure 12. Too many process steps are involved, which require special skills of the work force and extend any companies core business function. Therefore, Winkler suggests that a holistic production and waste recycling are most efficiently realized by building closed-loop production systems with chain partners of interacting companies which can help to improve the economical and ecological performance outcome of the production system. According to a previous field study within the Wettodry initiative at the Swedish School of Textile (Bergmann, 2012), this attempt has been highlighted by the Eco Circle™. The Eco Circle™ from Teijin Fibers
Limited is the world’s first closed loop recycling system for polyester products, able to use a chemical recycling technology to regenerate polyester products like PET bottles or PES fabric to new Polyester fibers for new garments. This recycling system could be directly used for material left over after the pattern pieces have been cut. In addition, if other textile fibers are used for material construction “textiles are nearly 100% recyclable, nothing in the textile and apparel industry should be wasted” (Wang, 2006 p. 7). Whether a textile is made out of cotton, viscose or PES, all these fabrics can be recycled into new products. Still, stating Fletcher (2008), it is preferable that a fabric consists of one material composite and should not be treated with chemicals through finishing. Due to the fact, that blended materials complicate the extraction of a pure fiber material, it becomes increasingly difficult to produce a value added material. In this case, a separation process for the different fiber composites is necessary which leads to an increase in time and energy. This is inefficient from an economical, as well as ecological point of view. This is also supported by Wang (2006), who created a hierarchy of the ability to achieve an efficient recycling process (Figure 13).

As can be recognized, if fabrics are composed out of a single fiber it influences recycling possibilities as it is ecological and recycling friendly. As materials are pure, no separating process is needed and a fast and easy recycling is possible. The more composite systems a material contains, the more complicated the recycling process becomes. Here the recycling process requires more time compared to the single material recycling process and extra costs are created for labor force and machines (Wang, 2006).

2.5.3 Conclusion on Supply Chain Management Theory

Summarized, an agile supply chain can be expressed as being market sensitive in unpredictable and volatile market environments where variability is high, product volumes are low and responsiveness and availability of goods are more in focus than low costs and quality compared to lean SCM. Since agile supply chains have a demand focus the chain turns backwards with a starting point on customer’s needs (different to lean
Theoretical Framework

SCM). This combination is commonly known under leagile supply chain management and is very significant for today’s competitive market conditions like the fashion industry. This leagile supply chain is used for mass customized businesses since it can be highly productive by starting with a low cost focused process design (lean) which is followed by responsive processes (agile) that enable a level of customization. Therefore, the mass customization strategy needs a flexible and dynamic supply chain management where lead-times should be as short as possible due to quick responsiveness. Depending on the level of customization, this customer order decoupling point can be on several places within the chain as described in Figure 9. Accordingly, the value chain for mass customizers differs from mass production processes. First, the chain turns 180 ° since the starting point is on the demand side with sales from customers. Secondly, process steps like preordering collections in order to show customers available product varieties or inventory are fully eliminated within mass customizers. This fact makes mass customization chains leaner, more transparent and flexible, resulting in more efficient chain processes. This can be seen in Figure 14.

Finally a successful strategy for mass customization depends also on the right alignment of supply chain management processes, given the fact that there is no standard answer for where to place the CODP most effectively and efficiently, since all products as well as markets are different. Consequently, it can be said that around the time of commercial applications like the internet, manufacturers can now mass produce customized products. Companies are effectively using new and wireless information and communication technologies which improve service and delivery processes. Those tools also ease the way to achieve stronger partnerships within the chain. This is essential in SCM since no firm is successful when treated as an island as even cautiously controlled processes are only as good as the links and nodes that support them. The digital supply chain model is strategically important since it shifts the orientation of physical supply chain processes to a digital supply chain model through the evolution of digital technologies. Through the integration of web based processes into the supply chain, the entire chain is able to react faster in the digital information age and without constraints.

Figure 14: Mass Production versus Mass Customization Supply Chain
(developed by the author)
And the internet with all its tools and interfaces allows customer’s orders to be communicated through the chain at a fast pace, from product selection and order placement to manufacturing, delivery, confirmation and payment. As already visualized in Figure 14, a mass customized supply chain involves less process steps and starts with sales, continues with production and ends with distribution. Going deeper into the production chain process and highlighting the replacement of conventional dyeing or screen printing through the use of a textile digital printer, even chain flows inside a manufacturing unit can be further streamlined. Because through the use of a digital printer, chain processes can be altered and designed in a less complex manner with reduced processes since extra steps like dyeing, finishing and fabric marking can all be fulfilled within the digital printing unit (Bergmann, 2012). This 3-in-1 process leads to economic advantages, enabling the reduction of lead times and being closer to market needs (Figure 15).

![Figure 15: Production processes within a mass customized supply chain using digital textile printer (developed by the author)](image)

This enhancement of supply chains’ efficiency and effectiveness through the use of digital technologies can become today’s key to gaining competitive power. One solution to achieve this flexible, sustainable supply chain might be an assessment of the triple bottom line approach for businesses, since today’s accounting principles do not include sustainability measures. Only if a company’s performance is not just measured by financial outcomes and also takes intangible assets, like greenhouse gas emission or soil depletion into account, the company is forced to change processes to achieve more sustainable results. On the other hand, one might say that the essential characteristics of logistic systems and sustainability seem contradictory, especially by facing economic trends like shifting to offshore production or increased lead time pressure and JIT deliveries. In the sense of a sustainable lifecycle management (LCM) a holistic, closed loop supply chain should be in focus. Return management within supply chains enable the closing of supply loops, since it focuses on backward processes. Since this thesis highlights digital textile printing as one possibility to reach sustainable alternatives for coloring fabrics, only environmental returns, precisely recycling steps are considered. In
particular, it is of interest how returns management can be designed for material leftovers due to pattern cutting processes. For the reason that digital printers dye not the whole fabric and only needed pattern pieces, plain and untreated material leftovers can be recycled back to fibers after the cutting procedure and consequently used for new textile production. Therefore, the demand for ordering new and virgin textile fabrics is reduced which lowers company’s costs and further resource depletion. Consequently, it can be said that behind the basic concept of supply loops and with tools like recycling, a company is able to achieve higher economical and ecological competitive advantages through converting non-value added, disposable waste into valuable raw material fabric.

2.6 Digital Technology

As described in Section 2.4, computer technologies like the internet, e-mail, EDI or RFID have evolved over the past two centuries and changed all aspect of micro and macro economy. Through the automated computerization of different supply chain tasks, new capabilities and opportunities have been opened to adopt highly flexible and agile chain networks that are able to respond quickly to customers’ needs (Section 2.5). Looking closer at digital textile technology, the developments for the last twenty years have changed textile printing possibilities. Through the adaption from digital paper printing on textiles in the 90’s it became possible to reduce the sampling time to a few hours (Ujiie, 2006). These first adoption printers of the Mimaki TX series were forerunners to produce short run printed textiles, and after the introduction of other industrial inkjet printers at the ITMA conference in 2003, digital printing technologies developed further and became a preferred printing technology (Moser, 2003). Although technology progress offers a niche to the printing industry for application areas like sampling, strike-offs and mass customization (Ujiie, 2006), it has not yet fully penetrated the industry (just-style.com, 2007).

2.6.1 Direct Digital Textile Printing

According to Phillips (2010) from the company Xennia, the key market drivers for using digital textile printers are a need for economical short print runs, fast and regular design modifications and changes due to increased demand for personalization, customization and niche products. Although the demand for digital printing is growing and a 20 % rise is forecasted, the market share for digital printing accounts so far to 1% and is therefore rather low (Figure 16).

![Figure 16: Share for Print Technologies (Phillips, 2010)](image-url)
As can be seen in Figure 16, 80% of textile printings employ either flatbed screen prints or rotary screen printing. Those are the oldest technologies used within textile industry. Rotary printing uses continuously rotating cylinders that have the function of a screen and contact with the fabric. The screen drums are fixed and during the printing process, print paste is forced through engraved parts which form a pattern to the fabric. These machines offer a high-speed production with efficient, economical long runs needed for mass production. Furthermore, dyes are inexpensive and a large color gamut, which is the range of available colors, is provided. On the other hand, flatbed screen printing makes use of flat screens for pattern design where one screen is determined for one color. These screens are arranged above the machine belt or blanket where the fabric is placed on and moved through the blanket during the printing process (Ujiie, 2006). Even though, digital printing accounted for 1% of the global market share in 2007, the lengths of textile print runs decrease where the demand for short-run production and JIT delivery in a fast paced world increases (Tyler, 2005), hence highlighting the possibilities of digital printing as a cost-effective solution. Still, according to Malachowski (2005) many specialists have concerns against digital technology due to low machine speed and the high costs of inks in comparison to screen printing, although digital printing offers new innovative potential for design and new product development.

Digital printing defines a set of technologies that are used to convert a digital design form onto the textile substrate. This can be done through three different approaches within ink jet technologies; piezo electric drop on demand (DOD), pulsed ink jet or continuous ink jet technology (Tyler, 2005). Since the explanation of these ink differences expands this report, further explanation can be found in the previous field study of the Wettodry initiative (Bergmann, 2012). However, it is important to know, that the most common printing technology on the textile market is the piezo electric DOD method. In general, digital printing technology can be differentiated from analog screen techniques due to several characteristics. Computer files used in digital printers can store a high variety of data due to unlimited storage capacity of files and any textile material, whether flat, curved, smooth, rough or hard can be used for printing, since the textile surface is not in contact with ink heads (Keeling, 1981). Furthermore, digital technology provides a large color scale based on CMYK (cyan–magenta–yellow–black) principle given that almost any color can be easily mixed. Moreover, machines can also run at high speed of up to several hundred m²/hour, depending on the resolution, head technology or machine width and only ink heads are moving in relation to the fabric (Keeling, 1981).
2.6.1.1 Digital Printing Machines

Textile printing machines, whether screen printers or digital printers remain a technologically complex field. Within the digital area, it was for a long time complicated to create financially feasible printers for longer production runs due to aspects like ink costs, speed or less available equipment for machines (Bergmann, 2012). Ink jet technology was first adopted in the carpet industry in the 70’s and followed by the apparel industry. The first textile digital printing machines were directly transformed from paper printing plotter devices in 1991 with differences regarding inks in order to establish formulations that keep dyes on fabric materials (Tyler, 2005). These so called adoption machines have since then been developed at an ongoing basis resulting in higher resolution possibilities, head advancements, enhanced ink formulations, different width types and high productivity which make industrial production as well as small batch production attractive. Since the 20th century many machine manufacturers released large format digital textile printers, such as Minolta, Reggiani, Dupont or Konica (Phillips, 2010). In general, industry divides digital printers into high-end (Robustelli, Reggiani, Konica Minolta, Osiris) and low-end (Mimaki, Roland, Mutoh) machines based on production outcome. Digital printers can be as cost efficient as traditional screen printers due to increased production speed and long run capabilities (Figure 17).

