WASTE MANAGEMENT APPROACHES IN SPORTS FOOTWEAR INDUSTRY THROUGH SUSTAINABLE DESIGN INNOVATIONS

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WASTE MANAGEMENT APPROACHES IN SPORTS FOOTWEAR INDUSTRY THROUGH SUSTAINABLE DESIGN INNOVATIONS

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ABSTRACT

WASTE MANAGEMENT APPROACHES IN SPORTS FOOTWEAR INDUSTRY THROUGH SUSTAINABLE DESIGN INNOVATIONS

The Master`s Program in Design Studies

Eru, Ece

Graduate School of Social Sciences

Supervisor: Assoc. Prof. Dr. Şölen Kipöz

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At the turn of the 21st century, sports footwear have not only been used for sports purposes, but also has become a product which has been adapted to non-professional athletes'_daily lives. This has led to a continuous increase in consumption and production, which adversely affected the production process. In the production process of a sports footwear, many chemicals and waste materials have been determined to be harmful to the environment. Waste needs to be recycling efficiently. Wastes which are not recycled efficiently, accumulate in the landfills and become a cause of environmental pollution. The product life cycle approach and waste management are useful methods for managing and reducing these wastes. Nowadays, there are insufficient and limited number of recycling systems for sports footwear production processes. Therefore, it has been determined that the innovations used in the selection of materials, methods and production technologies, and the decisions taken by the designers during the design phase increase the recyclability of the wastes. For this purpose, the thesis topic is defined as exploring the ways and strategies to reduce waste in the sport footwear industry according to the sustainable life cycle approach. In this frame, the types of wastes that are disposed within the certain stages of the production cycle and the efficient recycling methods of these wastes are examined. In addition, the effects of innovations in material selection, production method and production technology, along with the role of designer in this process are searched.

In this study, it is determined that innovations in material, method and production technologies, designer decisions that are used in the production of sports shoes, increase the efficient recycling of wastes produced during the production processes.

Key Words: Sports Footwear Production, Sustainability Design, Life Cycle Assessment, Waste Management, Recycling, Innovative Production Cycle

ÖZ

SÜRDÜRÜLEBİLİR TASARIM YENİLİKLERİ KAPSAMINDA SPOR AYAKKABI ENDÜSTRİSİNDE ATIK YÖNETİMİ YAKLAŞIMLARI

Tasarım Çalışmaları Yüksek Lisans Programı

Eru, Ece

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Spor ayakkabılar, 20. yüzyılın başından beri sadece spor amaçlı değil, aynı zamanda profesyonel sporcu olmayan kişilerinde gündelik yaşantılarına adapte ettikleri bir ürün haline gelmiştir. Bu da, tüketim ve üretimin sürekli artmasına sebep olmuş, bu artış ise üretim sürecini olumsuz yönde etkilemiştir. Bir spor ayakkabısının üretim sürecinde, çevreye zarar veren bir çok kimyasal madde ve atık madde oluşumu ile karşılaşılmaktadır. Atıkların verimli bir şekilde geri dönüşüme dahil edilmesi gerekmektedir, geri dönüşüme gitmeyen atıklar, atık sahalarında birikerek çevreye zarar vermektedir. Bu atıkların yönetilmesi ve azaltılması için, ürün hayat döngüsü yaklaşımı ve atık yönetimi faydalı bir yöntem olarak karşımıza çıkmaktadır. Günümüzde, spor ayakkabı üretim süreçleri kapsamında, geri dönüşüm yöntemleri yetersiz ve sınırlı sayıdadır. Bu yüzden, atıkların geri dönüştürülebilmesi aşamasında kullanılabilecek yeni teknolojiler ve spor ayakkabı tasarım aşamasında tasarımcıların aldığı kararlar ve kullandıkları metod ve teknolojiler ile atık geri dönüştürülebilirliğinin arttırılabileceği saptanmıştır. Bu amaçla, tez konusu; sürdürülebilir hayat döngüsü yaklaşımına göre spor ayakkabı endüstrisinde atıkların geri dönüştürülebilirliğinin arttırılması olarak belirlenmiştir. Bu çerçevede üretim döngüsünün hangi aşamalarında hangi atıkların oluştuğu ve bu atıkların geri dönüşüme hangi yollarla kazandırılabileceği incelenmiştir. Ayrıca, malzeme seçimi, üretim metodu ve üretim teknolojilerindeki yeniliklerin yanısıra tasarımcının bu süreçteki rolü araştırılmıştır.

Çalışmada, spor ayakkabı endüstrisinde kullanılan yeni malzemelerin ve metodların, yeni teknolojilerin üretim sürecinde ortaya çıkan atıkların ve üretim sonrası oluşan atıkların geri dönüşümünü arttırdığı sonucuna ulaşılmıştır.

Anahtar Kelimeler: Spor Ayakkabı Üretimi, Yaşam Döngüsü Analizi, Geri Dönüşüm, Yenilikçi Üretim Döngüsü

TO MY FAMILY

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LIST of ABBREVIATIONS

Abbreviations

GHG:	Greenhouse Gas
CO2:	Carbon Dioxide
LCA:	Life Cycle Assessment
PCF:	Product Carbon Footprint
PU:	Polyurethane
PVC:	Polyvinyl Chloride
GWP:	Global Warming Potential
UNEP:	UN Environment
MAT:	Material Assessment Tool
USA:	United States of America
VOC:	Volatile Organic Compound
PET:	Polyethylene Terephthalate
EU:	European Union
CE:	Circular Economy
ISO:	International Organization for Standardization
EoL:	End of Life

1. INTRODUCTION

1.1 Definition of the Problem

The footwear industry is one of the most destructive industries with enormous environmental impacts which can be harmful to the environment and human health. Most especially, conventional sports footwear production and consumption cycle are unsustainable. Because sports footwears are no longer used only for the purpose of making sports and they are commonly used for daily necessities with fashion anxieties. Nowadays, people have been preferred these shoes as a new casual clothing. The sports shoes in the thesis are the products that amateur people use not only for professional sports but also for their everyday life. Also, young people, old men, old woman and children are wearing them. Thus, sports shoes have been becoming a lifestyle. However, according to the emphasized fashion ideas, thrown away culture have been increased instead of permanence, also, the production and consumption rates of the sports footwear is increasing continuously. Furthermore, unsustainable consumption have been raised. It results to the depletion of natural resources such as materials, water, and energy. Moreover, the world wide consumption is estimated at 20 billion pairs of footwears per year which illustrates excess the magnitude of the challenge when dealing with the disposal of footwear (Staikos et. al., 2006).

Nowadays, there are some recycling approaches but still conventional recycling systems are inefficient and limited. There are not enough solutions for recycling processes for post consumer sports footwear waste. Also, recycling processes are insufficient for the disassembling of the mixes footwear products.

As a result, less than 5% of post consumer footwear waste is being recycled and, unfortunately, 95% of post consumer footwear wastes are disposed in landfill sites around the world (Lee and Rahiminfard, 2012). This situation is attributed to the problem of waste. Also, significant environmental problems arise due to post consumer footwear waste accumulation. Furthermore, according to the biodegradabilities of conventional materials, they remain in nature for a long period of time without deterioration.

In order to proffer a solution for the purpose of environmental impacts, the following research question was developed; Can the innovations used in the material process, production stages, and production technologies reduce the environmental impacts occurring in the conventional sports footwear production and consumption cycle? Additionally, innovative materials, alternative production methods, and innovative production technologies used in unsustainable production and consumption cycle is used to ascertain its effects on waste reduction.

First of all, sports footwear production and consumption cycle will be investigated to determine the environmental impacts in the processes, and then solutions will be investigated for reducing the environmental impacts in this unsustainable cycle. According to environmental problems highlighted above, effective recycling process is a significant need for waste reduction. Thus, the effects of waste reduction approaches and current end of life management approaches will be researched. In order to create a sustainable sports footwear and a sustainable production and consumption cycle, solutions need to be provided. Relevant to this issue, various examples of sustainable sports footwear and footwear companies' approaches will be investigated. In addition, the effects of innovative approaches will be researched for making sports footwear more sustainable according to innovative materials, methods, and technologies which are regarded as the most important factors. As a result, this study focuses on sustainable variables such as energy, water, raw material, emission, recyclability, compostability, and renewability. Furthermore, what designers can do to mitigate environmental impacts in the design phase will also be investigated. In the thesis, the ecological dimension of sustainability is mentioned. According to sustainable issues in order to design a sustainable design and process for reduce the environmental impacts, the role of designer and design phase will be investigated because according to environmental point, designer aim is designed to be as sustainable issues as possible, they need to try have little wastes as possible.

1.2. Aim of the Study

Today, majority of the environmental problems are associated with footwear industry. Also, mass production and over-consumption is continuously rising. Therefore, footwear production and consumption cycle have become unsustainable. Environmental impacts of the cycle of the sports footwear have increased. Therefore, the main aim is to reduce environmental impacts of sports footwear production and consumption cycle. For this reason, the unsustainable processes will be determined, first, in order to improve the solutions for a sports footwear cycle. As a result, the environmental problems of the conventional unsustainable system have been researched as to what the effects of these innovations will be.

Based on the importance of this thesis, limited academic research was specifically carried out on all the life cycle of the impacts of sports footwear. The literature describes only one of the processes or product life phases. Nevertheless, in order to talk about a sustainable system, we need to consider all the processes and stages. It is the only source of all processes in the production and consumption of a sports shoe. In addition, the old sources refer to conventional materials and methods of production, but these sources refer to innovative material, methods, and production technologists. In addition, since the inefficient recycling process and the environmental problems in the old system continue, these innovations in recent years have gain popularity across companies, industries, and academics. Also, innovations have become an important subject in today's condition for finding solutions to the current environmental impacts in an unsustainable footwear sector.

1.3. Method of the Study

In this study, a literature review was used in order to get a deeper understanding of the environmental impacts of the production and consumption cycle of a sports footwear and in order to design a sustainable sports footwear and production and consumption cycle through sustainable life cycle assessment, sustainable dimensions have been researched. For this reason, specific key words were determined; Sports footwear, environmental impact, life cycle assessment, waste management, Sustainable design, eco design, design for recycling, innovative design, material, footwear design, innovative material/ method/manufacturing technology, recycling, design, sustability were scanned in databases (Google Scholar, Elseiver, Springer, YÖK, Taylor &Francis) based on the title and the entire text.

As a result of the literature review, 150 works have been researched. From these studies, some of them are eliminated because of not related to the thesis subjects. Then, a hundred studies have been taken into consideration. The literature review is presented in detail in Appendix 2. According to the literature review, it can be said that most of the studies are about waste, waste management, sustainability and life cycle assessment. There are 25 studies that include key words; waste, waste management, environmental impact, end of life management and recycling. Also there are 63 studies when life cycle assessment, sustainability, eco-design, sustainable design, ethics, designer, eco-freindly design and sustainable manufacturing were scanned. There are 16 studies about innovative materials, methods and manufacturing technologies.

Also for the aim of the thesis, sustainable sports footwear examples have been investigated in detail in Appendix 1. These examples are sequenced in chronological order. When examining the examples, it has been seen that as the years progressed, innovations in the use of materials, production methods and production technologies have been increased.

As a result of the literature studies, insufficient recycling processes and waste problems occurring in all production and consumption processes of a sports footwear and the negative environmental impacts of these processes have been examined. In addition, innovations applied to materials, methods and production technologies that can provide solutions to these problems have been examined. Furthermore, it has been determined that environmental problems can be reduced by the critical decisions taken by the designers. These issues have been supported with examined sports footwear samples and alternative approaches about sports footwear.

As a result, different types of sources have been investigated in both printed and online sources. Also, secondary data was used to review the concept of waste reduction and sustainability in sports footwear industry from books, professional and academic journals, reports, thesis, conference papers, and patents, online sources e-journals, web pages, and online articles, and online dictionaries had a significant role to play. The literature review can be beneficial to create a framework for research and identify a problem worth working for. In particular, the following studies have been very useful in this thesis. Thus, this is explained in details below;

Theodoros Staikos wrote a Doctoral Thesis titled “The Realization of end of life product recovery to support a zero waste to land to approach in footwear industry” (Staikos, 2007). Consequently, the aim of his study was to develop a multi-criteria decision making model for post-consumer shoes, waste management, and the waste hierarchy (Staikos, 2007). In this thesis, these issues raised are related to Chapter Two.

The purpose was to minimize the amount of post-consumer footwear waste send to land fill through the generation of eco-design guidelines and bespoke recycling processes that underpin the realization of a sustainable product recycling chain for the footwear sector. The findings can be used in footwear industry in order to design a new recycling system, decrease post consumer footwear waste, and decrease material content in post consumer footwears (Rahimifard and Blackhouse, 2010). In this thesis, these issues raised are related to Chapter Two. Michael James Lee and Shain Rahimifard wrote an article titled "An air based automated material recycling system for post consumer footwear products" (Lee and Rahimifard, 2012). The purpose was to determine the inefficient recycling processes factors and unsustainable production and consumption cycle for footwear, as well as the innovative approaches for footwear recycling. In this thesis, these issues raised are related to Chapter Two. Heta Kupsala wrote a master thesis titled "Eco-Effective Fashion Theory, How to implement the Cradle to Cradle® concept into fashion and clothing design?" The designer's professional, economic, social and environmental role (Kupsala, 2013). The purpose was to determine the innovative materials such as bio-based materials and their features. Also, biodegradation process has been mentioned in this study which is related to my study in Chapter Three.

As a result of the literature review and based on the fact that studies are classified according to determined key words, only the general information about the shoe was given at the beginning, and what kind of materials were used in the production of the shoe. Then, the environmental effects of the materials were also mentioned. This is especially since most of the leather is used in the production process of shoes. Most of the literature studies made mention of the leather shoes, the environmental influences of such shoes, and the production process. Over the years, both material and production techniques are mentioned at the same time.

Since the year 2000, waste management were been mentioned, in particular the very limited number of sources related to various areas of development. Academically, supportive contributors to the literature include

Michael James Lee, Shain Rahimifard, and Theodoros Staikos from Loughborough University. The studies which constitute both current waste management and improved recycling systems, waste management options, environmental impacts in footwear sector, and environmental problems for footwear materials have been mentioned in details in their studies. Also, the new system has been developed for footwear at the centre for sustainable manufacturing and recycling technologies (SMART). In addition, a new air-based recycling process has also been developed with SMART. In 2013, the first closed-loop model was developed for a sport footwear production by a company. As the years unfold, innovations in materials, production methods and production technologies have been started to be used.

1.4. Structure of the Study

The thesis consists of four main chapters; the first main chapter is the introduction part which consists of four important sections: definition of the problem, aims of the study, method of the study, and structure of the study. The main research question used in this study is: Can the innovations used in the material process, production stages, and production technologies reduce the environmental impacts occurring in the conventional sports footwear production and consumption cycle? Additionally, innovative materials, alternative production methods, and innovative production technologies used in unsustainable production and consumption cycle will be researched on based on its effects on waste reduction. After determining the problems, aims and methods of the thesis, the second main chapter was written.

In the second chapter, the main title is “Production and Consumption Cycle of Sports Footwear in Regard to Environmental Ethics.” The concept of carbon footprint which is an environmental indicator can be defined first as a measure of the total sets of greenhouse gas (GHG). Secondly, creating a life cycle assessment in sustainable sports footwear was investigated. This is because all the stages should be examined one by one so as to be able to talk about the sustainability of a product or a system. The thesis continues with environmental impacts of a sports footwear such as post consumer footwear waste. In addition to this section, current waste reduction approaches and environmental impacts were searched. Then the problem of waste due to the production and consumption cycle of a sports footwear, which includes environmental impacts of waste and the waste management approaches for sports footwear, have been examined in details.

The third main chapter entails sustainable production and design methods of sports footwear for waste management, creating circular design systems and life cycle assessment, material innovation for sustainable footwear design, waste reduction through alternative production methods, and innovative manufacturing technologies for ecological footwear production are the main title of the third chapter. Material selection is a very important issue for the production and consumption cycle of a sports footwear. However, this is because the biodegradability of the material change in conventional materials has been changed and this change can affect the recyclability of the material, product, and process. According to the waste problem which is produced from the insufficient recyclable processes and different biodegradabilities of the conventional materials and also disassembly problems for the sports footwear, 3D print technology and dyeing technologies have been investigated for waste reduction. One of the main purposes of this chapter is to reduce the environmental impacts of using innovations in material selection, production process, and production technologies for a sports footwear product.

2. PRODUCTION AND CONSUMPTION CYCLE OF SPORTS FOOTWEAR IN REGARDS TO ENVIRONMENTAL ETHICS

Today, environmental problems are associated with footwear industry because shoe production is definitely rising. For example, according to the 2012 World Footwear Yearbook source, by 2011, world shoe production was around 21 billion pairs (Ayakkabı Sektör Raporu, 2014). Also, researchers have estimated that footwear consumption has doubled every year. As a result, the footwear industry brings a lot of pollution to the environment from production to post consumer wastes, i.e., it also affects the ecosystem negatively.

In particular, the sports footwear production and consumption level is also increasing. However, short product life cycle causes high disposal rates and over waste (Subic et. al., 2012). Besides, sports footwear is no longer used for sports purposes. Daily necessities are also used with fashion anxiety. As a result, the production of sports footwear has increased significantly. Unfortunately, various types of post consumer wastes are being disposed of in landfills, but these places are becoming extremely limited because only a few are recycled in today's conditions. In addition, other major environmental impacts in this sector includes the use of dangerous materials and chemicals in footwear production, especially the usage of chromium which is a highly toxic element and the usage of unsustainable adhesives and toxic solvents. Unsustainable raw material usage is very dangerous and most of them are responsible for some adverse environmental effect in the manufacturing processes. Therefore, these issues have led to significant health problems for human and environment (Jacques, Agogino and Guimarães, 2010). Overproduction and over consumption leads to the depletion of natural resources. Due to the industrial activities, consumption of raw resources such as materials, water, and energy is rapidly increasing. As a result of this processes, solid, liquid, and gaseous wastes have adversely affected the environment. The growth in the consumption of energy and water, in particular, create concern about future and environmental impacts. It can be said that the issue of waste is an extremely important problem for the footwear sector when these figures are thought to increase even more today.

> Theoretically, all the footwear produced each year will be disposed of at some time. Considering that almost 10,000 million pairs of shoes were produced worldwide in 1995, this potentially creates large disposal problem (Wilford, 1997).

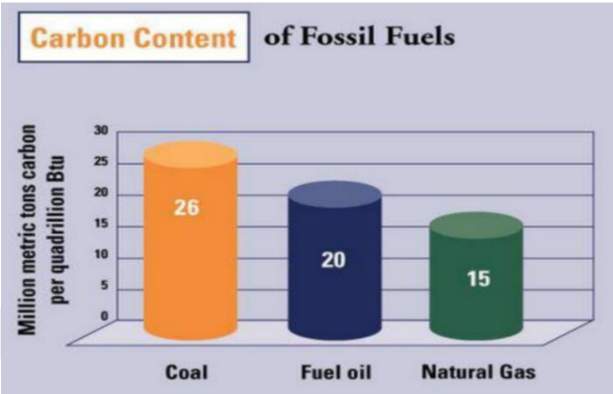
2.1. The Concept of Carbon Footprint

The concept of carbon footprint is an environmental indicator. The use of non-dangerous and low energy content materials, keeping the use of harmful chemicals to a minimum stage, and the usage of recycling materials and determination of energy consumption can be measured and arranged with carbon footprint (Herva, Alvarez and Roca, 2011).

> The carbon footprint definition is used to measure the total sets of greenhouse gas (GHG) emissions expressed in "CO2 equivalents" referred to as a product system in the atmosphere caused by a product, service, or organization through its whole lifecycle (Gajewski, et. al., 2014).

CO2 is the most common and widely-known greenhouse gas in the footwear supply chain, and it is used as a reference gas in the studies of the greenhouse gas effect (Gajewski et. al., 2014). Also, due to the gaseous emissions, global warming potential impact can be determined.

As seen in the following example, in particular, during raw materials extraction and production phases for footwear production, CO_2 is primarily emitted as a result of combustion of fossil fuels for electricity to power equipment and machines. This combustion is also known as the 'carbon footprint' (Footwear, Apparel and Accessories Industry Sustainability Guideline Volume 1: Energy). see in Graphic 2.1

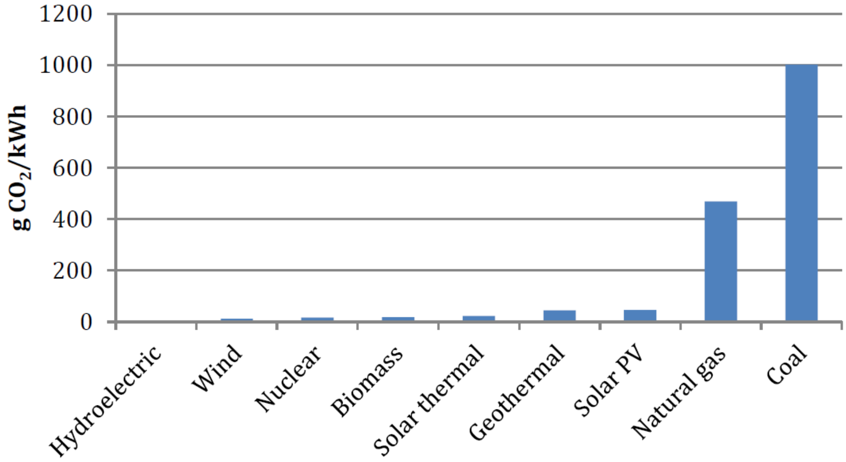


Graphic 2.1. Carbon Content of Fossil Fuels
Source: Footwear, Apparel and Accessories Industry Sustainability Guideline Volume 1: Energy

The carbon footprint increases when more carbon intensive fuels are burnt in factories; however, this combustion process has been increasing in recent years (Brugnoli and Král', 2012). According to Brugnoli et al. (2012), in 1992, CO_2 emissions were around 22000 million tonnes. Latest predictions demonstrate that in 2010, CO_2 emission cumulated to 30600 million tonnes (IEA, 2011). Thus, CO_2 concentration level seems to protect its importance. As a partial answer to this circumstance, the scientific communities, together with some industries, has improved attention in estimating the total amount of GHG produced during the different phases in the life cycle of products. The outcome of these calculations based on the Life Cycle Assessment (LCA) of the products is dedicated to Product Carbon Footprints (PCFs). PCFs are becoming significant in orientating choices both of companies and of consumers around the world (Brugnoli and Král', 2012).

> The carbon footprint establishes a quantitative measurement of the environmental impact produced by certain activities in terms of greenhouse gas (GHG) emissions (Gajewski et al., 2014)

An overview of the carbon content of major fossil fuels is outlined above. Consequently, the use of coal to generate electricity or steam creates a higher carbon footprint than diesel or fuel oil or natural gas, in that order. Using renewable energy sources, for example solar or wind energy, results in a much lower carbon footprint (Footwear, Apparel and Accessories Industry Sustainability Guideline Volume 1: Energy). Can be seen in Graphic 2.2



Graphic 2.2. Carbon Content of Fuels for Electricity Generation
Source: Footwear, Apparel and Accessories Industry Sustainability Guideline Volume 1: Energy

2.1.1. The Importance of Measuring the Carbon Footprint of a Sports Footwear

In this section, the importance of measuring the carbon footprint of the sports footwear's and the carbon emissions of life cycles of a pair of sports footwear were discussed. Current strategies are investigated for reducing the footwear's environmental impact. Due to the consumption of non-renewable resources, pollutions, emissions and wastes, heavy carbon footprint of a sports footwear were created (Subic et. al., 2012). In sports footwear designs, footprints have significant importance on the future due to the strict restriction on the use of resources such as raw materials, energy, and water exhaustion. The process of determining the environmental impacts of the production and consumption cycle of a sports footwear can be managed by using carbon footprint measurements.

2.1.2. Benefits of Measuring the Carbon Footprint of a Sports Footwear

Designers and producers will likely take advantage of carbon footprint measurement. The carbon footprint measurement is a beneficial outlines used to direct them in their choice of a more eco-friendly materials, designs, and processes when developing a new product.

Therefore, they are in search for ways to develop designs and decrease shoe's carbon footprint (Chu, 2013). The carbon emissions are emitted during all the life cycle stages of the sports footwear (Druckman and Jackson, 2010). The significance of carbon footprint measurements is that it can be made for every stages of the life cycle of a sports footwear. These measurements can be used to design a more sustainable cycle and product design. Therefore, alternative changes can be arranged when the environmental impacts of each life cycle stage are determined. The carbon footprint not only supplies a quantification of the environmental effect, but it also permits the identification of those aspects that indicate the highest effect in the manufacturing process of a sports footwear. Thus, footwear firms will be able to make the essential modifications in order to focus on decreasing the environmental effect of the footwear they produce. For this reason, it is a means of increasing the awareness about eco-design among footwear firms, taking environmental problems into account from the product design phase (Gajewski et. al., 2014). Nowadays, upgrading attention is being given to improve environmental management strategies for the supply chain (Kumar and Malegeant, 2006). Furthermore, brands are becoming increasingly more interested in encouraging their suppliers to decrease the carbon intensity of production and consequently the impacts of manufacturing on climate change (Footwear, Apparel and Accessories Industry Sustainability Guideline, Volume 1: Energy). For example, the Rio+20 Conference organizes a fundamental for companies to move towards a sustainable production process (www.unep.org).

According to the results of the Conference; The Rio+20 Outcome Document also reapproved the purpose to reach 2020 health management of chemicals along their life cycle and they are of dangerous waste in ways that guide the reduction of important negative impacts on human health and the environment, as organized in the Johannesburg Plan of Application (UN, 2012).

Additionally, waste management, energy efficiency, and resources usage are becoming important subjects for the footwear firms. According to the information above, it can be said that carbon foot print is an extremely important issue. As a result, companies operating in the footwear industry need to pay attention to the carbon footprint at every stage of the production process so that they can produce sustainable and recyclable process and products.

2.2. Creating a Life Cycle Assessment in Sustainable Sports Footwear

In this section, the concept of life cycle and life cycle assessment in sustainable sports footwear are examined. Also, why the life cycle assessment should be used for the sports footwear and how environmental impacts affect the life cycle phases have been explored. In addition, the parameters that are important for a sports footwear production process were researched. Also, the steps involved in designing a sustainable footwear can be designed according to sustainable principles. Here, life cycle phase which is the most important according to environmental impact levels were also investigated.