![Digital Machine Productivities](image)

Figure 17: Digital Machine Productivities

(Phillips, 2010)

It can be noted, that the ISIS printer from Osiris, released in 2008 has a productivity of 1200 m²/hour, able to compete against traditional screen printers. Although the average machines differ from each other, according to costs and productivity, it can be said that in general the productivity of 1 m²/hour costs around 5000 € in investment.

Based on design and textile preferences, as well as the area of application, machines can be differentiated and judged due to print head types, possible color gamut, printing widths, resolution rates (measured in dpi), productivity, available inks, supporting software (color and file management, raster image processor) and additional features like direct fixation (Tyler, 2005). Today, there are also machines that include fabric pretreatment and post treatment process within the digital printing stage (Ujiie, 2006).
### 2.6.1.2 SWOT Analysis for Digital Textile Printing

<table>
<thead>
<tr>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast design changes possible: no setup time needed (Phillips, 2010), and prints directly from easily stored, transmitted, and transported computer files (First2Print, 2012)</td>
</tr>
<tr>
<td>Economic for samples and short runs: minimal set-up time with low cost (Phillips, 2010)</td>
</tr>
<tr>
<td>No limitation of color gamut, all design patterns are possible</td>
</tr>
<tr>
<td>Reduced production costs: efficient use of textiles, no requirement to produce screens, no set-up, cost per print is the same for short or long runs, no inventory requirements</td>
</tr>
<tr>
<td>Increased productivity: no set-up time makes printer always work without down-times</td>
</tr>
<tr>
<td>Quick response: direct print on demand, just-in-time customization/personalization and delivery, faster realization of new designs (First2Print, 2012)</td>
</tr>
<tr>
<td>Applicable to all type of fabrics</td>
</tr>
<tr>
<td>Customers can control the design and printing process from distant locations</td>
</tr>
<tr>
<td>Eliminates color registration of plates or screens (First2Print, 2012)</td>
</tr>
<tr>
<td>Reduces risks, due to inventory obsolescence etc. (Bergmann, 2012)</td>
</tr>
<tr>
<td>Reduces proofing time from weeks to hours, faster design and NPD (First2Print, 2012)</td>
</tr>
<tr>
<td>Design modifications at any time without delays or cost increases (First2Print, 2012)</td>
</tr>
<tr>
<td>Reduce over-run waste endorsed by traditional volume-print pricing (Fibre2Print, 2012)</td>
</tr>
<tr>
<td>Cleaner, safer, less wasteful and environmentally hazardous than traditional textile printing (Ujiie, 2006; Tyler, 2005; First2Print, 2012; Phillips, 2010)</td>
</tr>
<tr>
<td>Simplifies the supply chain design and work flow (Phillips, 2003; Bergmann, 2012)</td>
</tr>
<tr>
<td>Due to automated processes labor costs can be reduces and production setups in western markets might be feasible (Bergmann, 2012)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very expensive inks increase production costs</td>
</tr>
<tr>
<td>Limited speed, makes traditional printing better for mass production (Bergmann, 2012)</td>
</tr>
<tr>
<td>So far, only economical for short runs</td>
</tr>
<tr>
<td>Digital printing equipment hard to get or expensive (Bergmann, 2012)</td>
</tr>
<tr>
<td>Quality issue of ‘banding’, which is referred to orthogonal drop formation that can lead to unprinted parts. Further quality issues might result from missing tail absorptions at the DOD printing technique (Taylor, 2005; Tippett, 2001)</td>
</tr>
<tr>
<td>Contact of print head with fabric might damage head or image design (Tippett, 2001)</td>
</tr>
<tr>
<td>Problem in color repetition for large prints through side-by-side printing (Tippett, 2001)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast developing technology for print heads and auxiliary equipment (Phillips, 2003)</td>
</tr>
<tr>
<td>20 % market growth expectations for the upcoming years (Phillips, 2010)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine manufacturers are dependent on print head, ink and software suppliers (Phillips, 2012)</td>
</tr>
</tbody>
</table>

Table 2: SWOT for Digital Printers  
(developed by the author)
Examining strengths and weaknesses of digital textile printers, it can be deduced that screen printing either rotary or flat bed, is the best method for large runs and digital printing has great potential for short runs. Still, according to Judson (2005) it is important to do an economical feasibility study for both methods in order to verify the later statement which is based on conventional wisdom. Therefore, Judson suggests determining the so called ‘break-over point’, which is defined as the turning point where screen printers achieve the same cost per yard than digitally printed textiles. Hence, it is important to consider “the amortization of screen production, proofing, setup and after-run wash-up as well as the storage and retrieval cost of screens”, as well as converting non-financial value like “time spent in communicating, sampling and approval” into costs (Judson, 2005). Moreover, intangible values like flexibility, just-in-time delivery, short runs and responsiveness to market needs need to be converted into financial measures. These total costs should then be divided by the production units. Following these considerations, Judson revealed that in cases where production requires less than 1000 yards, digital printing is an economically better choice over screen printing (1000 yards is approximately 914 meters). Ujiie (2006) confirms that screen printing starts to pay off after around 1000 m² of fabric printing. As noted earlier, once this break-over point is reached, screen printing’s unit costs are constantly declining due to economies of scale whereas digital printing remains steady.

### 2.6.1.3 Digital Printing as an enabler for Mass Customized Textiles

Digital printing technologies have several key advantages concerning the field of mass customization. According to Ujiie (2006), the run lengths of textile printing are constantly decreasing. Designers offer more options or design patterns and retailers focus on less inventory and together with customers they demand more variety of product choices. Furthermore, digital printing technology allows true production on demand with the possibility to produce small batches in mass quantities and changing the design digitally through CAD and ink jet technology, without negative impacts of a long setup time. Besides, digital printing technology can offer sampling and small batch production and have an increased design potential, plus could be electronically linked to the design department via EDI that accordingly transfers the printed pattern design by CAD on the printing machine (Tyler, 2005). Apparel designers can therefore work closely together with print designers since both uses the same technology principle for their work. Besides, both can work together on problem solutions because it is possible to transfer a CAD image into a printed fabric by digital technology. This can shorten lead times to be less than twenty-four hours for printing samples and fabrics in the design room (Tyler, 2005). It also leads to cost advantages since it is feasible to print directly from a digital file without any setup or screen production which reduces time, hence costs. Figure 18 shows supply chain constructions according to traditional and digital printers and visualize the tremendous time savings of around 1.5 months.
Furthermore, the cost per m² for printing digitally is almost flat, which means that low batch volumes are economical (Ujiie, 2006). Despite that, Tyler (2005) brings up the establishment of innovative designs and customized products as the main market opportunities for digital printing. The demand for small batch productions is even higher than six years ago, due to an ongoing increase in variety of choices and individualization (Christopher and Holweg, 2011).

General requirements for textile fabrics can be also fulfilled. According to Phillips (2010), functional coatings like water or dirt repellency, as well as fastnesses like color fastness or abrasion resistance can be applied parallel to the printing process. The needed chemical agents can be either included in the ink heads or are applied immediately after the printing process. On the subject of the quality aspect, regarding color and image formation there exist some obstacles within digital printers compared to traditional ones. Although there are no limitations of the number of colors printed on the textile, some shades like metallic, pastels or fluorescent yellow are not possible to achieve (Phillips, 2010). Still, these limitations concern more extraordinary color mixtures and probably influence design specifications rarely.

2.6.2 Other Digital Technologies supporting a Digital Supply Chain Design

Computer aided design (CAD) systems that are used for apparel patternmaking, grading and marker planning use interfaces for individual adjustments and can be set together for automatic production processes (Istook, 2002). CAD systems enable a quick, precise and customized garment creation. Digital interfaces among customer and company enable an information exchange. In the case of mass customized fashion, these interfaces go beyond e-mail, exchange forums or blogs and involve abilities to get customer’s body measurement in a fast, convenient manner and handle data efficiently.
For e-mass customizers that offer products online, data acquisition is more complicated than for “brick and mortar” mass customizers. Whereas retailers can measure customers manually at the point of sale through a measurement tape, online business have to use technology or train customers to measure themselves. Customers can be asked to measure needed body parts independently and access this information in a measurement sheet from the company. Still, this step might be complicated for some clients and can create a general barrier to entry. Another suggestion is to show customers the company’s size table with central measurement units for each size. This is an already established procedure for all fashion companies to give customers the opportunity for correct size estimations at that specific company, since each company can create their own size sheets. E-mass customizers could extend this practice by giving customers the opportunity for size adjustments. A woman could for example decide to by a blouse in size 36 but wishes to decrease the waistline by 2 cm and increase the hem length by 5 cm. Although both possibilities are feasible, they still involve manual steps.

Newer options are the so called 3D body scanners according to ISO 20685 standard and are for example offered by the company human solutions (2012). The light room scanning process guarantees an accurate and quick measurement through scanning the body surface area and allows the integration of consumer’s size and fit data into ongoing value chain processes (CAD pattern making etc.). Through arranging a scan day, customers could be guided to the next location to let them measure. Although one could argue that this extra step of customer involvement also creates a barrier to entry, it is a one-time action where customer’s figures can be stored at the company’s database and used or modified over a lifetime. This data can then be analyzed with needed quality checks, where analyzed dimensions and test person’s files are marked, stored and exported to further statistical systems like Excel-based applications.

Another possibility results from 3D body scanners, namely the generation of 3D avatars, which mirror customers’ body virtually and can be used for virtual try-on of customized apparel (Human Solution, 2012). When customers choose a product, virtual try on possibilities give customers a better imagination of how that product looks on his body. When an order is made, the company can rely on a customer’s measurements, customize a garment with little effort through CAD pattern tools (Gerber Technologies, Lectra Systems, Investronica, or Assyst) and as soon as the design is approved the product can be created immediately by a few clicks (Istook, 2002).

Given that more processes make use of digital technology, they can all be linked together and establish a continuous stream of data management that strengthen a seamless digital supply chain’s ability to support efficiency and effectiveness and increase transparency through information sharing among partners (Figure 19).
Theoretical Framework

The company Xennia gives an outlook of the whole product development process (Figure 20). This outlook realizes a totally digital and automatic supply chain, starting with yarn formation to draping a digital fabric where 3D developments replace physical samples and an automatic manufacturing process that replaces the manual and labor intensive sewing process by sewing robots (Phillips, 2010).

Fralix mentions that body scanners, CAD and digital printing technologies are “the essential hardware tools for apparel supply chains specializing in mass customization” (2001). Furthermore, Chapman and Istook (2002) reflect that 3D designs can be used with the aid of body scanners and this pattern or design data can then be continuously carried through the digital printing machine by CAD software. May-Plumlee (2002) further extends this concept by addressing issues of material consumption and costs.
2.6.3 Environmental Aspects of Digital Printing

Digital printing technologies are cleaner than traditional ways of color application, whether compared to dying or screen printing. According to Tyler (2005) following facts support that statement:

- Digital printing does not waste inks or dyes and guarantees a nearly 100 % color take-up with CMYK color system. Furthermore, no test prints for color take-up are required. This saves cost and reduces water effluent.
- Digital printing has a higher fixation rate compared to screen printing. Whereas 65 – 70 % of dyes are usually fixated using screen printers and around 80 % in dyeing procedures (Christie, 2007), digital printing works with a rate of 90 %.
- Screen printing methods need to include carriers and thickeners in the dye paste which need to be washed off after printing, resulting in even more waste water. Inks for digital printing do not need these chemicals added and in some cases fabrics are pretreated upfront to achieve an equal print integrity.
- Conventional dyeing methods use a lot energy and wastewater to distribute the dyes on the fabric, without a guaranty for an efficient dye take up ratio.
- In digital printing only those parts are printed which are used in garment construction, meaning that no dyes are wasted, leftover material is unprinted and ready for further usage or recycling programs.

Considering pretreatment and post treatment processes, no major differences between digital and conventional printing or dying techniques can be found (Tyler, 2005). Phillips (2010) points out that energy consumption for digital printers are lower compared to screen printers. Whereas screen printers need an average of twenty-five liters per one meter printed fabric, ink jets do the same job with less than two liters of water.

Furthermore, the company MCL Global (2012) released an article that also favors digital printing combined with finishing as a sustainable solution. The Netherlands-based company Ten Cate, together with Xennia and other European partners evolved a research project to develop sustainable coatings for digital printers. Together they have produced a new, “eco-friendly, flexible and reliable process, that enables to micro-dispose small quantities of multi-functional fluids – like inks and coatings – over textile substrates on demand by means of multi-nozzle jets technology in a continuous – and speedy – process” (MCL Global, 2012). By that, printing and coating goes hand in hand in a parallel manner, which saves an additional process step, hence time, and replaces conventional wet and high temperature processes. This printing device can be integrated in existing finishing lines as seen in Figure 21.
3.6.4 Conclusion on Digital Technology Theory

Although rotary printing is faster than flatbed screen printing, both technologies are outdated since they do not fulfill demands of the changing textile printing requirements. Since digital printing machines are more appropriate for producing short runs through a flat cost distribution line depending on production outcomes, it makes digital printing technology even more interesting from an economical point of view. Just here lie the possibilities for using digital printing technology for mass customized fashion since it requires short run production. This is also evident when considering current market demand changes from volume purchases on stock for the lowest possible cost to more timely purchases based on actual customer’s needs. Moreover, the textile retail industry wants to reduce inventory, risk, and response time through supply chains, which push print providers to focus more on producing shorter runs with rapid turnaround than large volumes at low costs. Here mass customization has great future potential. Based on the time savings shown in Figure 18, the time aspect should be considered a fundamental advantage for mass customizers, since an on-demand production always involves longer lead-times compared to forecast based production. This fact should convince customizers to at least consider digital printing technologies. Having outlined the possibilities of a digital textile supply chain in Section 2.5.1 and highlighted the digital printer as a key technology for textile mass customizers, there are also other digital ICT and manufacturing technologies within the industry sector, as summarized in Section 2.6.3 that can be combined to establish a fully digital supply chain design. Since digital printers print just needed pattern, untreated waste material can be reprocessed after cutting which results in less costs and a cleaner green supply chain. Besides, digital printing and finishing processes are more environmentally friendly compared to traditional wet processes.

Consequently, digital technologies, ICT and CAD systems are the enabler to automatically customize garments in a seamless digital supply chain, regardless of the point of production. Accordingly, a local and less fragmented supply chain design is possible, which has the possibility to lower dependency from low-labor cost production countries (China, Bangladesh, India, Vietnam etc.) in order to strengthen the competitive power of the western textile industry.
3 Case Study Bivolino

This Chapter observes the state of the art company Bivolino.com in order to increase the probability of scientific support.

3.1 Brand History

The company was founded in 1954 by the two brothers Louis and Jacques Byvoet in Hasselt, a small town east of Belgium (Bivolino.com, 2012a). At that point, the company started as a traditional B2B industrial shirt maker in Europe with the German retailer C&A as a major account (Appendix a). The family had been in the textile industry since 1900 due to the brother’s grandfather, Jacques Byvoet who had been in the linen trade. Therefore, the business concept was planned to produce customized men shirts mainly from linen fabric. Consequently, the brand name should represent the family’s linen heritage, as well as the family name Byvoet and emerged to the still present company name of Bivolino. At its beginning, the company employed around eighty employees and produced nearly 350,000 customized shirts yearly in their own production plant by using the latest production machines and technologies. At this early stage, Bivolino shirts were sold in Belgium, but also exported to the Netherlands, Luxemburg, Germany and Switzerland, which accounted to 35 % of the business. Soon after, Bivolino became the pioneer within the shirt market and established a good reputation as a qualitative and fashionable shirt manufacturer with a perfect fit. Bivolino captured the current zeitgeist, since costumers demanded fashionable, colorful styles and fabrics for their shirts, away from the classic white shirt and this demand forms the foundation of Bivolino’s business concept until now.

During the recession in the 70’s, the company observed a change within customer’s consumption behavior, since consumers bought less than usually but put more emphasize on fabric and garment quality. This fact motivated the company even more to strengthen its craftsmanship skills and quality requirements. Parallel to that, Bivolino was constantly researching new and innovative fabric possibilities to stimulate customer’s interest in the brand. They introduced fabric properties like Terlenka soil release or the self ironing popelines Belofast, as well as new fabrics for shirts like polyester and jacquard. By now, Bivolino was constantly growing and produced 900,000 shirts yearly with an employment of 270 people. A turning point in the company’s history arose on October 1987, where a fire destroyed the Bivolino plant in Hasselt. Within just one year, sales decreased by 80 % leading to a serious crisis within the company which struggled to recover. By that time, the two brothers passed on the family business to Louis’ son Michel Byvoet. In order to stay in competition, the mass shirt production was further moved to the low-cost countries Tunisia and Romania (Appendix a). Bivolino could remain in business and due to its market sensibility the company used the growth of the internet in the late 90’s. Bivolino founded a new digital
studio at the Limburg Science Park in 1997 and could start to sell their shirts through an online shop in 1998. Bivolino made a turn-around with made-to-measure manufacturing and became an e-shirt web seller to private consumers (B2C). Since 1998 the business changed from “brick and mortar” to a purely e-commerce micro business concept with a totally automated production fulfillment system that connects all partners within the supply chain. Through this B2C platform, Bivolino.com offers e-mass customized tailored shirts and blouses. These MTO shirts are delivered within 2 weeks for a consumer price of about 50 €. Moitier, the COO, explains this shift the following way: “We saw the bubble burst and we had two options: close the company and admit failure or rebuild it and come back with something even better” (Diplomatic World, 2010). Until now, the company is managed by Moitier and Michel Byvoet, as the CEO, who runs Bivolino Services which licenses the Bivolino platform to other businesses. In 2010, the company also integrated e-services within a B2B stage for the biggest e-tailors that concentrate around 3-dimensional configurations, e-commerce and micro eco-manufacturing. Therefore, Bivolino provides software as a service (SaaS) and machine assisted assembly systems (MaaS). Both concepts, SaaS and MaaS contribute to a Manufacturing Service Ecosystem (MSEE), which is explained in detail in Section 3.3.2. Through this MSEE, the company’s aims for 2013 – 2015 are to further reinforce these B2B services within an ecosystem, as well as extending Bivolino’s B2C customized products and the accompanied service aspect (Appendix a). This e-mass customization concept also includes women shirts since 2011 in its assortment, as well as ties, cufflinks and men’s boxers. All in all, Bivolino’s history can be divided into three major phases (Figure 22).

![Figure 22: Bivolino’s Development](developed by the author, 2012)

**3.1.1 Brand Logo**

The Belgium place Hasselt, where Bivolino was founded, is known for its sandy area which is the perfect base for squirrels (Bivolino.com, 2012b). Before 1954, the squirrel logo was representing the former Byvoet linen business, where two squirrels sit on a weaving spindle holding the letter B. The brothers were inspired by watching the squirrels running freely in front of their manufacturing plant. When the Bivolino shirt business established in 1954, the brand logo changed to a simpler version representing just one squirrel. The inspiration came from the similarity between Bivolino and the squirrel, since “it has a personalized style, and moves quickly and elegantly with freedom” (Bivolino.com, 2012a). Since then, seven logos emerged where four represent the family linen business and the latest three the customized shirt business (Figure 23).
Today, the squirrel logo has become a symbol for high quality fashion, where each shirt contains an embroidered symbol. To express the gratefulness for inspiration, Bivolino currently supports two projects that focus on preventing red squirrel extinction.

### 3.1.2 The Customized Shirt

Bivolino started to customize bespoke shirts exclusively for men and since March 2011 a complimenting women range has been included as well (The Bulletin, 2011). Each season, a group of designers together with a graduate fashion designer from the Academy of Antwerp produce a new shirt collection based on latest fabrics, color trends, styles and pattern cuts (Bivolino.com, 2012a). Meanwhile customers can choose from approximately 170 fabric options, twenty types of collars and sleeves, seven different cuffs and thirteen button styles (The Bulletin, 2011), allowing customers to design their bespoke shirts online in a 2/3D environment where “everything [...] can be tailored to create a totally custom look” (The Independent Shopper, 2011). Furthermore, customers can choose from four style categories: Business, Party, Fashion and Arty. This results in millions of design options for manufacturing a shirt. The 3D order process is constructed by using several filters which guide customers through the design process. Figure 24 shows one example for a classic business women blouse.