2.2.1. Life Cycle Stages of a Sports Footwear

Life cycle assessment (LCA) can be identified as a device for helping environmental decision making, by means of describing the environmental effects produced by a product or a process (Canals, et. al, 2002). In analyzing the environmental impacts level, the whole production cycle from raw material extraction to end of life of a product should be investigated. The environmental footprint of a sports footwear can be determined by using the life cycle assessment (LCA) (Jacques and Guimarães, 2012). The life cycle of shoes which includes all activities within the system boundaries are shown in Figure 2.1

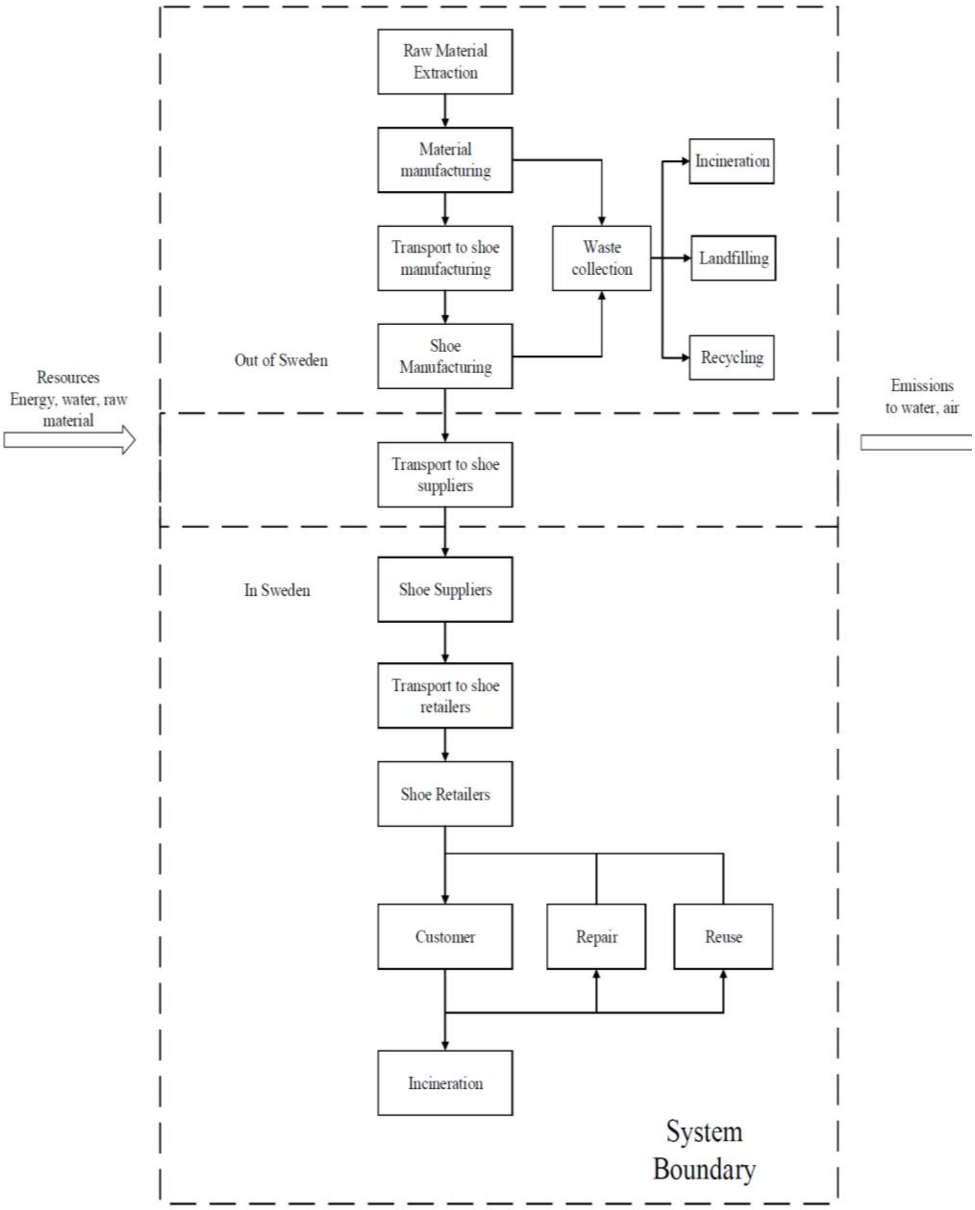


Figure 2.1. An initial flowchart for the life cycle of footwear for Sweden
Source: Gottfridson and Zhang, 2015.

According to the figure above, it can be said that each of the life cycle stages has a variety of inputs such as materials, energy and water, and output such as waste, emissions pollutants etc. The figure also illustrates that wastes are generated in every stage. However, according to the Abbey et. al., there will be occasions to decrease wastes and emissions at every phase in the process. The LCA determines to measure the global warming potential impact of the product. The negative environmental impacts can be reduced when life cycle stages are identified. The life cycle assessment can help designers to understand the effects of the products which they created. Efficient use of natural resources, raw material choice, and energy consumption can be selected properly by using life cycle assessment (LCA). Therefore, designers can evaluate potential developments in their future designs (Cheah et. al., 2013).

Particularly, in the sports footwear industry, the product life cycle approach is used to produce less damage to the environment. For example, there are some environmental aims such as decreasing and removing hazardous solvents in the sports footwear industry (Subic et. al., 2012). Horne et al. (2009) expressed that life cycle assessment can be used for checking environmental effects connected to different products and in answering the question of which of them has the lowest impact. Starting from this point of view, it can be said that a LCA approach was proper for comparing impacts of different shoes (Gottfridson and Zhang, 2015). Life cycle of a product is shown below;

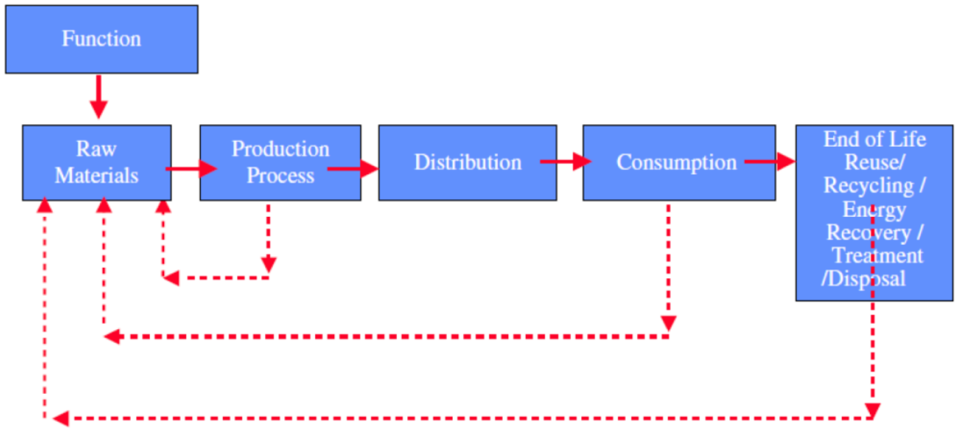


Figure 2.2. Stages of the Product Life Cycle
Source: Maxwell and Sheate, 2006

All life cycle stages and a closed loop approach should be considered together. This is because to be able to talk about a sustainable product design, we first have to try to understand the entire life cycle of a footwear. Also, there is need to think about the social and environmental effects of footwears from raw material extraction stage to the stages of manufacturing, distribution, use, and destruction while trying to understand the entire life cycle of a product.

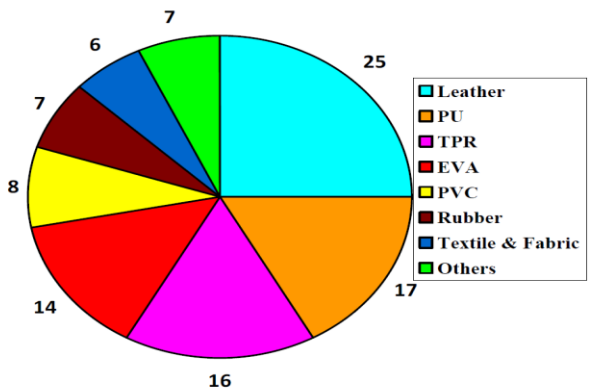
Producers, suppliers, and sub-suppliers can measure their environmental impacts by using life cycle assessment which helps in reducing the damages of the industrial activities such as emissions and waste, which are generated at all phases in the process of production of sports footwear. Nowadays companies have started to take account of their products' greenhouse-gas contributions. Also, companies have begun to measure the amount of carbon dioxide associated with every process throughout a product's life cycle. Hence, this is because there is an intense carbon emission during the production of sports footwear.

In addition, the usage of life cycle assessments will be beneficial to footwear designers in improving their designs and in determining new ways to reduce the footprint of footwears. For example, ASICS, which is an athletic equipment company based in Japan, have began to use life cycle assessment for a running shoe manufactured in China. They took a "cradle-to-grave" approach, breaking down every possible greenhouse gas-emitting steps from the point at which the shoes' raw materials are extracted to the shoes' demise, whether burned, landfilled or recycled (http://news.mit.edu). Based on the research and the information above, determining the life cycle stages of the sports footwear design is beneficial for sustainability. Furthermore, the life cycle stages are considered for the sports footwear design which consists of five stages. They can be counted as; raw material selection, producing, distribution, use, and end of life of the product.

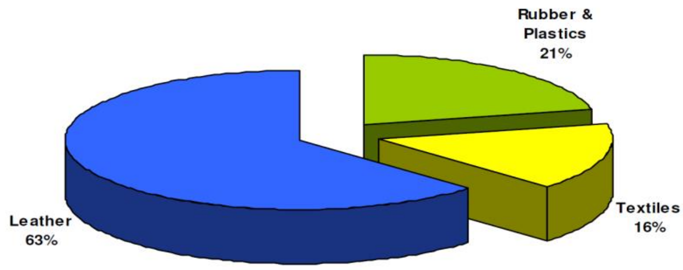
According to sports footwear life cycle assessment, two of the life cycle stages have the most significant effects in the order of other stages. It has been revealed that the carbon footprint measurements show that most of the emissions are released during the manufacturing phase (68%) and during the shoes material processing (29%) for a sports footwear (Cheah et. al., 2013). Improvement of raw material extraction and manufacturing processes are provided for decreasing negative environmental effects of the production of sports footwear (Jacques, Agogino and Guimarães, 2010). Therefore, this section focuses more on life cycle stages, especially the raw material and manufacturing stages. These steps are described in details as shown below:

2.2.1.1. Raw Material Extraction Stage

Raw Material can be defined as a primary and secondary material which is used to manufacture a product, whereas secondary materials include recycled materials (Principles and Framework, 2006). For the raw material phase, in footwear industry, extensive variation of materials are provided for making various range of styles and several types of footwears (Gottfridsson and Zhang, 2015). Examples of these raw materials used in footwear production can be seen in Graphs 2.3, 2.4



Graphic 2.3. Material composition in average shoe (%)
Source: Rahimifard, Staikos and Coates, 2007



Graphic: 2.4. Footwear Manufacture Breakdown by Materials
Source:http://ec.europa.eu/environment/archives/ecolabel/pdf/footwear/final_report_footwear

According to footwear materials, leather is the most common footwear raw material. Additionally, in sports footwear manufacturing, leather is the most used material (Tagang, 2014). Cotton, latex, rubber, PU, Eva, PVC, and synthetic fibres are other raw materials used for the production of footwear.

In the Appendix, the material used in the production of sports shoes was mentioned in details. For the processing of raw materials, the global warming potential (GWP) have a significant impact on data in terms of kilograms of CO2 equivalent emitted per kilogram of material processed (Frischknecht et. al., 2007; Frischknecht and Rebitzer, 2005). According to researches, material production has a high environmental effect compared to the other impact sources in the life cycle of footwear (Gottfridsson and Zhang, 2015).

During raw material production of footwear, significant environmental problems and processes are occurring such as; ***chemical process, harmful chemicals, excessive amount of water and energy consumption, emissions and hazardous materials***. These environmental problems are detailed below:

- ***Chemical Process:*** According to an environmental point of view, when the impact categories are considered, it can be said that the environmental impact of tannery is the most harmful chemical production process in the footwear sector. Chrome tanning is the most common type of tanning in the world and it is the method for remedying animal skins for manufacturing leather that is mainly used for sports footwear uppers (http://www.designlife-cycle.com/leather). During the tanning process, it is important to highlight that most of the leather used in the footwear sector is tanned with such substance which is called chromium3 (Guilen et. al., 2012). Chromium is also used as a primary chemical ingredient by modern leather tanner. Nevertheless, chromium has some of the most adverse impacts on the environment (http://designlife-cycle.com/leather). Direct exposure to chromium is also a dangerous health risks; when chromium is inhaled, it triggers respiratory problems such as tract irritants, resulting in airway irritation, airway obstruction, and lung, nasal or sinus cancer (ATSDR, 2014). Also, chromium poses a risk both to the environment and human health when it oxidizes to chromium4. Moreover, chromium4 which is highly toxic and carcinogenic also causes allergic problems when it comes in direct contact with the skin (Gajewski et. al., 2014). Also, environmental issues are associated with tanning industry such as; the waste water discharge. For these reasons, intensive studies have been carried out on the method and material used instead of chrome (Deri ve Deri Ürünleri Ayakkabı Ayakkabı Yan Sanayii ve Suni Deri Sektörü, 2004). According to Deselnicu et al. (2004), a material called "Ti-A1" has lesser damage to the environment instead of chrome. Therefore, the table 2.1 explains the impacts of Chrome and Ti-A1.