#### Style & Fit
- Women can choose between 3 different garment styles
  - Anastasia: a very trendy slim fit with vertical, back and bust darts
  - Georgia: a classic relaxed fit with only bust darts
  - Racilia: a sophisticated slim fit with vertical, back and bust darts

#### Fabric
- Customers can choose their fabric according to 6 different criteria
  - Collection and corresponding Price (e.g. charming, chic or outlined)
  - Material and Weave (13 different ones, from 100 % fabrics to material blends)
  - Color and Color Groups
  - Finishing (11 different classes from easy care, to easy iron, sanded or satin, as well as ökotex 100 finishes)
  - Design and Pattern (6 different choices from plain, checked or dotted)
  - Structure (14 different ones like Heringbone, Jacquard or Oxford)
3.2 Bivolino’s Innovative Technology

Bivolino combines fashion heritage with latest technological innovations and therefore became the e-commerce pioneer to create bespoke shirts (Diplometic World, 2010). Instead of investing into advertising and marketing, the company concentrates mainly on novel research to create innovative, groundbreaking technologies and to strengthen existing tools. Starting in 1969, Bivolino invested in modern technology to support their customization concept by introducing a new ergonomic measurement system with the help of IBM, which eased an individual fit of shirts to a customer’s body (Bivolino.com, 2012a). At that time, this technology was unique in Europe and used 1,200,000 body measurements that reinvented a new, more adapted fit to the shape of the body. Later in 1981, Bivolino continued with its pioneer position and as the first shirt maker the company started to invest in computerized production by replacing manual grading of...
pattern pieces through an automatic, computerized pattern grading software. By that, grading could be realized by one click and resulted in enormous time savings, which for that time was a real revolution. This step was the beginning of Bivolino’s digital development, which continued throughout the digital revolution in the late 90’s together with the growth of the internet. Today, the company replaces manual work steps and processes by computerized technology as good as possible.

To facilitate the digitalization aspect, Bivolino established a new digital plant in the High Tech Science Park Limburg, invested in newest technology and in 1997 the brand sold its first shirt online via the World Wide Web and changed to a pure online company in 1998. From now on, customers could shop their products online by choosing their favored fabric, collar and cuffs with the ability to personalize their design through embroidering initials. At this stage, lead times took two to three weeks and customers had to take their body measurements by themselves at home and pass them over to Bivolino. This design process changed in 2004 by launching its most innovative and patented (Patent nr EEC-EP1341427 & US-7346421) technology of biometric sizing (Diplomatic World, 2010). Within a two-year research project, Bivolino developed a formula able to calculate the perfect cut and size for each customer. By using this method, the measurement process, which normally needs at least twelve basic measures, is completely replaced through the use of four centric body information, namely customer’s height, weight, collar size (men) or cup size (women) and age. This technological improvement offers customers a 100 % satisfaction warranty and due to its success, it has achieved several awards (Bivolino.com, 2012a). According to Daily Mail (2011) the average return rate of clothes bought online is still around 40 %, whereas Bivolino could reduce its return rate to 4 % due to this biometric sizing technology (Whosjack, 2010). Implementing 3D configurations, B2C customers can create their personal avatars and try on different personalized shirt options via a virtual dressing room on the worldwide web (Appendix a). Computer aided design (CAD) tools enable computerized sketching, pattern and grading design, as well as making a marker plan. In addition, computer aided manufacturing (CAM) software through computer numerical control (CNC), facilitate managing digital fabric printing machines and the cutting machine. According to Michel Byvoet, these CAD/CAM equipment and software are provided from the French company Lectra (Appendix a). That application software accompanies the product development process digitally through the whole lifecycle, from the pattern drawing board to the pattern cutting process (Lectra, 2012). Bivolino’s latest innovation has been introduced in 2010, known as a 3D shirt design platform. Within the Open Garment research project, a new zoom function could be created that present collars, cuffs or pockets as realistic as possible in real time. Furthermore, design combinations as using different fabrics for pattern pieces like inner collars, back panel parts, contrasting sleeves, stitching or removable bones could be realized online through the design tool.
3.2.1 Direct Digital Printing Technology

According to Michel Byvoet, the fabrics are printed directly with a digital textile printing machine (Appendix a). For this printing process, the Mimaki inkjet printers from the Tx400-1800 series are used. These direct-to-garment (DTG) printers make a short run production possible. Whereas traditional textile printing machines, whether rotary or screen printers require long production runs to be efficient, environmentally unfriendly processes and increased setup time, which result in increased costs (Tyler, 2005; Ujiie, 2006), modern digital printing machines like the Mimaki Tx400 series solve all those issues (Mimaki, 2010). Accordingly, digital textile printing is an economically feasible solution for producing short runs since it supports a “cost saving workflow and production process” (Mimaki 2010).

Those Mimaki printers offer the availability for small and large volume production onto a high range of fabrics, from silk, cotton, polyester, nylon, wool or any other fabrics with a high quality direct print (Appendix b). Accordingly, the machine can be operated with different ink types (reactive dye, acid dye or dye sublimation) depending on the fabric material. Furthermore the machine offers the high advantage of providing unattended print runs, which means that machines can run over night and fulfill long production runs easily and cost efficient. This is made possible through Mimaki’s integrated Uninterrupted Ink Supply System (UISS) which automatically replaces empty ink cartridges during printing. Through the use of two-liter ink bulk containers, ink costs are significantly reduced. Moreover, digital printers do not need to print the whole fabric width and can print directly in ready to cut pattern pieces. This results in using only required quantity of ink for the print, which limits water usage and ink waste and automatically lowers the environmental footprint for print production.

The Tx400 machines are available for normal and rather stiff fabrics (Tx400-1800D) or for elastic fabrics that have the tendency to stretch during the printing process (Tx400-1800B). Both machines come with a print width of 1800 cm and depending on the color gamut and resolution, a production speed from 15 m²/hour (6/8 colors – 900 x 900 dpi) to 30 m²/hour (4 color – 900 x 900 dpi) and up to 99 m²/hour (4 color – 600 x 300 dpi) can be reached (Hybrid Services, 2012). All together, a high quality image at even high production speed can be ensured. Furthermore, a heater system integrated in the machine let fabrics dry quickly and directly transfer them onto a powered take-up roller.

Moreover, using this digital printer decreases the production time, since the print job can be fulfilled immediately as soon as an order arrives and this also reduces response time. Compared to traditional screen printers, there is no need to prepare screens or mix each different color which results in massive time savings and handling time as visualized in Figure 25.
After the patterns have been printed, Bivolino uses a computer controlled pattern cutter, namely the DCS 2500 GERBERcutter® for single-ply cutting (Appendix a). This technology ensures a high-speed cutting process and at the same time it results in high quality pattern cuts, since it uses a vacuum system that prevents the fabric from movement (Gerber Scientific, 2012).

### 3.3 Supply Chain Management

As seen in Section 3.2, Bivolino uses innovative technology throughout the whole supply chain and replaces manual and labor intensive process steps as well as possible through digital computer aided tools. Still, as most processes can be managed electronically, Bivolino’s supply chain suffers from one last aspect that is still depended on craftsmanship skills from humans. Given that the sewing process, the final product assembly part cannot be robotized due to soft materials and 3D human body fit (Appendix a), it requires manual steps. Given that Xennia anticipates a robotized sewing process in nearer future, which enables a totally digital supply chain design (see Section 3.6.3); the requirements for Bivolino’s bespoke shirts still result in a need for highly skilled labor force. According to Michel Byvoet (Appendix a), the sewing of one bespoke men’s shirt needs fifty minutes which result in high labor cost and pushes sewing to cheaper European regions. When asking Bivolino to which region the production is exactly outsourced, they did not give a precise location and only referred to the Mediterranean region with manufacturing plants owned by Bivolino at a 2000 km distance from Hasselt, Belgium, which indeed can cover Europe, Asia and Africa. In order to still capture a labor cost advantage, it might be Turkey, known for their textile production skills or African countries like Algeria, Tunisia or Morocco, where the French language is spoken which could simplify collaboration to partners or workers. Since Bivolino already outsourced to Tunisia in the 80’s, the plants may still be situated there. Nearly 300 orders of shirts arrive daily at the company and 100 shirts are produced daily as soon as an order arrives (Bivolino1, 2012). The virtually and vertically integrated ordering and manufacturing process takes less times for garment construction with lead times from order placement to delivery of around two weeks.
Furthermore, Bivolino’s supply chain setup promotes a made-to-order or made-to-measure approach which starts with the end customer and pulls production upstream the chain. According to Byvoet (Appendix a), this concept opens the way to a digitalized reversed supply chain, where no garment is produced until an order is placed. This means a straight forward and real time consumer driven manufacturing is achieved, which is also connected digitally and hence this webified 100 % automated supply chain brings further advantages. It ensures a one-piece production, with producing one order after another, where processes are managed seamlessly without any manual intervention. At Bivolino, patternmakers and designers are not constantly involved and only needed for the setup and innovation phase, which automatically saves labor costs. This on-demand strategy is also connected to the fact that no inventory stock is needed, which means no depreciation and sales clearances, less waste in the system and no consumer returns due to bad fitting. Furthermore, Bivolino only offers their products online without setting up “brick and mortar” shops.

Besides including e-commerce and 3D configurations like CAD/CAM technologies on a B2B and B2C level, they also use QR codes and RFID in order to track and trace their products through the supply chain (Appendix a). Furthermore, through the use of Lectra’s CAD/CAM system a total product lifecycle management (PLM) can be fulfilled electronically to streamline the supply chain without any manual gaps. According to Lectra (2012), this software solution eases collaboration among chain partners, apart from where these networks are located globally. This increases flexibility of the supply chain setup, because as processes are managed digitally, response time and lead times until delivery can be highly decreased regardless of location. And this is exactly the case at Bivolino. Although lead times of around 10 – 14 days are the general case, current technology at Bivolino also allows the company to produce a garment within 3 – 4 days from order placement to delivery (Diplomatic World, 2010). According to Moitier (Diplomatic World, 2010), this short delivery time will be captured as soon as the market becomes more mature, since customers are still skeptical about the fact that a bespoke shirt can be created by just four measurements. Without adding more confusion to it, through a garment delivery after three to four days which might also leave doubts in Bivolino’s business concept, deliveries are kept within a two weeks framework.

Bivolino’s vision for the future is to continue with the digital supply chain concept and focus more on the establishment of new forms of hybrid manufacturing companies. These hybrid companies will arise by connecting independent manufacturing plants that will act as managed service providers (MSP) with service oriented architecture (SOA) to set the right nodes and connect different supply chains of dedicated specialized micro plants (Appendix a). These hybrid companies collaborate to develop services that support sales, differentiate products and satisfy customer’s personalized expectations. The vision is researched by two projects, explained in the ongoing Sections.
3.3.1 Open Garments Project

The Open Garments movement is an EU-funded research project that aims to provide several types of mass customized fitted and custom-designed garments for online customers (Diplomatic World, 2010). It is an initiative from a global association within nine countries that consists of five research organizations, five technology providers and five industrial partners (Open-garments, 2009). The apparel company Bivolino is one of the technology providers, as well as industry partner. This initiative has the aim to initiate and strengthen new production technologies that have the ability to support the competitive advantage of western markets. Within that, the overall objective is to reach the so called business model of a Manufacturing Service Provider (MSP) which introduces a new form of individual design, production and sales. This possibility enables customers to act as designers, produces or retailers and set up their own micro business within the system by connecting to chain partners that provide expertise in required fields where all partners equally contribute and share knowledge. Furthermore, the European Textile and Clothing Industry (TCI) can “create and provide individual garments with a very high degree of customization in terms of fit, fashion and function at a comparable price in approximately 72 hours” (open-garments, 2012).