	TOTAL ASSESSED IMPACT									
Catego-ries	Global Warming Potential (GWP 100 years)		Ozone Depletion Potential (ODP)		Acidification Potential (AP)		Eutrophication Potential (EP)		Photochemical Ozone Creation Potential (POCP)	
Unit	kg CO2 equiv.		kg R11 equiv.		kg SO2 equiv.		kg PO43-equiv.		kg C2H4 equiv.	
Techno-logy	Cr	Ti-Al	Cr	Ti-Al	Cr	Ti-Al	Cr	Ti-Al	Cr	Ti-Al
Quantity	11.4848	9.7250	.00001	.00000	0.0883	0.0802	0.0171	0.0176	0.1513	0.1535

Table 2.1. Total Assessed Impact of Life Cycle Assessment Impact Indicators for Chrome and Ti-Al Leather Production Technologie
Source: Deselnicu, Crudu, Ioannidis and Brugnoli, 2004

Table 2.1 demonstrates that the new tanning agents based on Ti-Al were developed in the INNNOVA-LEATHER. The Ti-Al generates a significantly smaller environmental impact than chrome tanning agents and related technologies. Thus, it was recommended that for increased industrial use for a more sustainable and eco-efficient leather production, latest and innovative low carbon technologies help to decrease greenhouse gas emissions and it constitutes new employment and growth (Deselnicu et. al., 2004). As a result of this study, it was found that vegetable-tanned leather has a bio-degradation capacity of 84%, chrome-tanned leather has 23%, and synthetic leather has a bio-degradation capacity of only 9%; thus, this shows that vegetable-tanned leather is biodegradable to satisfy biodegradability conditions (Deselnicu et. al., 2004).

- ***Harmful Chemicals:*** Due to the production of materials, some toxic chemicals are being used. Generally, traditional footwear production process uses petroleum-based synthetic materials and these materials contain toxics (Albers et. al., 2008). Antimony substance for PVC and polyester production, for cotton material, production of pesticides and fertilizer are used. Fertilizers, therefore, causes water pollution (Chapagain et. al., 2006). Also, pesticides induce adverse health effects on both human and the environment. These toxic chemicals are hazardous because these toxic chemicals are being dumped in the environment which gradually leached into our water, soil, and air. In order to prevent emissions and thereby avoid the risk on people, the chemical usage can be decreased for the environment (Kemikalieinspektionen, 2001). Harmful chemicals are very important subjects for the environment and human life. Starting from this point of view, it can be stated that manufacturers and companies should apply a chemical management system to describe and control potential risks.

- ***Excessive Amount of Water Consumption***: Water is an important resource in the footwear industry (Sustainability Insights, 2017). Generally, there are excessive amount of water consumption which are used for the uppers, such as; in raw material extraction in textile production process and in leather and cotton production process (WWF, 2005). According to water usage, cotton farming is responsible for 2.6% of the world's water use (Chapagain, 2005). The availability of water is becoming scarce in some countries and, proportionally, the price of water is increasing according to UNEP report. So for companies, reducing water consumption would lead to financial saving in the future (http://www.unep.org). In many countries, pollution has reached water sources. Thus, it is making water to become insufficient for human consumption and unusable for industrial use. Therefore, improving water quality and reducing water quantity for industrial use would be ideal for preventing the depletion of water sources globally (Footwear, Apparel and Accessories Industry Sustainability Guideline/ Volume 2: Water). Water saving measures may include water monitoring management techniques. New technologies for footwear production provide elimination of water effectively such as Waterless Dying. Thus, the dying technology will be mentioned in the next chapter in details.

- ***Emissions:*** Most of the CO2 emissions are generated due to raw material extraction process. During raw material production, greenhouse gases are generated such as methane (CH_4) and ammonia (NH_3). Also, during polyester production, the emission of cobalt, antimony, and other basic toxic substances from heavy metals has emerged (Fletcher, 2008).

- ***Hazardous Materials:*** There are some hazardous materials that have emerged in the footwear production process. Different types of hazardous wastes which can be defined as solid, liquid and gases can be generated from the all life cycle of the footwear products. According to Altun (2006), a great deal of industrial waste is associated with the process of tanning such as; disposal of chrome sludge which is about 6 million tons/year from the entire world leather. Also, during cotton manufacturing, too much cotton dust was generated. For manufacturing footwear designs, according to sustainable principles and moving green, companies have made collaboration with each other. Due to the reduction in environmental impacts from raw material phase, there are some alternative initiatives such as Material Assessment Tool (MAT) created by Nike. Nike made a new sustainable invention that impressed other footwear companies, encourage innovation, and inform producers and designers (NIKE, INC. FY12 Report). The life cycle of all raw materials were defined to analyze in terms of the manufacture of the Material Assessment Tool (MAT) (Henderson et. al., 2009). In analyzing the materials Chemistry, Energy/CO2-equivalence, Water/Land Use, and Waste were categorized for materials assessment (Nike Considered Design, 2010). In the table below, materials with the lowest and highest points in each material were highlighted red and green. Nike developed the sustainable index tool for improving the environmental footprint. Furthermore, the other companies can use this index for their products because the tool is an open tech platform that enables experts worldwide. This tool is very beneficial to designers because with the use of this tool, designers can use environmentally impactful materials for their footwear designs. As seen in the table 2.2

Material name	Chemistry Total	Energy/ CO2-eq Total	Water/Land Use Total	Waste Total	Total LCA score
Maximum possible points	*40*	*24*	*16*	*20*	*100*
Cotton - Recycled	28	15	16	13	72
Silk	34.5	13.2	9	7	63.6
Polyester - Recycled, Solution Dyed	16.1	17.5	12	12.3	57.9
Polyester - Recycled, Piece Dyed	20.1	17.3	9	11	57.4
Down	21.1	20	9	4	54.1
Polypropylene - Virgin	18	20	12	4	54
Lyocell	18.2	14.7	11.5	4	48.4
Polyester - Virgin, Solution Dyed	12.6	18.8	12	5	48.4
Rayon - Beech Cellulose; Polynosic	15.2	16.3	11.5	4	47
Polylactic Acid (PLA) - Virgin	12.1	17.5	13	4	46.6
Cotton - Organic	21.8	16	3	5	45.8
Polyester - Virgin, Piece Dyed	9.4	16.3	9	5	39.7
Cotton - Conventional	13.8	16.3	4	5	39.1
Hemp	18.2	10.3	6.3	4	38.8

Table 2.2. Materials with the Lowest and Highest Score
Source: Nike, FY12/13 - Sustainable Business Performance Report

2.2.1.2. Manufacturing Stage

The design stage is the first step of the manufacturing process. Also, environmental problems are emerging based on the results of wrong decisions which were taken at the design stage. Moreover, depending on the insufficient design at the manufacturing processes, wastes were generated. For example, a designer who thinks in regards to environmental considerations should make design for sustainability and should be respectful to create alternative solutions for the environment. He should also consider generations unborn. Designers should design according to “cradle to grave approach” because 70 percent of a product's environmental effects are being defined in the design stage (Niinmaki, 2010). At this point, designer can effect the greatest change by looking at the problems from different angles and behaving responsibly for the designs they are presenting to the world. The designers should try to eliminate the environmental impacts of the design with a sense of ethics.

Based on the challenges faced by the designers in the design stage, designers' responsibilities and designers' limitations are the two main important subjects for the production phase. According to designers' responsibilities, social and environmental issues are the two major responsibilities of the designers. Designers are responsible for the designs they created for both human and nature. In every step of the design processes, they can be criticized and they should investigate and think on alternative materials, methods, and technologies for decreasing environmental impacts of the product and processes. Regarding the production stage, designers determine the raw materials, manufacturing methods, and appropriate technologies used. Then the designers determine the amount of adhesives usage for construction of pieces, product usability, and post-production scenarios with a sense of ethic. In addition, the designer can be able to rethink the process to generate and correct the deficiencies of the process.

Footwear is a complex multi-material product. Therefore, fewer materials which are used in its construction help to provide an increase in the recyclability of the product. According to recycling, the type of construction is an important issue for the separability of the components. Furthermore, sustainability criteria should be integrated into product design. It can be said that designers have a huge power on the sustainability issues. In order to manufacture sustainable products, they use life cycle assessment criteria for decreasing the environmental effects of the product and processes by using the lowest energy content materials, non-hazardous material, and recyclable materials as well as encourage the use of clean and regenerable energy sources (Hemel, 1995). According to throwaway or disposable society, long-lasting products can be designed to maximize its lifespan.

The second significant subject can be described as designers' limitations, such as the designer depends on the conditions at the workplace. For example, the production of a shoe mold is both time-consuming and costly. As a result, the designer cannot make designs in a way that will create new molds. In addition, they have to make appropriate designs that use existing molds in that company. This limits the creativity of the designer. When designing a sports footwear, problems can be raised where the shoe designer cannot solve, like designers may not know certain chemical terms and the harms of these chemicals. Sometimes, engineering may be necessary. In this case, the designers need to work with scientists for ergonomy of a product and foot anatomy, as well as chemists for material science. Nevertheless, the designer has to comply with the conditions of the company he/she works for, which reduces the designer's productivity and prevents innovative designs. Another important issue that needs to be considered is the question on how many of the designers can really interfere with company's production practices in regards to the production process and designer relation. With respect to this subject, many international footwear brands have transferred most of their production to suppliers in Asia and have sold their products in the USA and Europe (Markkaren, 2009). This is because in these developing countries, the labor cost is cheap and suppliers are required to minimize cost and maximize productivity (ILO, 2005).

Due to weak social and environmental protection systems in developing countries, as well as lack of enforcement of regulations, these issues still persists (Hau-Chung, 2014). Moreover, majority argue that job opportunities are being offered in these manufacturing places which are in developing countries and the people here are helped. However, footwear workers are being paid low wages, with excessive long working hours in an unsafe working environment and environmental violations. Also, child workers and environmental pollution have been constantly found in footwear production supply chain (Hau-Chung, 2014).

What should be the designers' role in that point? How can they join the cycle of the global economy or try to keep creating alternative solutions for sustainable issues? According to waste reduction, through shoe production, how can waste in each stage be reduced or eliminated?

In order to better understand these issues, firstly the conventional footwear production process has been examined through the production process. Conventional shoe production consists of many stages; cutting stage, mechanical stage, and finishing stage. These basically are the three main process of footwear manufacturing. After determining the materials of the footwear, the upper parts materials are cut, and then these pieces are sewn. The second process consists of molding. Generally, for the conventional footwear production, model maker and designers create the models by hand. Thus, these processes are time-consuming. These processes and the other processes of footwear production can be seen in the Figure 2.3.

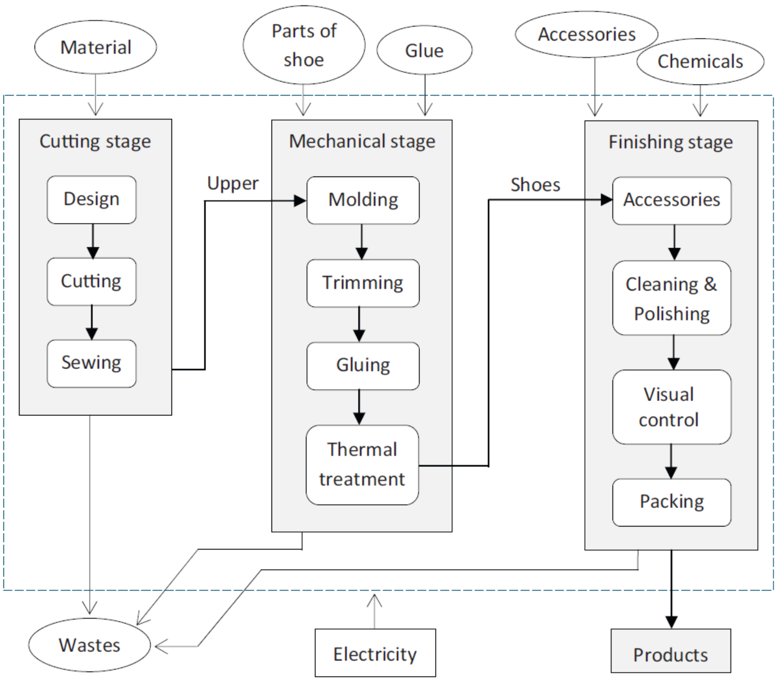


Figure 2.3. Flowsheet of the Shoemaking Factory
Source: Herva, Álvarez and Roca, 2011

As seen in the Figure 2.3, at every stage of shoe production, waste materials have emerged. The amount of waste is also important during the process of shaping the bases with metal molds. When a quantity of polymer seeps through the two faces of the molds, a thin piece of material emerges. Waste can be milled in thermoplastic molding. Also, it is possible to mix it with more pure material and turn the process without affecting the quality of the product.

Wastes from thermoplastic molding can be reused. For trimming, gluing, and thermal treatment stage and at this stage, the prepared upper parts and soles are assembled. According to Harvey (1982), cementing, injection moulding, and stitching are the three main assembling methods used in footwear industry. At the finishing stage, materials are firstly stained, secondly polished, and then waxed. Manufacturing stage is the most significant process because a great amount of emissions are released during the production stage (68 percent) (Cheah et. al., 2012). Most of the emissions in shoe production are released when creating shoe uppers (Gottfridsson and Zhang, 2015). This shows that footwear designers should be able to focus on upper parts and materials for reducing environmental impacts (Cheah et. al., 2013). For example, the Flyknit sports footwear attempts to address this, with shoe uppers knit from mainly recycled PET rather than polyester fibers made from virgin raw materials (Chen and Burns, 2006).

Manufacturing stage includes design phase, material selection, and the use of suitable methods and technologies. There are many process steps involved in the manufacturing of a sports footwear for producing and assembling of the products parts. An example can be seen in Figure 2.4. Most of the processing stages include cutting and stitching together the 53 parts in the footwears' upper part. The mid and outsoles are pressed, while the trusstic is injection molded (Cheah et. al., 2013). According to Cheah et al. (2013), the pressed parts can be buffed while the footwears are assembled; glued and pressed. Most of these phases are carried out either by hand or by workers operating individual machines.