This vision is possible through web-based virtual communities of individuals and an integration of digital technologies for design and production of personalized garments. Then, SME act as Manufacturing Service Providers by coordinating, supporting and managing the Open Innovation (OI) consumer community and Open Manufacturing (OM) network (Figure 26).

The concept of Open Garments should result in open innovation within virtual communities on a B2B and B2C level, as well as enabling open manufacturing that result in flexible and fast manufacturing through integrating digital technologies like digital printing machines. This concept is regarded as the perfect business model for the future, enabled through digital technologies and the internet which ease connections to partners on a global level and transforms chain networks to virtual and open communities.
3.3.2 MSEE Project

The Manufacturing Service Ecosystem Project started in October 2011 and consists of nineteen partners from nine different countries that aim to develop Factories of the Future (FoF) within the next three years (MSEE a, 2012). This project is funded by the European Commission with the overall objective to collaborate and establish virtual factories and enterprises through integrated ICT solutions which ensure innovation and increased efficiency among network oriented operations of chain partners. Through these intelligent manufacturing processes, goods should be produced in a smarter and innovative manner in order to recapture a competitive advantage position of the European manufacturing industry in the global marketplace. To achieve this goal, the initiative consists of three priorities:

- **Smart Factories** - for instance agile manufacturing and customization
- **Virtual Factories** - through value creation, global network manufacturing and logistics
- **Digital Factories** - electronic driven manufacturing design and product lifecycle management

Therefore, the Factories of the Future should strive towards new Virtual Factory Industrial Models with an increased service orientation and innovative collaboration approach. The vision for these virtual factories should be achieved through self organized and distributed non hierarchical ecosystems of manufacturing assets which are distributed as a service along a globalised value chain in 2015. This vision can be fulfilled through Service Oriented Architecture (SOA) and Digital Business Ecosystems (DBE) that change hierarchical production supply chains into open manufacturing systems. These goals and objectives will be tested in four industrial test cases that already set the right foundation to fulfill these requirements (Figure 27).

Bivolino is one of these test cases, which will be used as a pilot company to test management, methodologies and run experiments to set the guideline for a broader adoption of MSEE. Bivolino will cover the full product lifecycle phase, namely development, manufacturing, operation and end-of-life. The challenge for Bivolino is to outline “how service-oriented supply chain automation and interoperability within an apparel manufacturing
ecosystem could enable new business and industrial models oriented towards a dynamic made-to-order micro-plants ecosystem” (MSEE c, 2012). Therefore, the supply chain setup is in a reversed and digital manner by SOA and as virtual as possible through sharing virtual prototyping models along several micro plants and involving consumers in co-creating fashion items. Through the MSEE project, Bivolino will realize an ecosystem of many MSP in order to achieve the following aims (MSEE, 2012d):

- Offering on-demand apparel and related services to end consumers
- Create a manufacturing landscape and supply chain network of interrelated micro factories and home labs
- Creating distribution channels based on interrelated e-commerce services

3.4 Bivolino and Sustainability

Referring to Bivolino’s homepage, the company claims to constantly strive to reduce the environmental impact of their related processes with the statement that “by creating, buying and sharing at Bivolino, you go Green” (Bivolino.com, 2012d). The sustainability challenge is already captured through the unique business model of Bivolino, since a consumer driven manufacturing process through a made-to-order supply chain setup results in less waste throughout the system. Accordingly there is no need for an inventory stock of ready to wear garments and instead only assemblies of fabrics, buttons or trimming are stocked, which promotes a truly sustainable supply chain. Furthermore, through the digitalized virtual supply chain network, labor costs can be saved and the loss of achieving economies of scale through mass production can be compensated by this e-mass customized business model. This results in the fact that manufacturing can be done closer to the company’s region with a more locally oriented supply chain network, which constantly results in less carbon emissions.

What is even more convincing within the sustainability aspect, is Bivolino’s investment in computerized technologies, which allow products to remain in digital form as late as possible (Appendix a). Those sustainable technologies, starting with CAD sketching, pattern making and digital printing are regarded to be more sustainable because products become physical at the very latest stage. The fact that Bivolino uses a digital fabric printer shows that the printing process is more environmentally friendly than fabric dyeing or screen printing, which has been reflected upon in Section 2.6.4 and further supports a sustainable production process.

Moreover, Bivolino could lower its return rate of final products to 3.8 % through the biometric sizing technology for their customized shirts (Bivolino.com, 2012d). The returned shirts are subject to improvement or donation to charity organizations. Compared to the average clothing return rate of 40 % this improvement is also a huge step to producing less waste, since almost no depreciation or disposal of end products is
created. Furthermore, the company tries to influence the impact of packaging waste which is automatically a necessity for online companies that have to deliver their goods, compared to “brick and mortar” stores. This negative side effect is subject to limitation through biodegradable branded bags of the environmentally friendly plastic material Ethylene Vinyl Acetate (EVA) since 2008. Within one year those bags are fully biodegraded without creating any pollution. In addition, Bivolino tries to reduce packaging by refusing on single packaging for each shirt and instead they use the same bag for all ordered shirts by one customer. This dual package consists of a bubble envelope with the same size of shirts due to not wasting any space. Moreover, the company decided to stop sending out fabric swatches to customers, although this act is mostly regarded as a must for online fashion companies since the impression of the real touch and feel experience of fabrics is important. Still, in spite of Bivolino’s sustainable initiatives it would be contradicting to send fabric samples, since it increases packaging, delivery and fabric waste.

In addition, Bivolino and a study team found out that online shopping, thus an e-commerce business model is more sustainable than traditional “brick and mortar” stores (Bivolino.com, 2012d). Although one might wonder whether parcel deliveries to each single home do not account in higher carbon dioxide emissions than having all goods stocked in one retail shop, the study revealed exactly the opposite. The carbon footprints of the delivery process from online and conventional shopping have been compared. The result is, that an average van based home delivery produced 181 g CO₂, and a typical drive to the shops by car produces 4274 g CO₂. It showed that as long as consumers purchase less than twenty-four small, non-food items within one shopping trip, online shopping is more environmentally friendly. Although one might argue that public transportations are not considered, the result is still convincing.

All mentioned efforts show that Bivolino covers the e-mass customization concept to the fullest and achieves a totally digital clothing supply chain from costumer order placement to design, manufacturing and distribution. This results in more environmentally friendly processes, minimized returns and a reduction of waste as a part of lean manufacturing within agile, flexible, vertically integrated and virtual chains. Through the focus of e-configurations, digital design toolkits or online dressing facilities a digitalized supply chain is achieved where customers create and order a shirt that is digitally displayed and configured without the need of samples. According to Bivolino (Bivolino.com, 2012d) this concept is the “Googlification” of the apparel industry.
4 Results

This Chapter summarizes the findings from the company observation of Bivolino.com in order to present results that are related to the thesis’ objectives.

By observing Bivolino, it is noticed that an on-demand business concept through e-mass customizing apparel goods sets new successful strategic directions to withstand current western market forces. This is proven by the company’s sales increase of 60% within the last two years (Bivolino1, 2012). It shows that consumers valid customized and personalized products which combine qualitative fabrics, manufacturing skills and ecologically friendly processes over mass produced standardized garments. The fact that customers need to wait 10 – 14 days for customized shirts instead of buying items immediately straight from the shelf, seems a tolerable issue. Moreover, choosing to deliver garments through the online distribution channel by establishing frontend interfaces which use specific filters that navigate customers through the product configuration phase, does not lead to a barrier to entry. In addition, the loss of experiencing a fabric’s touch seems to be acceptable considering the company’s success. It is also interesting that Bivolino is able to offer such bespoke shirts at a price starting from 50 €, which is financially compatible to mass produced shirts. Bivolino’s sales prices point out, that by using high quality manufacturing skills in order to tailor a made-to-measure shirt does not need to be directly connected with higher sales prices. And without owning “brick and mortar” shops, no sales staff needs to be hired and no rent needs to paid, which results in further financial savings.

Bivolino includes highly innovative and modern technologies into chain processes, which demonstrates that organisations today have all technological tools available that enable an e-mass customized apparel business in an efficient and effective manner. Through the internet, interfaces to consumers and chain partners are created that foster a virtual chain network, supporting innovation and knowledge sharing. With regard to Bivolino’s lead times which can be minimized to three till four days, this on-demand reversed digital supply chain competes against lead times of fast fashion market leaders like Zara or H&M. Although H&M uses a modern ICT based rapid reaction supply chain, lead times are still around twenty-one days and even Zara’s JIT small batch assembly line accounts to lead times of fifteen days (Li Li, 2007). Hence, the conventional wisdom that fast fashion chains achieve fastest lead times industry wide, is no longer valid.

Through integrated technologies and an on-demand production, a more sustainable business model is reached, since products remain digital until the final assembly part. This system results in fewer inventories and less production waste. Moreover, fewer post consumer waste is ensured since returns are minimized to around 4%. Through the personalization aspect, a more conscious consumption pattern is achieved. Especially
through the use of direct digital textile printers, Bivolino is able to streamline a truly
digital supply chain without manual interruption that consequently results in a win-win
situation for the ecology and economy. Using the Mimaki Tx400 textile inkjet printing
machines, perfect requirements for a continued short run production demand are set,
where lower costs and more creative print result can be achieved. This findings are also
fostered by Duncan Jefferies (Sign Update, 2010), who says that choosing direct digital
printing “makes the introduction of a low inventory business model possible, drastically
reduces environmental impact and delivers what the customer wants, in the time that
they need it”. Further cost saving come through Mimaki’s 2 liter bulk ink cartridges that
are less expensive, ensure long and unattended print runs and high quality print results.