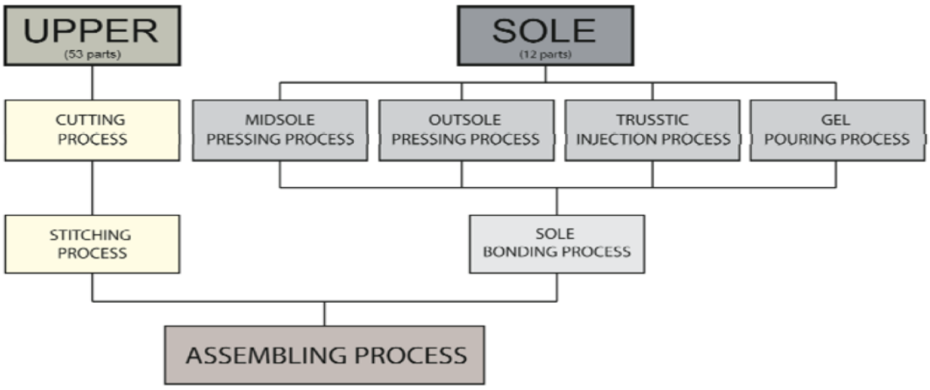
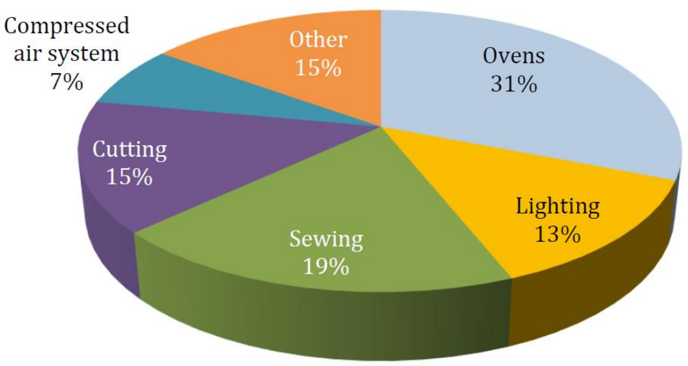


Figure 2.4. Processing Stages in Producing Running Shoes
Source: Cheah et al., 2013

A sports footwear manufacturing as summarized in the Figure 2.4, according to all production steps of a sports footwear, should be known. Thus, the effects of these steps on the environment can be assessed in this way; and through this way, producer and designer reduce the environmental impacts. According to Albers et al. (2008), in particular, manufacturing phase has the greatest environmental impact when all product life cycle stages are considered. During manufacturing process, **emissions, harmful chemicals, and manufacturing waste** can be identified as the three major things that have a negative impact on the environment. These environmental impacts are detailed below;

- ***Emissions***: Rubber is used with soles in sports footwear manufacturing and it also has important environmental impacts, especially along the processing stage. Lead and zinc which are both metals results in adverse environmental health problems in the course of the vulcanization process of processing rubbers. Lead known as a toxic chemical can lead to health related problems such as; "nervous system damage, slowed growth, hearing problems, headaches reproductive problems, hypertension, and muscle and joint pain" (US EPA, 2009). Also, PVC is a material which is used for footwear production. When PVC is burned, organo-chlorine substances, which are extremely toxic, emerged causing harm to nature and human beings. According to Cheah et al. (2013), Greenhouse Gas emissions from producing are supposed to arise from three sources: The first one is electricity use; the second one is fuel combustion; and the last one is waste disposal. According to a study, electricity use was the greatest in the Assembly Midsole buildings and outsole, with a total of 23 GWh over all buildings. Coal is also the dominant source of electricity and it is used to generate steam or to heat equipment during production in the factory itself (Chu, 2013). The average emissions associated with the use of coal is 2.0 kg CO2/kg of coal combusted (Cheah et. al., 2013). Moreover, energy is manufactured from combustion of fossil fuels like coal. Processing of footwear materials, including dyeing and other chemical processing, consumes a significant amount of energy and electricity (Sustainability-Insight, 2017). Electricity consumption is driven by machines like ovens, sewing and cutting machine, and also lighting. In the figure below, electricity consumption level can be seen.



Graphic 2.6. Typical Footwear Factory Electricity Consumption (%)
Source: Footwear, Apparel and Accessories Industry Sustainability Guideline, Volume 1: Energy.

- Industries looking at long-term growth, for considering energy saving options and adopt renewable sources of energy, aims to reduce theircarbon footprint significantly. This is attributed to the fact that energycosts present the most significant costs after labor and raw materials for manufacturers. With fuel and electricity costs increasing across the world, energy efficiency suggested an ever-increasingly appealing source of potential cost savings (Footwear, Apparel and Accessories Industry Sustainability Guideline, Volume 1: Energy).

- Developed energy efficiency can be counted as one of the most cost-effective method for decreasing greenhouse gas emission, increase energy safety, and decrease the quantity of money spent on energy (unep.org). The energy saving opportunities can be categorized by different systems or applications, such as heating, lighting, and cooling that consumes energy in factories (Footwear, Apparel and Accessories Industry Sustainability Guideline, Volume 1: Energy). It is beneficial to understand in regards to how much energy is used, where the most energy is consumed, and the best opportunities are to invest in energy efficiency.

- ***Harmful Chemicals***: Toxicity problems are the most dangerous problems in footwear production processes. Also, using adhesive is part of this problem (Rivera Munoz, 2013). A market evaluation at European adhesive manufacturers shows the following adhesive types presented for footwear producer in general and for sole bonding in particular (European Commission, Guidance 14: Footwear Manufacture, 2009). According to the table 2.3 below, the most used adhesive is solvent based adhesives which contain substances that damage nature. Due to the footwear production, the use of solvent-based adhesive is the most significant source of solvent related VOC "Volatile Organic Compound" emissions during footwear manufacture.

	Number	Share	Number for sole bonding	Share
Solvent-based adhesives	151	55,1 %	74	79,6 %
Water-based adhesives	61	22,3 %	15	16 %
Hot melts	61	22,3 %	4	4,3 %
Tapes	1	0,3 %	0	0 %
Examined amount	274	100 %	93	100 %

Table 2.3. Evaluation of adhesives offered for shoe production for sole bonding.
Source: Scherer, 2005

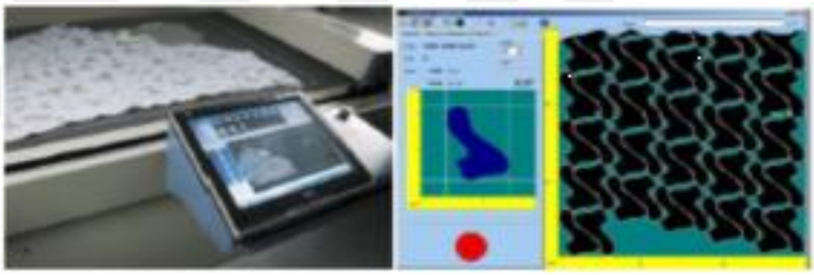
Subject to the type of shoe, on the used materials and the performance of the adhesive, the applicability of solvents can be changed (European Commission, Guidance 14: Footwear Manufacture, 2009). The quantity of adhesive used depends on the size of shoes, but an average of 25g per pair can be assumed (DFIU, 2002). Recently, with worrying over the depletion of the ozone layer and air quality raising legislation, considerable efforts have been made to decrease the use of solvents (Wilford, 1997). The solvent based glues are very dangerous for the people and environment e.g., solvent vapours. However, solvent-based adhesives are more cheaper than water-based adhesives. As a result, this type of adhesive is preferred. Water-based adhesives are (VOC) free, with the exception of a few products containing up to 2 % VOC (DFIU, 2002). Other alternatives include hot melt systems. Hot melts can be described as solvent-free systems which are based on polyester, polyamide, and vinyl acetate.

- Manufacturing Waste: Usage of petroleum-based products and synthetic fibers are the group that causes the most serious problems in solid waste due to the fact that they do not disappear for a long time in nature. Besides, the most studied subject in the researches is related to the environmental effects of the leather material and how it will reduce its impact on the environment. Since leather material is one of the most harmful materials in the environment, investigations have been conducted on these subjects in general (Wilford, 1997). One of a characteristic instance of leather processing danger is the dust created in the course of its operations. Results of waste audits at footwear manufacturing sites.

	Factory 1	*Factory 2*	*Factory 3*	*Factory 4*
Leather	39	43	23	52
Synthetics	25	28	12	29
Paper/card	4	8	-	9
Moulding	-	11	54	-
Other	32	10	10*	10

Table 2.4. Results of Waste Audits at Footwear Manufacturing Sites Source: Wilford, 1997.

Table 2.4 gives figures from several waste controls showing typical waste levels and composition. The highest single percentage is for leather. The quantity of dust is almost as much as for the leather from cutting. Most trash comes out during the cutting process such as; dust is also a potential risk with leatherdust being listed as a suspected carcinogen (Wilford, 1997). Abbey et al. (2006) stated that solid waste generation is about 4 million tons a year. The most effective way to reduce waste is to not create waste in the first phase. Generally, leather cutting waste level change due to qualities, the efficiency of the stamp, and the ability of the cutter. Today, computerized systems are used effectively by manufacturers all over the world. Such systems can be encouraged compared to cutters. The automatic cutting used for the cutting of leather aims to increase productivity. Cutting wastes quantity is directly linked to pattern design. The outsole cutting phase, insole, and reinforcement creates about 25% to 35% of waste which occur 80 of waste/million pairs (UNIDO, 2000). Cutting pieces automatically by computer can be seen in the Picture 2.1



Picture 2.1. Cutting Pieces with Computer
Source: Kılınç, 1999

2.2.1.3. Distribution Stage

The third stage of the life cycle of a sports footwear is the distribution phase. After the products are manufactured and priced, products are distributed to the market. The distribution function is very important to the economic well-being of society because it provides the products and services requested by the consumer. Distribution terms will be mentioned in the Appendix in detail.

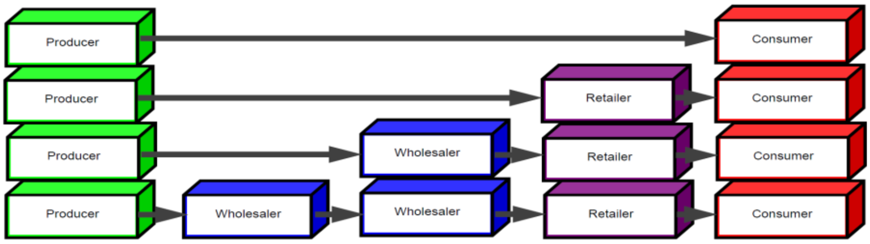


Figure 2.5. Distribution Types of Consumer Goods and Services
Source: Business 101, The Basics/Product Distribution

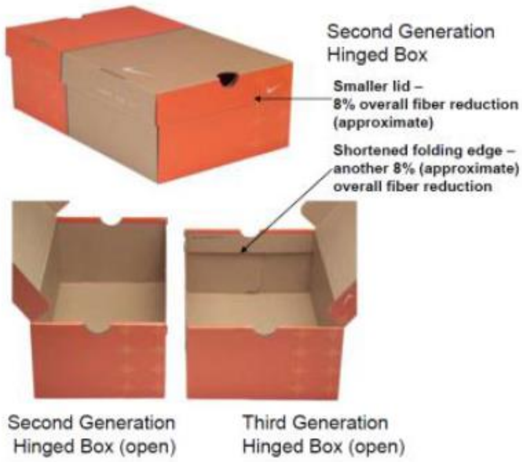
In the distribution phase, transportation and packaging issues are related to environmental impacts. Transportation will continue to play an important role in the sector and would allow the movement of raw materials, component, and parts necessary for the production process, while also delivering the end product to local and international customers (UNEP, 2013). Based on the transportation process, railroads, trucks, water carriers, and air freight are the four main transportation vehicles. Environmental impact of transportation is based on the CO2 emission related the fossil fuels (Banister and Button, 1993). Critically, 37% of worldwide emissions relating to trade are caused by the transport of materials and products (Avetisyan et. al., 2010). The impact of transportation vehicles on the environment can be determined by the amount of CO2 per ton-mile. Bora Akı (2015) estimates the CO2 levels of transportation vehicles. Environmentally, efficient distribution helps in ensuring that the product is transported efficiently from the factory doors to the retailer and finally to the user for consumption. Eco-design includes the avoidance of environmentally harmful forms of transportation; so the choice of transport mode is very important (Wakulele et. al., 2016). Furthermore, a solution for reducing transportation can be worked out with local suppliers to avoid long-distance transport (Hemel and Brezet, 1997).

Furthermore, packaging is an extremely important element in the supply chain and distribution system too. For this reason, during the developing of new packaging, the footwear companies should always make compromises between the environmental, social, and the economic aspects of packaging. Most especially in the footwear sector, packaging is a very visible part of the product as nearly all the shoes comes in shoe boxes. Also, the packaging is necessary to design in the direction of sustainable principles in order to reduce environmental impacts because the packaging has negative impacts due to the huge accumulation of various types of packaging waste on garbage. Most of them create packages that come with raw materials that are used to pack products such as cardboard, plastic film, and wooden pallets. Additionally, paper packaging affects the total waste level significantly.