Still, the sewing process remains manual at Bivolino and results in a need of many skilled
labor forces, where labor cost competition pushes manufacturing outside Western
Europe. Nevertheless, Bivolino tries to shorten production distances as good as possible
and owns manufacturing plants 2000 km away from the home base, which is still less
than going offshore to Asian-Pacific markets. But according to the interview with
Bivolino (Appendix a), this current situation might change in nearer future, since Byvoet
clearly underlines that by merging from MTS to MTO through a reversed, digital supply
chain, manufacturing can be done closer to home. These advantages of a webified and
100 % automated chain process compensate the loss of achieving economies of scale
and paying higher production wages. Additionally, having a MTO setup means that no
stock is required, resulting in economical and ecological advantages. This innovative and
flexible close-to-home manufacturing plants are also accompanied by shorter distances,
meaning that faster deliveries are possible, less fossil fuel is combusted and let into the
air while needing less fuel means economical and sustainable benefits as well.
According to the present Open Garments and MSEE projects, Bivolino’s business
strategy and concept promise even more advantages. These new, technologically driven
manufacturing companies are forming virtual network clusters that will develop services
to support sales, share know-how and differentiate products in order to satisfy
customer’s needs for more unique and personalized goods and services. All in all, the
following result from Bivolino’s business strategies can be given (Figure 28).

![Diagram showing the relationship between Digitalization, Webification, Virtualization,
and Servitalization (developed by the author)]

Figure 28: Bivolino’s development results
(developed by the author)
5 Analysis

This Chapter compares the results from the observation in relation to the several conclusions from the literature review. With respect to the discussion of Bivolino’s results and the combined findings from the theoretical framework an analysis is given.

5.1 Sustainability

The e-mass customization business concept of Bivolino fulfills the meaning of a sustainable economy like visualized by the three pillars of sustainable development in Figure 3. Although Bivolino does not implement a TBL approach as suggested by Elkington, the company’s organizational actions throughout the whole supply chain show a highly sustainable and conscious behavior. As Bivolino practices the mass customizing strategy for apparel goods, it shows that this concept has the best potential to address aspects within the TBL by producing exactly what customers demand (people), which might increase the value of goods and hence its lifecycle (planet), while having more available cash flow since, for example, no capital is bound in forecasted goods (profit). Mass customization has been also reflected upon from the S-MC-S research project as the most sustainable strategy approach, because products are produced when needed; waste, inventory, energy consumption and manufacturing costs are reduced. Furthermore, a flexible supply chain management is outlined as a financially and ecologically sustainable alternative to manage processes. The concept of Sustainagility mentioned by Dixon and Gorecki in Section 2.5.2 precisely fits the case Bivolino, since their reversed and digital supply chain accounts for a win-win situation for the economy and ecology. Such a supply chain setup is the most compatible one with regard to efficiency and environmental sustainability, and is assessed as a trendsetter in Figure 11 according to Shukla et al. as well. Here, Bivolino achieves a pioneer position with their worldwide unique reversed, digital SCM among the textile and apparel industry sector and combines efficiency with ecological sustainability.

In addition, Slater revealed that transportation and production accounts for the most environmental harm, where both aspects are resolved by Bivolino, since transportation distances are limited due to closer production plants. Besides, referring to textile wet processes as mentioned by Chen and Burns in Section 2.1.2, the enormous water amounts during textile production are also limited at Bivolino by replacing screen printers through digital printing machines. All these actions at Bivolino lower the ecological world footprint ratio, as explained in Section 2.1.1. Moreover, Bivolino addresses further issues within this ratio by producing in the Mediterranean region which reduces the delivery distance and renouncing to send out fabric samples. In addition, Bivolino invests in biodegradable packaging materials, and through the on-demand production with digital printing machines less environmental depletion is ensured. Additionally, Bivolino tries to face the general environmental impacts of the
fashion industry by distancing its business strategy from the fast fashion movement. Meaning that the company does not constantly design and produce new shirt collections in thousand variants, and rather place this responsibility to customers who can co-create their shirts independently according to predefined assemblies (fabrics, buttons, patterns). This strategy fits to Davis’ bottom-up view of mass customization 2.0 as mentioned in Section 2.3 as customers are actively involved into business processes through product co-creation. This modular assembly production has been revealed as a sustainability advantage by Sutherland in Section 2.3.5 since it offers increased environmental manufacturing possibilities. Furthermore, customer co-creation reduces forecasting errors and obsolete inventory waste. Moreover, through Bivolino’s participation in the MSEE project, the company captures the full product lifecycle phase by solving issues that are related to product development, manufacturing, operation and end-of-life processes. Consequently, Bivolino balances ecological and economical approaches by limiting negative side effects of industrialization and globalization in shifting from mass production to mass customization in 1998. This change was accompanied by targeting customer’s needs more efficiently, which limits overconsumption and fabric discard and in addition to former mentioned processes account to a low ecological footprint.

5.2 Changing Condition

The increased environmental awareness among society is faced by Bivolino through offering Ökotex certified finishes like non-iron Ökotex 100 fabrics. Furthermore, Bivolino targets the highest hierarchical need of Maslow’s pyramid as explained in Section 2.2, namely the need for self-actualization and individualization, which is strongly demanded within modern western societies. Consequently, the need for an ethical design of business and consumption models as demanded from Carbonaro and Votava is well addressed by Bivolino. Because they offer goods, that aim to fulfill a meaning to customers by producing unique items that are not easily exchangeable and replaceable.

Additionally, Bivolino hits the current zeitgeist through establishing new supply chain patterns for a more conscious, collaborative and open macroeconomic business model. This is captured by the involvement in the Open Garments and MSEE projects, as the only textile or apparel organization within these projects. This step sets new directions of innovative business reality, where all participants within the chain (B2B and B2C) are equally integrated and can therefore freely collaborate to produce goods and services together. This involvement finally has the potential to create one solution for the actual need of eco-savvy consumers as mentioned by Hethorn and Ulasewicz, in order to actively participate in business practices and influence those.

By observing Bivolino’s history, the reason for the company’s ongoing success can be seen in the fact, that they always reflected current socio-cultural and economical
changes and adjusted business processes considerably by, for example, investing in innovative technologies or shifting to e-commerce. As a matter of fact, Bivolino’s attempts to constantly adjust processes and business strategy to environmental surroundings and the firm’s business success actually proof that the strategic concept of e-mass customization captures the present and future market trends.

5.3 Mass Customization

As stated in Chapter 4, Bivolino defends its pioneer position by seeing shortcomings of mass production early. Hence, a forecast based production for the meanwhile vulnerable and uncertain western fashion marketplace is outdated. Bivolino switched to the strategic counterpart of mass customization, required for a post industrialized economy and offers bespoke shirts at mass production prices. Furthermore, according to Gilmore’s and Pine’s four “faces” framework for MC as explained in Section 2.3.2, Bivolino’s mass customization approach reaches the highest level for customizing goods, known as collaborative customization, where the functionality and visual appearance are changed in collaboration with customers. This collaborative customization approach points out that by supporting a MTO model, where customers use modern ICT through the internet and actively design their shirts independently through pre-selected assemblies; a MC strategy is an attractive and realizable concept for the fashion business. Besides, Bivolino accomplishes all six success factors as defined from Da Silveira et al. in Section 2.3.3, which additionally supports the high potential behind implementing a MC strategy for the western fashion industry.

Even more convincing is the further fact that the case Bivolino reveals, namely that conventional trade-offs between time, variety and costs can be overcome through an e-mass customization strategy. As a result, the concept of mass customization shifts away from being a paradox as mentioned In Section 2.3.1 and becomes a new strategic chance were trade-offs between cost and customization are resolved. This possibility has been carefully attempted in Section 2.3.6 as the author’s conclusion on MC theory and through the observation of Bivolino this hypothesis can be verified now. Given the fact, that Bivolino is able to produce within shorter lead times of three till four days, shirts can be configured into 1000 different design variations and are sold at mass production prices.

5.4 E-Commerce

In 1998, Bivolino established an online purchasing platform for their B2C processes, which was, according to Moitier itself, the best decision since it rescued the company from bankruptcy. This proves that an online sales strategy works for the fashion industry, even though the touch experience of fabrics is lost. With regard to servicing mainly niche customers through an e-mass customization strategy, customers can be better targeted through this distribution channel as location boundaries disappear and
all potential customers are easily reached worldwide. This fact play in concert with the principles of Anderson’s long tail economy highlighted in Section 2.4.1, since Bivolino fulfills all three long tail forces and supports the high variety product possibilities for fashion items. With the addition of the e-commerce strategy and through the integration of innovative manufacturing and information and communication technologies, Bivolino extends the concept of MC to e-mass customization. This results in a holistic digitalization transformation of products, processes and network relationships to chain partners, as has been visualized by Coletti’s and Aichner’s e-mass customization model in Section 2.4.2. This brings additional economical and ecological benefits, since digitalization increases a firm’s efficiency and effectiveness by transforming a digital product into a physical item at the very latest stage. This digital transformation has been highlighted by Fralix in Section 2.5.1 as one of the main challenge of total digital textile supply chains and accordingly Bivolino is able to solve it.

Furthermore, regarding Roos’ study in 2007 mentioned in Section 2.4, the internet becomes increasingly present as a media tool and customers get familiar with the usability of technological interfaces and get used to shop online. The ordering and customization processes within Bivolino’s platform, reflected in Section 3.1.2, can be summarized as an understandable design interface that guides customers step by step through the shirt configuration. Together with the combination of today’s available technological tools like CAD/CAM systems, e-commerce is a recommendable strategy for mass customizers from an economical and ecological aspect.

5.5 Supply Chain Management

For an effective mass customized supply chain setup, it has been proven in literature by Goldman or Fralix in Section 2.5.1 and through the case Bivolino that chain processes must be highly flexible to respond in a quick manner. One way to achieve this is through automation by integrating computer aided technology and evaluating the perfect CODP to benefit from a leagile concept with a MTO supply chain pull strategy. Furthermore, a supply chain setup that supports economies of scope through a MC strategy is considered as a more successful strategy for low to medium volume production output.

These findings are considered at Bivolino, since it follows a reversed, digital MTO supply chain where product configuration is pulled from consumers to suppliers. Bivolino, as a SME micro business with 300 orders per day, benefits significantly from this flexible MC supply chain management. The digital aspect is pushed as far downstream as possible, so that the sewing task remains the only manually operated task. This fact is probably the reason why Bivolino is still producing offshore in order to save labor costs. With regard to Bivolino’s lead times of three till four days, integrated technologies within chain processes and the use of digital printers, the company realized a streamlined,
digitalized and flexible SCM. Through this digitalized supply chain, processes become faster, more responsive, cleaner and reduce inaccuracies.

This point out that e-mass customization is also very attractive from a supply chain perspective. Given the fact, that the whole data, such as customer order confirmation, pattern and grading sheets or any other information can be immediately distributed worldwide within a few seconds, without physical boundaries and at fewer costs, it makes this SCM highly responsive with very short lead times. The Bivolino case supports this theoretical assumption by achieving lead times of three to four days, which is clearly a result of their on-demand, digital and reversed SCM design.

Although there is no information that states Bivolino’s involvement in any logistics actions supporting a closed loop business strategy as outlined in Section 2.5.2.1, the company has the best potential to achieve such a goal. Since digital printing machines are used, Bivolino could after cutting recycle untreated fabric leftovers. With regard to Bivolino’s future vision of establishing a virtualized, service oriented manufacturing ecosystem tested within the MSEE project as mentioned in Section 3.1.1, this concept eases connections to partners on a global level and transforms chain networks to virtual and open communities. Therefore, it is an easy task to handle this recycling task over to one service company within the network that is specialized in recycling fabrics. Since closing supply chain loops are hard to realize by one focal company as already mentioned by Winkler in Section 2.5.2.1, Bivolino would fulfill the ideal preconditions through such a global chain network. Since half of the fabric choices are made of a pure 100 % material, the recycling process can be managed in an uncomplicated manner. Consequently, today’s key to competitive power within supply chains, is the integration of digital technologies that enable highly flexible and agile chain networks.

5.6 Digital Technology

As mentioned by Ujiie in Section 2.6.1.3, digital printing is truly the most economical business strategy for a SME fashion company due to realizing short print runs for mass customized products much cost efficiently. Conventional screen printing machines are still a preferred option for mass produced long runs due to achieving scale economies once the break-even point is reached, a turning point explained in Section 2.6.1.2. Mostly, if a standardized shirt should be produced more than 500 times by using the same fabric pattern, at least 1000 meters of fabric need to be printed in one run, by which screen printing machines result in an economically attractive option. However, considering the true or full cost of production, today’s companies need to integrate the cost of environmental exhaustion as well. With that in regard, digital printing can be a more financially feasible option even beyond the break-even point.
The greatest deterrent against investing in digital textile printers is still the high ink costs. The Bivolino case shows that this issue can be solved by, for example, investing in late-model machines that offer bulk ink storage of 2 liters which are cheaper in the long run. Furthermore, as mentioned in Section 2.6.1.1 low-end and high-end digital printers have both improved within recent years and become financially attractive. High-end machines can compete well against screen printing machines with their increased productivity at production speed and their long run capabilities. The SWOT analysis in Table 2 revealed that the strengths of digital printing machines outweigh weaknesses and pose a convincing option, since production costs, risks and waste can be reduced and SCM is simplified through the digitalization aspect. A digital printer accounts for time savings of 1.5 months, a much desired advantage in any supply chain. These automated processes further strengthen western market forces. Besides, digital printing allows true production on demand, where design can be changed digitally through CAD. These immediate design configuration possibilities and with the elimination of machine setup requirements for design changes show that the main market opportunities for digital printing are innovative designs and customized products. Digital printing has also the possibility to include pre- and post treatments for fabrics into the printing step, which is a unique advantage. Moreover, other CAD and CAM technologies like grading, marker plan or cutting become more innovative and further support the establishment of digital printing. Due to the fact, that if more processes that run before and after printing become digital and are controlled by computers, the resulting benefits of this transformation should be convincing enough to transform the last manual gap of screen printing. This final change will push the supply chain design development into the digital age. Since this digital implementation has already been captured by Bivolino, this company is the most present and worldwide unique business example that can be called an e-mass customization business. Because the observation of the case Bivolino showed, that all manual steps and processes have been replaced digitally and further advanced in house like Bivolino’s patented biometrical sizing technology. Furthermore, this sizing technology makes it unnecessary to consider any barriers to entry, a concern mentioned in Section 2.6.2, since the measurement process becomes simpler for customers.

Summarized, it can be noted that digital printing is not just economically feasible for SMEs that are in the MC sector, but also from a sustainable point of view. Digital printing supports a cleaner production with less energy supply, without producing fabric waste and excess ink wastage through a 100 % color take up, which accounts to water savings of around 90 % and also limits water pollution. Inks for digital printing do not require chemical agents or thickener in the dye paste, which is the case for screen printing and dyeing. Furthermore, Bivolino highlights digital printing as an environmentally sustainable process. All this lead to the fact that screen printing does not fulfill today’s changing printing requirements and is rather an outdated technology.
6 Conclusion

The purpose for this thesis is to evaluate, whether the concept of e-mass customization, supported through the supply chain integration of digital technologies can become an ecologically and economically sustainable solution for the fashion industry. Consequently, with regard to findings from the theoretical framework and through the practical observation of the company Bivolino, following statements can be concluded.

Through the supply chain integration of the latest technological innovations, environmental degradations for which the textile industry is massively accountable can be remedied. By replacing screen printing machines through modern digital printers, new business standards can be set that positively influence both the ecological footprint and the bottom line efficiency of companies. With respect to the break-even point of 1000 meters for digital printers, it can be confirmed that it is a financially attractive process for SME and micro businesses. However, due to constant developments in digital printing technologies, high-end digital printers can reach the productivity that is required for long-run production, and so digital printers could be considered for high volume outputs as well. Furthermore, it can be confirmed, that buying and creating garments in a digital form is environmentally more sustainable, as less waste is introduced in the system. Additionally, supply chain processes become digital and hence more flexible since any orders and changes can be transformed immediately, regardless of chain distances. Together with today’s internet possibilities, the concept of e-mass customization can withstand increasing labor costs in former low costs countries, since it becomes financially feasible to move production back to the European market. Thus, supply chain processes can become less fragmented and can be empowered to reduce lead times significantly. More local - or national - supply chain processes result in less CO₂ emission due to shorter distances. This is why digital, reversed and fully flexible supply chains are the best alternative to resist volatility and respond quickly on demand.

The concept of e-mass customization offers possibilities to gain a competitive advantage in matured western economies, especially in the volatile textile marketplace, by responding better to customer’s needs. Introducing this concept can lead to strategic benefits and economic value. As mass production by its pure reliance on forecast trends becomes an outdated strategy for a post industrialized society, a sales guaranty can no longer be assured. In addition, since supply chain power has shifted from suppliers to customers, MC seems to be the better alternative for the fashion industry since it addresses individual needs effectively. Moreover, since MC leads to an on-demand production, it also supports the sustainable development.

In summary, interlinking all four factors, namely the need for sustainability, e-mass customization, digital SCM through technological integration and digital printing, can
Conclusion

lead to reaching a holistic sustainable prosperity for the textile and fashion economy and the way society consumes and values products. This new prosperity is responsible for corporate wealth beyond the bottom line approach by considering environmental aspects within processes. A new, sustainable textile business reality 2.0 is fostered, which is displayed by the model in Figure 29.

![Figure 29: New Sustainable Textile Business Reality 2.0](developed by the author)

Consequently, this model verifies that once an organization targets ecological and economical targets, the outcomes lead to a win-win situation for the business, the society and the ecosystem. Implied in the word itself, a conventional profit oriented economy can turn into a sustainable eco-nomy.
7 Outlook and Future Research

This Chapter gives a general outlook for possible future developments within the textile and fashion industry. Suggestions to further research according to these foreseen developments are given.

With regard to the current developments within the fashion industry, it can be assumed that future developments will continue to expand into parallel extremes. Present trends of fast fashion on the one side and slow fashion on the other side will continue. This will be supported by a societal gap of consumers who are highly aware of sustainable issues and consumers who consider fashion consumption as a purely self satisfying act. Nevertheless, also firms that are not involved in sustainable practices and do not see a need for doing so, will be forced through governmental regulations to change their behavior in the long run since resource depletion will affect anyone in the textile sector. Similarly, the trend within western markets for mass customizing fashion items will continue and expand into several different fields. Consequently, an active customer involvement through customer co-creation will be regarded as a future strategic opportunity that ensures financial success. This will lead to an establishment of open organizations, where business success will depend on the quality of chain networks and knowledge sharing. Nevertheless, mass production will still have an influencing role within the industry sector, which will slow down implementations for a sustainable development. On the other hand, as former low labor cost countries within the Asian region become more dominant and increase their economical influence globally, labor costs will rise. This change can already be observed today and will rise in the near future. This fact increases the pressure for western organizations that are highly reliable on cost efficiencies due to their outsourcing strategies to eastern regions. One solution that can prepare companies to withstand this cost pressure is given in this thesis. Through the investment into latest technologies, chain processes become more efficient and flexible, can replace human involvement and hence the point of production becomes less important. Considering, digital textile printing machines, tools will constantly improve and hence these machines will increase productivity and replace screen printers steadily. As a matter of fact, digital printers will become financially feasible for short run production, as well as for mass producers that require a long run production output.

Consequently, all mentioned trends lead to the reality that more and more enterprises will consider a paradigm shift and evaluate strategic changes like producing closer to home or shifting to ecological friendly processes. Furthermore, e-commerce practices will expand and goods that are offered via online shops will increase. Although, the need for conventional “brick and mortar” stores will remain, the e-distribution channel will become as present as the stationary channel. With respect to the mentioned outlook scenarios following research topics are suggested.
Outlook and Future Research

**Sustainability and Digital Textile Printers**
*Topic: Assessing Sustainability Performance for Digital Printers in Relation to Screen Printers*
Using universally known sustainability indicators to measure the performance for digital and textile printers and set both outcomes in relation to each other. The result observation can be done financially, ecologically and from a risk perspective.

**Changing Conditions**
*Topic: Where to draw the Line for active Consumer Involvement?*
Since consumer co-creation is a relatively new field and organizations might be unsure how deep such participation can be assured less risky, an active research would be beneficial for firms. A SWOT analysis from the consumer perspective, as well as business perspective could reveal the answers. Similarly to different supply chain strategies, the different levels for customer co-creation can be expressed as CODP within the value chain. Each CODP can be further research through a risk analysis.

**Mass Customization**
*Topic: Will Consumers replace Designers through the concept of Mass Customization?*
Since MC becomes a more present business reality, it would be interesting to reveal how the new role of consumers can be defined from a business perspective. Respectively, even more interesting is the evaluation of the function of apparel or product designers.

**E-Commerce and SCM and Sustainability**
*Topic: Can the Distribution Strategies of a Focal Company’s Online Shop be merged with its traditional Brick and Mortar Shops to support an Environmentally Conscious Behavior?*
Big fashion companies that have a multi channel strategy, could benefit financially and ecologically by merging the distribution of both channels together. Customers could have the convenience of shopping online, but in order to lower the firm’s transportation volume, online purchased goods will be delivered together with stationary goods to the shops warehouses. Customers could then pick up their items in shops, try them on directly and if disliked these items can be returned immediately in shop. This realization potential could be tested by considering several aspects.

**Digital Technology and SCM**
*Topic: The Possibilities for Track and Trace Products within the Supply Chain*
Making supply chains and hence business processes more transparent can have positive and negative effects for parties involved in chain practices. These consequences are worth to be uncovered, since it eases any investigation decisions into RFID or QR codes.