Reusable packaging should also be considered. Well established packaging and recycling industries are available in some countries (Kılınç, 1999). In many developed countries, packaging constitutes, at least, of 28 countries which currently have laws designed for encouraging decreased packaging waste and greater recycling of packaging discards according to Karl and Henrik (2002). With the implementation of packaging legislation, producers have increased their tendency to minimize packaging. According to environmental issues, the manufacturing of today's card and paper from recycled materials such as recycled pulp began. Thus, this is regarded as the base materials of the footwear packaging in traditional footwear boxes. This part of the research give examples of what producers have done which contains sustainability related to the packaging. First example is about Nike's Airmax shoe box. The shoe box can be seen in the picture 2.2

Picture 2.2. Nike Airmax Shoe Box
Source:https://www.dezeen.com/2017/03/27/nike-releases-air-max-shoebox-made-from-recycled-cartons-coffee-lids-design-sustainable-packaging-arthur-huang-miniwiz/

Nike Shoe box is redesigned and new one is sturdier and lighter. Nike Airmax shoe box is made from recycled plastic and coffee lids. The shoe box can be used multifunctionally and can be made using less material of 30%. For instance, this new box is provided to decrease the materials by 3% and result in a calculated $6 million protection (Lesser, 2012). Thus, this innovation protected about 200.000 trees.



Picture 2.3. Nike's Shoe Box
Source: http://www.treehugger.com

Nike use water-based inks for printing to their shoe box and use no-glues and staples. Also, the shoe box is made of recycled paper which has increased nowadays. For corrugated wall structure, it makes use of a double wall to a single wall. Another sustainable shoe box example was designed by Puma;

Picture 2.4. Puma Sustainable Shoe Box
Source:https://medium.com/@pikkpack/thoughts-on-sustainable-footwear-industry-b9c5aa2f7314#.f7rsyohut

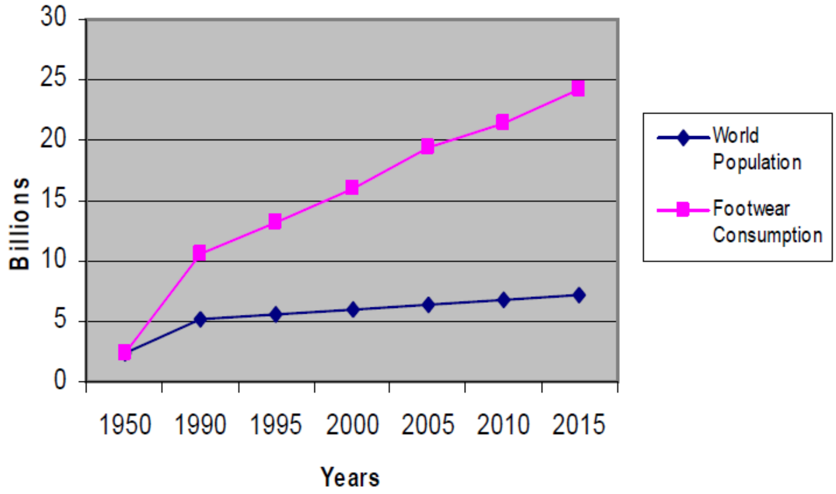
Puma designed a packaging technology that releases a minimal footprint as possible (https://medium.com). Also, it identified the bag “the Clever Little Bag”, and they made replacing its shoe boxes with reusable boxes. The new “box” contains one piece cardboard. 65% less cardboard is used with the packaging method and the created bag's materials are 100% recyclable material. With this method, they are protected 60% annually because the producing of the box uses most importantly less water, energy, and fuel. The light weight of the new packaging makes it cheaper and more eco-friendly to transport 500.000 liters less of diesel fuel needed (Paul, 2010). The new shoe box is completely different from the traditional ones; it could be folded into a smaller piece and therefore take up less space, distribution cost, fuel usage, and low CO_2 emission. With this new box, Puma saved 1 million liters of water and a total of 8.500 tons of paper (https://medium.com). The box has no laminated printing, no tissue paper, weighs less in shipping, and it replaces the plastic retail bag. The cardboard structure is die cut from one flat piece of material and it has no additional printing or assembly and, therefore, it can be returned to. The box is non-woven which means less work and waste (it is stitched with heat). Another example can be seen in Picture 2.5 with this new model of shoe bag, Newton Sportswear Company claims to be more ecologically friendly.

Picture 2.5. Newton Running Shoe Box
Source:http://creativity-online.com/work/newton-running-shoe-box/14817

Newton Running reusable shoe bag is made up of 100 percent recycled pulp and bamboo fiber. Also, the box is stackable and it eliminates any need for additional packing materials. As can be seen from these examples above, mass producers are now beginning to produce more sustainable boxes which demonstrate the importance of sustainable production of shoe boxes for a sports footwear cycle.

2.2.1.4. Use Stage

Staikos et al. (2006) expressed that unsustainable consumption has caused a rise in waste production for a long period of time. “In UK, 2003 retails figure was 338 M pairs of shoes sold and waste arising from post consumer used was estimated to reach 169,000 tonnes” (SMART, 2007). Also, the graphic below shows the global footwear consumption. As shown below, the consumption of footwear is increasing year by year and it can be said that the amount of waste related to shoes increases the consumption level.



Graphic 2.8. Global Footwear Consumption
Source: SMART, 2007

Consumers should be aware of the environmental problems and their responsibilities. Therefore, they should be a part of the sustainable system to provide a sustainable cycle. According to post consumer waste reduction, consumer awareness is very important because the sustainable awareness of a consumer will result to change in new standards of business, especially in footwear. They can put pressure on producers. According to the Jacques et al. (2010);

> Users should be well informed and incentivized to help close the loop by returning the product after its service life to the company through a product take-back system or to nature by composting it (Jacques et. al., 2010).

At least, the conscious consumer should ask some important questions concerning the products they are about to buy such as; which material is used, under what conditions, by whom was it produced, what are the effects of the materials used in production to the environment and people, and what is the amount of natural resources used in production? However, today consumers have began to be more sensitive about environmental issues because of reduction in natural resources. As a result, companies have started to produce ecologically friendly products. The issue of producing environmentally sensitive products has also started to affect the footwear industry. The eco-friendly footwear is produced to meet the consumers' expectations for quality, price and performance, as well as their concern on the environmental issues.

2.2.1.5. End of Life Stage

The end-of-life disposal of the footwears is the major environmental worries in the footwear industry. This is because unsustainable production and consumption of footwears is rapidly increasing (Jacques and Guimarães, 2012). Additionally, mass production of sports footwear causes a lot of wastes which was generated from entire life cycles. Moreover, this resulted to millions of footwears being thrown away every day (Derrig, et. al., 2010). The significant challenge is in dealing with the final disposal of footwears because footwear waste cannot be disposed of properly, and there is a general lack of recycling with less than 5 percent of the footwear being recycled (Lee and Rahimifard, 2012). However, there will always be a need for footwear production. Also, the useful life of footwears is relatively short and progressively reducing as a result of rapid marketplace changes and consumer fashion trends (Staikos and Rahimifard, 2007). Therefore, a proper waste management system should be established to manage the shoe manufacturing process more sustainability and to lessen harm to the environment.

According to the problem of waste due to the production and consumption cycle of a sports footwear; nowadays, majority of the environmental problems are associated with footwear industry because shoe production is definitely rising. For example, according to the 2012 World Footwear Yearbook source, by 2011, world shoe production is around 21 billion pairs (Ayakkabı Sektör Raporu, 2014). And also, researchers have estimated that footwear consumption is doubling every year such that the footwear industry result to a lot of pollution to the environment from production to post consumer wastes. Thus, this also has a significant impact on the ecosystem negatively. In particular, the sports footwear production and consumption level is also increasing. However, short product life cycle causes high disposal rates and overwaste (Subic et. al., 2012).

Besides, sports footwear is no longer used for sports purposes. Daily necessities are also used with fashion anxiety. As a result, the production of sports footwear has increased. Unfortunately, various types of post consumer wastes are being disposed of in landfills. Nevertheless, these places are becoming extremely limited because only a few are recycled in today's conditions. In addition, other major environmental impacts in this sector include the usage of dangerous materials and chemicals in footwear producing, the usage of chromium which is a highly toxic element, and usage of unsustainable adhesives and toxic solvents. Unsustainable raw material usage are very dangerous and most of them are responsible for some adverse environmental effect in the manufacturing processes. Therefore, these issues led to significant health problems for human and environment (Jacques, Agogino and Guimarães, 2010). Overproduction and over consumption leads to the depletion of natural resources. Due to the industrial activities, consumption of raw resources such as materials, water, and energy is rapidly increasing. As a result of this processes, solid, liquid and gaseous wastes have an adverse effect on the environment. The growth in the consumption of energy and water, in particular, created concern about future and environmental impacts.

> Theoretically, all the footwear produced each year will be disposed of at some time. Considering the fact that almost 10,000 million pairs of shoes were produced worldwide 1995, this potentially creates large disposal problem (Wilford, 1997).

It can be said that the issue of waste is an extremely important problem for the footwear sector. Hence, these figures are thought to increase even more today.

According to the environmental impacts of wastes generated in the life cycle stages of sports footwear; a wide range of materials are used including leather, cotton, polyester, nylon, PVC and PU etc. Also, production and usage of these materials affected the generation of waste in raw material extraction and manufacturing stage. When these materials become garbage after use, if they are not disposed of under suitable conditions, they accumulate in garbage areas and become harmful to the environment. In addition to this, many of the materials used in shoe production have a different length of time in nature. As a result, it is necessary to make a selection of materials by paying attention to these issues. In addition, the use of different methods and technologies also has a significant effect on the waste generation (Wilford, 1997). The processes for footwear manufacturing and different types of wastes can be seen in Figure 2.6

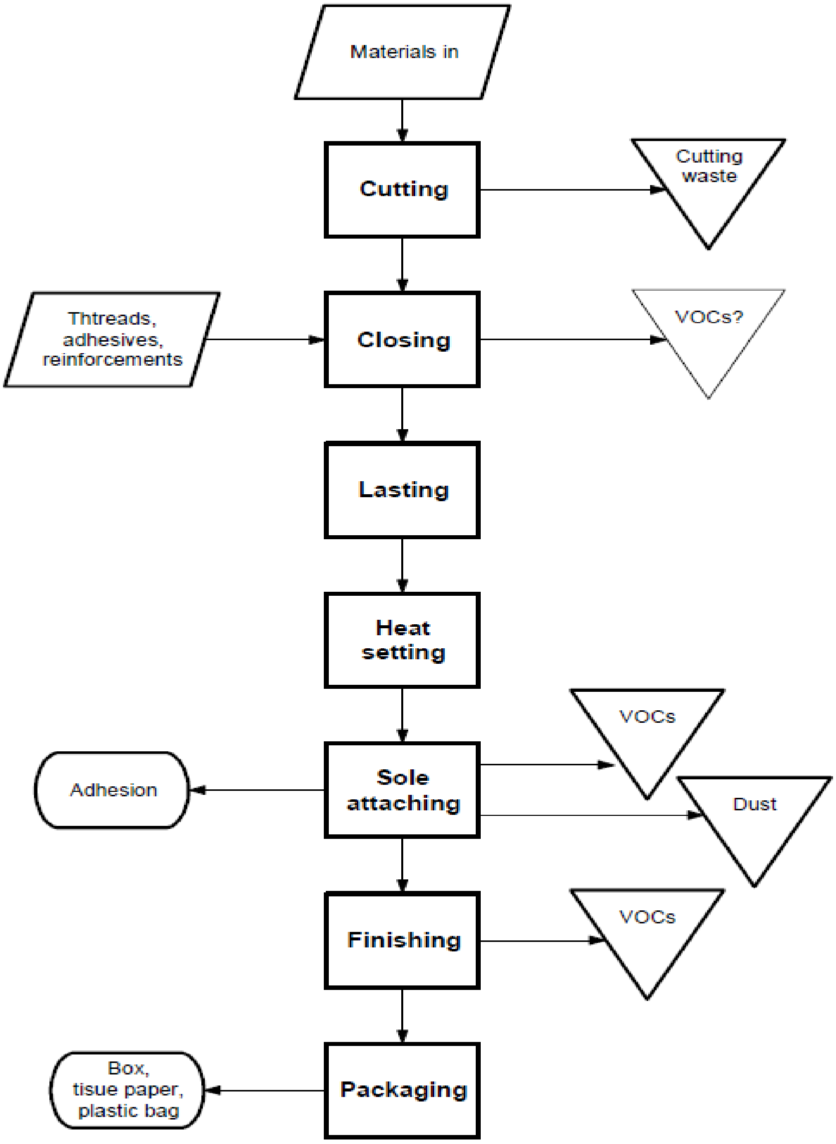
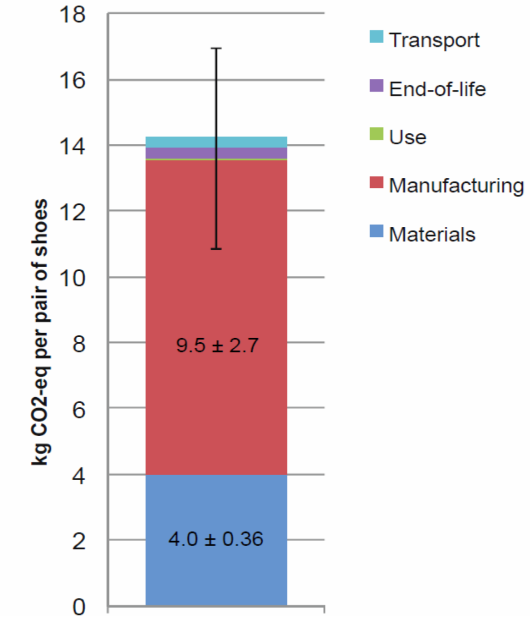


Figure 2.6. Main Processes in Footwear Manufacturing
Source: Wilford, 1997

Overwaste problem is a very important issue based on environmental impact measurements. This is because these wastes make the production cycling to become unsustainable. According to Cheah et al. (2013), waste is a common problem seen at all stages because wastes can emerge at all stages of a shoe production life cycle. Therefore, waste reduction approaches should be put in place. Furthermore, wastes can be categorized into three types; solid, liquid, and gas. Solid wastes can be counted as; cutting waste, dust, post consumer footwear waste, and unused parts of raw materials i.e., packaging wastes. (www.afirm-group.com). Liquid wastes can be counted as; waste water, chemicals, oil, etc.