Bergmann, H., 2011. *Profit meets Sustainability – Can this Synthesis work for the Textile Business?* Thesis for the degree Bachelor of Sciences, Germany, Hochschule Niederrhein


List of References


Daily Mail, 2011. How up to 40% of clothing bought online is returned... but internet trade is still on the rise. [Online] Available under: http://www.dailymail.co.uk/femail/article-1353496/How-40-cent-clothing-bought-online-returned--internet-trade-rise.html#ixzz1swioXMz7 Accessed on: April, the 24th 2012


Fletcher, K., 2008 Sustainable Fashion & Textiles. UK, London: Earthscan


Larsson, J., 2011. Mass customised fashion - Development and testing of a responsive supply chain for mass customised fashion garments. Doctorial Thesis of Philosophy, University of Borås, Swedish School of Textiles


Li Li, 2007. Fashion Magnates’ Supply Chain Contest. China Business Feature


List of References


### Appendix a

- What are Bivolino's business concept, mission and vision plan?
- Which market gap does Bivolino target?
- From your point of view, are there any social and economical changes within western markets that support your business model?
- How would you describe the corporate culture, hierarchy and leadership style of Bivolino?
- Through the aspect of “e-mass customization” how does Bivolino differ compared to a traditional fashion retailer in terms of:
  - a) Marketing, Advertisement and Customer Relationship
  - b) Work processes within the value chain
  - c) Communication
- How is the setup of Bivolino’s supply chain, and why?
- How are the average lead times for customized shirts?
- How does your on-demand business model with a make-to-order supply chain design influence:
  - a) Lead times
  - b) Sequence of production process steps
  - c) Cost structure (Cash flow, ROI)
- What benefits and problems are associated to this demand driven supply chain model?
- Where, geographically, does Bivolino source the needed materials (fabrics, trimmings etc.)?
- Where does the production take place?
  - a) for the digital printing of fabrics
  - b) for the sewing of the garments
- Besides digital printing, does Bivolino use other printing technologies and if so, why?
- Could you describe production workflows for a digital printer, from the order arrival point onwards?
- Why did Bivolino decide to use digital printing technologies? What are the main advantages and weaknesses within this technology?
- Which digital printing machine do you use and what is special, unique about digital printing in general?
- Is digital printing an opportunity for a more sustainable production? If so, could you motivate your answer?
- Why is it more sustainable to create and buy a garment in a digital form?
- How do you measure the sustainable advantage, how do you back up the statement with hard facts that digital is more sustainable?
  - For example: When Bivolino switched from screen printing to digital printing, did that change also result in a more financial and ecological sustainability?
- Do you release CSR reports?
- Does your business concept support a triple bottom line approach?
- Is the concept of e-mass-customization a sustainable alternative compared to a traditional fashion business model?
- In general, will mass customization play a bigger role in the near future?
- What impacts on the economy and business processes could the concept of mass customization have?
- Will digital printing result in possibilities to switch back to local production in order to strengthen the western economy?
- Based on your own experience and knowledge, why do most companies still decide to use conventional screen printing technologies?
- How is the reaction of customers in terms of:
  - a) Usability of your design interfaces
  - b) Results of your biometrical sizing technology process
  - c) Quality and appearance of final products
Answers from Michel Byvoet:

1. The major difference between the clothing sector and many others (cars, textile, household devices) is that the ‘sewing process’ cannot be robotized (because of soft material & 3D human body for fit), we still need a lot of human manual sewing (50 minutes for a men shirt) and so labor cost competition pushes manufacturing outside Europe resulting in massive imported bulk-container ‘fast fashion’ mass productions pushed throughout the supply chain with >65% of the apparel sold at discount prices or >45% returns from e-shops ——> hugh waste!

Can we bring manufacturing closer to the EU and simultaneously fulfill customers ‘new decade’ expectations: personalization, creativity, individualization, fashionable and well being/feeling/fitting, sustainable, made to measure- @ the same price, home shopping, quick delivery, no fitting room ....?

YES

How?

We have to merge from “made to stock” —> made to order —“made to measure”:

CUSTOMER FiRST

this opens the way to a ‘digitalized’ REVERSED supply chain =

- No order is produced before it is purchased
- No garment is produced before it is sold

Indeed, whenever a physical sample is created, waste is introduced into the process

—> this means no stock (no depreciation, no sales, less waste, no returns), no brick & mortar shop (no sales men, no rent)

Thus a straightforward ‘real-time’ consumer-driven manufacturing is put in place: advantage of this webified -100% automated (all 1/1 orders are processes without manual intervention: patternmakers, designers are not involved, only for the set-up and innovation)) - process compensated the loss of productivity of scale (a lot of sewing minutes), so that manufacturing can be done more close to home and this with zero carbon-delivery

Thus sustainable technologies will be implemented (require ‘intelligent workers’) they include e-commerce, 3D configurators, personal avatars, virtual dressing rooms – B2C - computirised sketching, cad, pattern design, grading, marker-making, cam - B2B - , digital fabric printing, computer numerical control (CNC) - single ply- cutting, track and trace (QRcodes, Rfid).

In fact, any technology which allows the product to remain in digital form until later in the process can be considered to be more sustainable. Companies will thus generate savings by eliminating sales costs, accurately managing inventories and production schedules. This results in less waste and, therefore, a more sustainable supply chain. These saving will compensate the expensive sewing minutes and make manufacturing (and logistics) close to home again affordable.

New kind of hybrid (manufacturing) companies will emerge connecting manufacturing plants: they will act as Msp (SOA) –SERVICE provider – orchestrering the supply chain of dedicated specialized micropplants. New brains for more flexible close-to-home manufacturing.

But there is more: these new (manufacturing) companies will develop services to support sales and differentiate products, and to satisfy customer expecting personalized experiences.
2. Who is Bivolino?

- Start as a traditional industrial shirt maker in EU in the ’50 with C&A as a major account
- Move up to low-cost countries in the ’80-90 for mass shirt production
- Make a turn-around as mtm manufacturing integrated e-shirt webseller to consumer (b2c)
- end up in 2010 with e-services (b2b) for the biggest e-tailers concentrating around 3d configuration, e-selling and micro eco-manufacturing (Saas/MaaS)
- aims over 2013-15 (through MSEE) to re-inforce these B2B services in an ecosystem, as well as to extend our ‘differentiated ‘B2C products (product as services)
- or summarized in 3 big phases:
  - phase1: end 90’s traditional stock manufacturer
  - phase2: now digitalized MtO product manufacturer

3. Lessons learned:

- A reverse supply chain can be digitalized
- Digitalization leads to webification
- Webification leads to virtualization
- Virtualisation leads to Servitization
- Servitization leads to new products, services, sales channels and business models, B2C and B2B
- All better fullfilling customer’s wishes for goods produced closer to home

Further E-Mail Contact:

| Betreff: | Bivolino questionnaire supporting thesis on Mass Customization |
| Von:     | Helene Bergmann (helenebergmann@yahoo.de) |
| An:      | byvoet@bivolino.com; |

Dear Michel Byvoet,

thank you so much for sending the answers. They are all very helpfull for the thesis and back up my findings and analysis from the literature framework perfectly, since Bivolino is the only clothing company that has the most suitable solutions to face current challenges. Also, your answers brought me new perspectives. For instance, I was not aware of the MSEE project, and now it seems to be a necessary reference within the thesis.

Maybe, you could also answer these last uncertainties:
1. Although made-to-order brings a lot of advantages, are there still any problems within the concept with which Bivolino has to struggle? No

2. According to your homepage, your manufacturing plant is still offshore, which means the sewing step is not done locally. Can you tell me, in which geographical region you produce (eastern europe, asian or asian-pacific) and if you plan to change it locally? Mediterranean

3. Which digital printing machine do you use? Can you name me the brand? Dcs2500 gerber cutters & mimaki inkjet printers & lectra cad/cam

4. I read, that you received around 300 orders per day (B2C) in 2004. Is this number still valid today? Yes

5. By mentioning your future aim of an hybrid (manufacturing) company, do you mean an organizational concept like explained in the video of the Open Garments movement? Yes
A New Age of Digital Textile Printing

Inks
- Multiple inks, adding versatility
- The Texjet series employs high-quality inks that currently available in its type dye sublimation and reactive dye inks, adding versatility to the machine.

High density black printing
- When printing black, low-scintile, high-density black ink shows an excellent deep black reproduction and density.

Continuous printing
- Uninterrupted ink supply system
- With the Uninterrupted Ink Supply System (UISS) technology, you will never run out of ink while printing large volumes of print. If an ink container runs out, the next container automatically begins supplying ink. A maximum of 4L of each color can be loaded at one time. The ink system allows for adding new inks while the machine is in full production mode.

Applications
- Substrate high-quality prints non-stop
- One operating process, direct sublimation printing, up to 56 m/min.
- Produce beautiful and sharp images.
- Low curing and ink waste.
- Suitable for a multitude of applications, both outdoor and indoor: flags, tents, point-of-sale, banners, light boxes, etc.

Fast fashion and interior design
- Produce at a lower cost, without compromising quality and uniformity.
- Print on cotton, polyester, linen, and many other fabrics.
- Simultaneous dye ink supply system and CIS for continuous unattended overnight printing.
- APPLICATIONS: Substrate textile designs, cushions, wall and floor coverings, and other fashion accessories. Also suitable for upholstery.

Fast fashion and interior design
- Print on cotton, polyester, linen, and many other fabrics.
- Simultaneous dye ink supply system and CIS for continuous unattended overnight printing.
- APPLICATIONS: Substrate textile designs, cushions, wall and floor coverings, and other fashion accessories. Also suitable for upholstery.

Industrial high speed printing
- 2- and 4-colour mode

<table>
<thead>
<tr>
<th>Speed</th>
<th>Black</th>
<th>C</th>
<th>M</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 x 400 dpi</td>
<td>1.0808</td>
<td>2.050</td>
<td>2.050</td>
<td>2.050</td>
</tr>
<tr>
<td>600 x 600 dpi</td>
<td>1.0808</td>
<td>1.0808</td>
<td>1.0808</td>
<td>1.0808</td>
</tr>
<tr>
<td>800 x 800 dpi</td>
<td>1.0808</td>
<td>1.0808</td>
<td>1.0808</td>
<td>1.0808</td>
</tr>
</tbody>
</table>

High print quality
- Selectable ink drop sizes
- ink droplets sizes can be selected according to the substrate and the intended design; in order to achieve sharp and exact reproduction.

1. If the type of ink used differs significantly, please always test and individualize for each substrate.