(www.afirm-group.com). Lastly, gas wastes can be counted as; emissions (www.afrim-group.com). Most especially, health risks, climate change, and atmospheric pollutions are caused by greenhouse gas (GHG) emissions (www.unep.org).

Apart from the waste problem, which is the common problem identified in the entire life cycle stages, the effects of these life cycle stages are examined. The life cycle phases of a sports footwear and total impact factors can be seen below;



Graphic 2.9. Breakdown of Total GWP impacts of a Sports Shoe's by Life Cycle Phases
Source: Cheah et al., 2013 mail at

According to Cheah et al. (2013), impacts of footwear production life cycle stages were accounted for, and graphic shows an analysis of the total global warming potential (GWP) effects by life cycle stages of a sports footwear. The raw material extraction stage and production stage are the most important stages in the generation of greenhouse gas emissions (Cheah et. al., 2013). And also, Albers et al. (2008) stated that according to all the product lifecycle stages considered, material extraction and, in particular, manufacturing phase have the greatest environmental impact. For instance, the carbon footprint measurements show that most of the emissions are released during the manufacturing phase (68%) and during the shoes material processing (29%) for a sports footwear (Cheah et. al., 2013). However, the stages in which the next effect is most important is the transportation and end of life stage. Packaging was found to be the least impactful phase in the life cycle. Due to the information provided by the footwear producer, “the total GHG emissions over the sports footwear’ life cycle was calculated at 14 ± 2.7 kg CO2eq”. According to Cheah et al. (2013), looking at the total impact for comparison, driving 100 km in a passenger vehicle, produces approximately 18 kg CO2 eq, or a person emits the amount of carbon dioxide equivalents by using a 100 watt light bulb for a week (Arcenas and Holst, 2009). The carbon emissions are emitted during all the life cycle of a footwear which has a negative effects on the environment and on people’s health.

3. SUSTAINABLE PRODUCTION AND INNOVATIVE DESIGN METHODS OF SPORTS FOOTWEAR FOR WASTE MANAGEMENT

The environmental problems that arise in footwear production with traditional methods are mostly concerned with the material and methods. In this section, innovations and waste reduction issues are generally emphasized. Therefore, innovations in materials, methods, and manufacturing technologies have been researched based on how to provide waste reduction in sustainable sports footwear production processes.

In this section, material innovation for sustainable footwear design, waste reduction through alternative production methods, and innovation manufacturing technologies for ecological footwear production are the three main topics of this section. In the first part, material innovation has been explored for producing a sustainable footwear design. It is used to determine the effects of innovative materials on the production of ecological sports footwear. In order to understand the effects of material innovations on a sustainable sports footwear design, Biodegration, InCycle Process, and Boost materials have been explored in details. In the second part of the chapter three, pattern efficiency and disassembly production methods have been examined for considering the concept of design for recycling. In the third part, technological innovations have been researched for producing a ecological sports footwear. Therefore, 3D print, Dyeing, and Knitting technologies are the new technologies under investigation in this subject. At present, the footwear industry is unsustainable and wasteful according to unsustainable production and consumption cycle. For this reason, they tried to find solutions for reducing the environmental impacts of the processes.

Firstly, for better understanding of these issues, the concept of zero waste and waste reduction approaches were investigated. Also, CE (circular economy) which is an alternative and sustainable model, instead of conventional linear model, was investigated because circular economy refers to the concept of an economic system in which there is no waste. Moreover, examples of sustainable footwear designs have been investigated for this study through these critical categories which are discussed here according to material usage such as reusable, recyclable, low impact or regenerative materials, the ability to compost at the end of life phase and water and energy efficiency, and environmental impacts of the designs like greenhouse gas emissions. In addition to these issues mentioned above, in this section, the solutions to the environmental impacts are focused on the material and production processes more. This is because according to literature reviews, most of the emissions are released during the manufacturing phase (68%) and during the shoes material process (29%) (Cheah et. al., 2012).

3.1. The Concept of Waste Management and Waste Management Approaches for Sports Footwear

In this section, the concept of waste management, waste hierarchies, and waste management approaches for sports footwear are mentioned. Also, the effect of waste reduction factors has been researched. Additionally, alternative waste management approaches are examined in regards to how to provide a sustainable production and consumption cycle for a sports footwear.

Green-Standarts plays a very important role for the end of life stages of a product. For example, ISO 14000 standards are a set of standards aimed at minimizing the use of natural resources, minimizing damage to the soil, water, and air. ISO 14001 standards are a system of management that is developed to systematically reduce or, where possible, eliminate damages that businesses may or may not inflict on the environment (http://belgelendirme.ctr.com). Companies can express their environmental responsibilities by using the ISO 14001-14000 standarts (www.unep.org). Additionally, identification of legal requirements and environmental legislation has a significant effect on the footwear industry. At this point, the legislation that applies to shoe companies can be appointed for each of the environmental problems. Nevertheless, it might result to discharges, waste, emissions, and the main legal requirements that flow from this legislation (www.step2sustainability.eu). ISO14000 (International Organization for Standardization) described the concept of waste reduction as; the standard series of environmental management, published in September 1996, which controls the establishment of a system that starts with the raw material of the product throughout the final product for minimizing the damage caused to the environment; this is achieved by controlling the environmental factors determined by the necessary examinations and precautions at every stage of the process (Hietala, 2015). According to sustainable environment matters and our resources, it is important to know how wastes are generated after being consumed and how these wastes can be disposed. For this reason, an integrated waste management system is required. Waste management is essential for the conservation of the natural resources as well as the conservation of the environment and sustainable development (Öç, 2013).

A waste hierarchy framework was set up by The European Commission and based on environmental impacts, waste management options can be determined orderly using the framework (European Commission, 2003). The figure below shows the waste hierarchy framework;

Figure 3.1. Waste Hierarchy Framework
Source: European Commission, Preparing a Waste Prevention Programme, 2012

As a solution to reduce environmental pollution about product, products should be remedied without becoming waste. Additionally, waste level should be reduced. European Commission’s waste management hierarchy consists of five tenets. The first tenet of the hierarchy pyramid is waste prevention and it defines the most efficient and sustainable use of resources. The second tenet is re-use while the third one is recycling which are important parts of this tenets. Also, the last two tenets are recovery and disposal options which are the steps of the waste hierarchy ranks. Tenets are described in details below;

- Reduce is the most important step. According to the waste hierarchy, it is the reduction of the amount of waste generated by a person or organization. This step, which forms the uppermost ring of the waste hierarchy, is intended to be reduced at the source of waste (http://ec.europa.eu). For example, when less waste is produced, fewer resources will be used and thus less money and energy will be spent to recycle this waste.

- Reuse refers to an existing product being used again within the same production chain.

- Recycling is another part of the hierarchy. It can be defined as the process of converting waste materials into new materials and objects. Recycling is beneficial for saving materials and it helps to produce lower greenhouse gas emissions. It converts waste to potentially beneficial materials and decreases the consumption of fresh raw materials.

- Recovery: energy recovery can be regarded as another possible waste management system for post consumer shoes. Heat and electric energy can also be generated. Incineration, gasification and pyrolysis are the three main technologies for the energy recovery.

- Disposal: waste management for post consumer footwear waste. Waste is disposed of in landfills or thrown away.

The waste management methods mentioned above should be considered by all enterprises and the production processes should be regulated accordingly for more sustainability and environmentally friendliness. By using the circular economy concept, producers take more responsibility throughout the product life cycle and supply chain to ensure that the overall production processes are sustainable (www.unep.org). One of the instrumental designations of circular economy (CE) concept were brought by two English environmentalist; David W. Pearce and Kerry R. Turner (Pearce and Turner, 1989). Circular economy has become an alternative model for a traditional linear economy model. Hence, recycling is considered as an important issue in the circular economic model. The main objective in the recycling process is to recycle waste materials and to recover the waste materials of such new raw materials for a new product or process (Zaccai, 2008). A circular economy features are; low consumption of energy, low emissions of pollutants, and high efficiency of resource use throughout the economic activity. In addition, circular economy can build integrated, closed-loop manufacturing systems in which the by-products of one industrial process become the resources for another (www.unep.org). According to Pearce and Turner (1989), reduction of waste, resource productivity and reduction of ecological scarcities can be considered useful subjects of (CE).

Based on the waste hierarchy, we can say that the responsibilities of waste reduction belong mostly to the producer (Albers, Canepa, and Miller, 2008). Also, the concept of the producer responsibility was first developed by Thomas Lindhqvist in 1990. This report has been prepared for the Swedish Ministry on environmental and natural resources issues (Lindhqvist and Lidgren, 1990). With the concept of producer responsibility, it has placed an emphasis on achieving an influence on the design of products. The concept, as a preventative environmental protection strategy and also producer, have the capacity for making alterations at the source for reducing the environmental impacts of their product throughout all its life cycle (Van Rossem, Tojo and Lindhqvist, 2006). According to Staikos et al. (2006), the concept led the producers to notice the products life cycle, post consumer waste, and waste management matters. Besides this, the close loop is been put into consideration with this concept. Furthermore, with the help of international standards, codes, regulations, and the governance arrangements, policies and local authorities are forcing the producers to take responsibility for end of life of waste with the aim of reducing their environmental impacts (Ehrenfeld and Hoffman, 2013).

According to waste management approaches for sports footwear; firstly, post-consumer footwear waste and waste management options are mentioned and alternative waste management approaches are examined. Waste management is a big opportunity for reducing impacts of shoe production and consumption processes because with millions of shoes being manufactured worldwide every year and at the same time, some are thrown away into garbage areas (King et. al., 2010). Thus, it leads to the generation of huge amount of post-consumer shoe waste. Most of the wastes are disposed of in landfill places around the world (Staikos and Rahimifard, 2007). On the other hand, the fundamental problem is that the capacities for recycling rate of the landfills are limited.

In order to create a sustainable system and for the life cycles of the product to exist, the waste management system needs to be adopted. For the sustainable cycle, treatment of waste and adoption of cleaner production technologies should be established (Sharif et. al., 2003). Considering the amount of post-consumer waste generation, waste management is the most influential and effective process to manage material flows in the industrial and economic systems (www.oecd.org). Furthermore, the waste management process is also an important issue for the sports footwear sector because it has a high waste rate. The waste management hierarchy established by the European Commission can also be applied to the footwear sector. Starting from this point of view and based on the hierarchy mentioned above, an integrated waste management framework for footwears has been improved (Staikos et. al., 2006). Thus, the framework which is described in Figure 3.2 depends on reactive and proactive waste management choices.

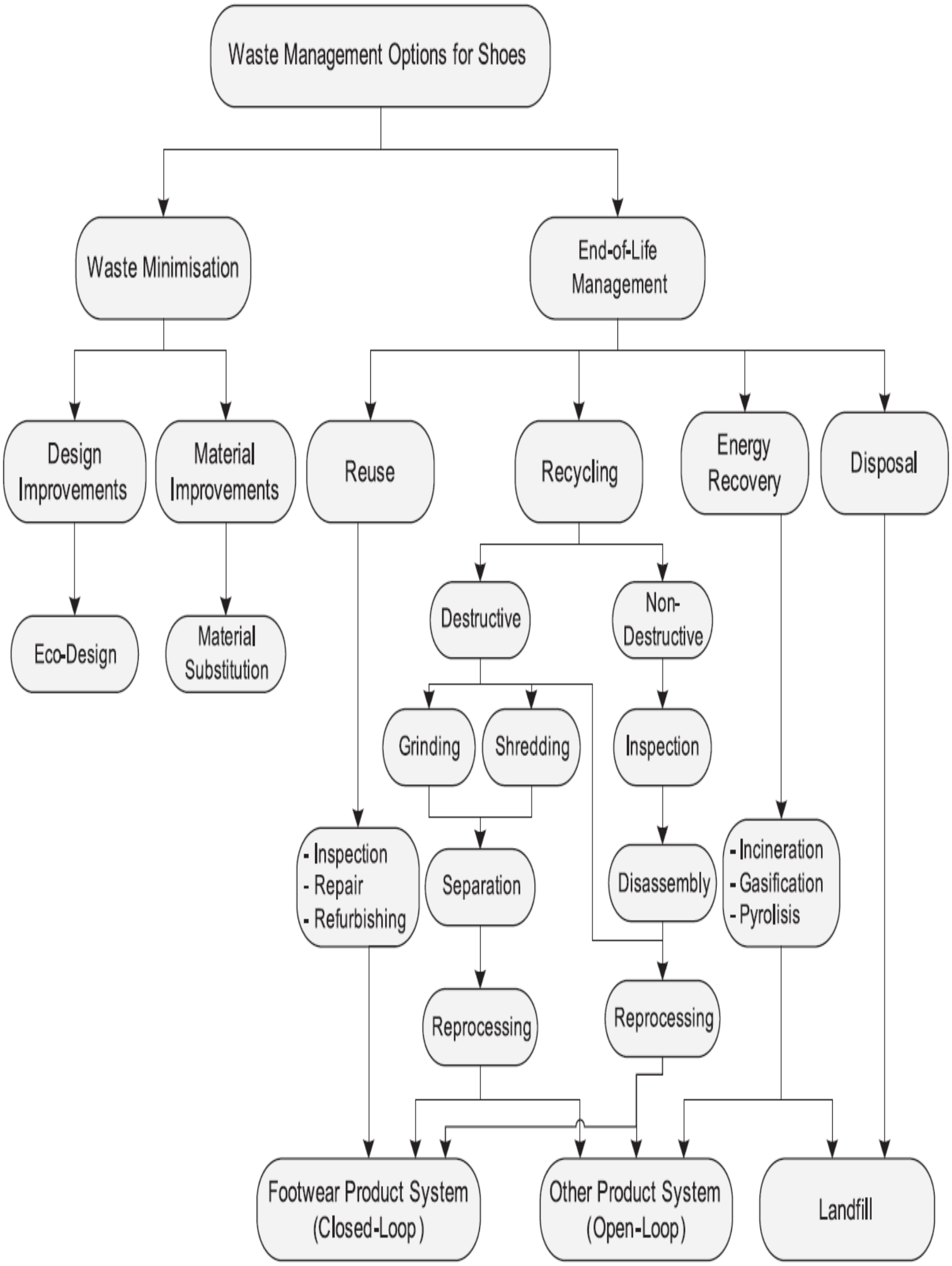


Figure 3.2. Waste Management Framework for Footwear Products
Source: Staikos and Rahimifard, 2006

According to this framework, proactive and reactive approaches are the two main waste management options for footwears. The first approach is a proactive approach. It contains all measures in order to take the goals for reducing or minimizing waste at the source. The meaning of waste reduction can be explained through decreasing of waste. Waste reduction methods can commence at the beginning of the product’s design process and continue throughout all its life cycle processes. In minimizing waste at the source according to the figure above, design improvements and material improvements are the two main methods.

Eco design methods can be used for design improvements. Eco design improvements can have a significant impact on environmental quality and decrease the amount of material required in footwears design (Staikos et. al., 2006). Secondly, material selection is an important step for the proactive approach. For a product to be recyclable, it should be able to regenerate. Also, the environmental characteristics of a footwear can be developed by selecting various materials such as; eco-friendly fabrics, recycled materials, natural materials, and biodegradable materials. These materials can be used in place of traditional materials for developing the environmental characteristics of footwears. For instance, these sustainable materials can be recycled easily (Staikos et. al., 2006). Besides that, the choice of material is affected by the end of life of footwears. Also, the materials selection is very significant because some materials can emit greenhouse gas in footwear production cycle. According to framework, the second approach is a reactive approach. It contains solutions which are waste management options for the post consumer footwear wastes (Staikos et. al., 2006). There will always be wastes which can be seen in all life cycle of a footwears because total waste elimination is not possible. However, a proper end of life management approach is preferred for the environment and people's health with minimal risks. However, this approach is also referred to as “end of life management”. Reuse, recycling, recovery, and disposal are the four major end of life management approaches for the footwear.

Regarding the first approach, reuse which is used with minimal processing can be an applicable process for footwear. The collection system, distribution system, and the conditions are the three significant variables of the footwear reusing (Staikos et. al., 2006). For less-developed countries, reuse of second-hand footwears is one of the old-established techniques for gathering worn and unwanted footwears. Second-hand shoes are collected for less developed countries. However, these second-hand shoes are accumulated in the landfills when they are not used. These nations cannot recycle secondhand footwears because they have insufficient technology and system to recycle. In addition, second-hand footwear is mostly not wearable (Rahimifard et. al., 2007). Thus, post consumer waste problem is likely to continuously occur in less developed countries. The second approach is recycling. Also, recyclability efficiency levels can be increased for the creation of a sustainable system which is for the sustainable cycle and protection of the environment. In addition, recycling helps to protect the natural resources. For a sustainable footwear recycling chain, waste management system needs to be established and used properly. For this reason, the post consumer waste need to be separated in an appropriate way and also disassemble of post consumer waste depending on the importance of the material used, the number of parts to be used, and the production techniques and technologies to be used. However, post consumer sports footwear's material recycling is an important problem caused with most of them including different types of materials such as rubber, textile, leather, and metallic pieces. Staikos and Rahiminfard (2006) defined recycling as a strategy which includes the reprocessing of end-of-life footwear materials, components, and parts not only for the same design cycle (closed loop) but also for the different types of design cycle (open loop). In the recycling process, after a series of recycling processes, the post-consumer footwear waste is reintroduced back into the market for use.

According to footwear waste management framework, destructive and non-destructive methods are the two major methods for recycling processes. Post-consumer footwear can be turned into another beneficial material by using shredding and grinding sub-methods which are used for the destructive phase of the recycling system. In shredding method, firstly, post-consumer footwears are gathered and moved to special areas, and then wastes are shredded for manufacturing materials that are used in secondary applications (Staikos et. al., 2006). Non-destructive sub-methods are the other methods of recycling, which include; inspection, disassembly, and reprocessing. With this method, recycled materials of post consumer footwear can be used for an extensive range of implementations with second materials whose qualities cannot be lost (Staikos et.al., 2006). Other methods for end-of-life management approach include Energy Recovery and Disposal. Firstly, recovery can be defined as shown below;

> Establishing a value recovery chain for post-consumer shoes, once end-of-life footwear wastes are collected, separated, and converted into a form that can be used either by the footwear industry or by other industrial sectors, it must compete with virgin materials both on price and performance (Staikos and Rahimifard, 2007).

Energy recovery can be regarded as another possible waste management system for post-consumer shoes. Post-consumer footwear waste can be used for generating energy such as; heat and electrical energy. Incineration, gasification, and pyrolysis are the three main technologies for the energy recovery (Staikos and Rahimifard, 2007). Incineration can be defined as the controlled combustion of solid waste in converting it into heat, flue gas, ash and fly ash. However, due to environmental issues, it can be harmful for air emissions (www.law.berkeley.edu). Consequently, the second technology is gasification which transforms any carbon-containing material into a combustible gas. This, therefore, can be utilized such as the use of fuel in producing heat and electricity. However, it might be an expensive technology (Staikos and Rahimifard, 2007). According to Milà et al. (1998), the electricity used in different processes will affect the total environmental impact and this depends on the country in question. So generating energy from post-consumer shoe waste will be beneficial also for companies and countries. Secondly, one of the most common waste management selection for post consumer footwears is disposal method. Unfortunately, not all of the post-consumer waste can be prevented or recycled. Therefore, some waste is disposed of in landfills or just thrown away. This waste management method has the highest environmental impact (Staikos and Rahimifard, 2007). Thus, it is a method employed as the last resort. One of the benefits of an integrated waste management is that it helps in creating sustainability awareness. The sustainability criteria are also awaking the interest of the firms. Decreasing of wastes, greenhouse gas emissions, energy and water consumption, and also reduction of raw material usage can be considered as an important sustainability criterias for the environment (Subic, Shabani, Hedayati, and Crossin, 2012). Firms are forced to reduce their impacts for the environment in regards to increasing the awareness of environmental problems. Also, the pressure for decreasing harm to the environment, coming from both consumers and legislation, has the greatest impact because it is a compulsory thing (Galdeano et. al., 2008).

Hence, different companies are presenting initiatives on the improvement of environmental friendly footwears, like Nike, Adidas, and Puma (Birch, 2012). Some of the initiatives companies have begun to use include reducing greenhouse gas emissions, creating sustainable designs, and trying in eliminating waste (Salmi, 2014). For sustainable issues, firms are beginning to pay attention to the environmental impacts of the products they produce (Öç, 2013). For example, Nike's "Trash Talk" sports footwear is an excellent example that is made with sustainable and recycling waste materials. In order to better measure the environmental foot-print of Nike products, Nike Considered Index was improved by the design team of Nike. The index uses a life cycle approach for examining design and production factors consisting of material selection, solvent use, garment treatments, wastes, and innovation issues for their sports footwears. The index is used for creating innovative sports footwears and it provides focus on sustainable design innovation concept. "Trash Talk" shoe was among the first sports performance shoes under the Nike Considered Index (www.northlakecollege.edu). Nike's Steve "trash Talk" footwear was the first performance basketball footwear made from manufacturing waste. The Nike's Trash Talk sports footwear can be seen in the Picture 3.1

Picture 3.1. Trash Talk Shoe
Source: Stonebrook, 2014

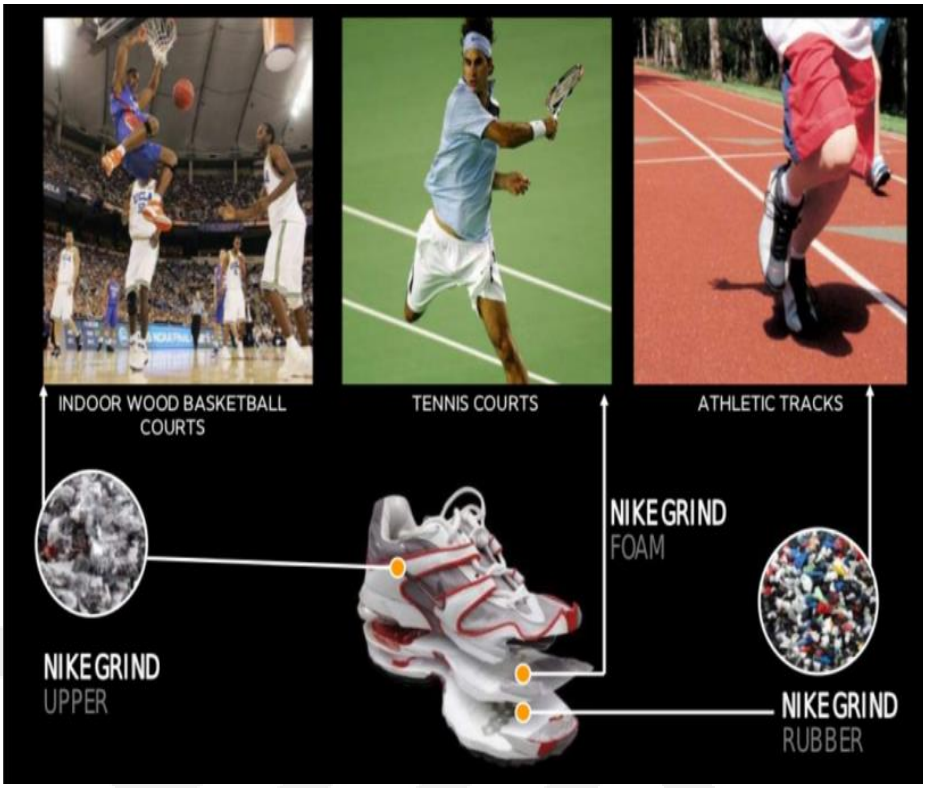
When a finished product's life cycle is over, it could enter into a new cycle that will produce the same or another product. As these wastes get back into the system, the resulting environmental problems will be reduced and the need for new sources and new materials will be reduced. In regard to these issues, the take back method can be given as an example. Take Back program is another innovative method for recycling. Also, several footwear producers have implemented product take-back programs. Producers, distributors, and consumers are required for this method (Toffel, 2003). Also, a competitive advantage, a source of profit, and an increase in a firm’s environmental image can be provided with a take back program (Doppelt, 2001). When companies act sensitive to the environmental impacts, consumers may start moving around sensitively to the environment. For example, European Recycling Company suggested that;

> If consumers were made aware of the positions of footwear recycling banks, this approach may still supply the most appropriate collection method (Rahimifard, Staikos and Coates, 2007).

According to take-back programs for reducing environmental impacts, Puma has "Bring Me Back Program" (about.puma.com). Puma’s CEO, Franz Koch, stated that a closed-loop cycle is created with Puma's take back program (Shea, 2012). Firstly, the post consumer sports footwears are collected from the consumer. After the shredding process, they moved to another composting of beneficial system which is broken down into natural-humus and can be recycled. Thus, it is turned to a new product's raw material or the new material can be reused when they are still in an appropriate condition. According to "take back" programme, the company is helping to keep the nature, purposing to eliminate post consumer footwear pieces for creating new ones. According to “Bring Me Back program”, “Puma has collected approximately 4,000 kg of used goods so far in its stores and outlets worldwide” (about.puma.com). The sample recycling box placed in the Puma shop under the "Bring Me Back" program can be seen in the following example.

Picture 3.2. The Sample of Puma's Recycling Box
Source: www.medium.com

Another example of take back program is recycling project of Converse and Nike. Old sports footwears are turned into a new surface places. The take-back program is called "Reuse a Shoe" which is established by a sports footwear producer, Nike (Rahimifard, et. al., 2007). According to King et al. (2010), there has been an important potential for decreasing negative effects about post consumer footwear by using the "Reuse a Shoe" program. According to "Reuse-A-Shoe" programme, post consumer sports footwears are collected first and then they are shredded for manufacturing a new material which is called "Nike Grind" (Rahimifard et. al., 2007). The grinding and separation are the two main processes of the take back program; and according to Nike Grind, upper parts, rubber outsoles, and foam midsoles of sports footwears are used to prepare grind materials (www.nikegrind.com). Afterwards, Nike Grind Material is created and used for sports surfacing which can be seen in Picture 3.3



Picture 3.3. Reuse a sport footwear; Nike grind sport surfacing
Source: https://www.slideshare.net/StanfordBusiness/nike

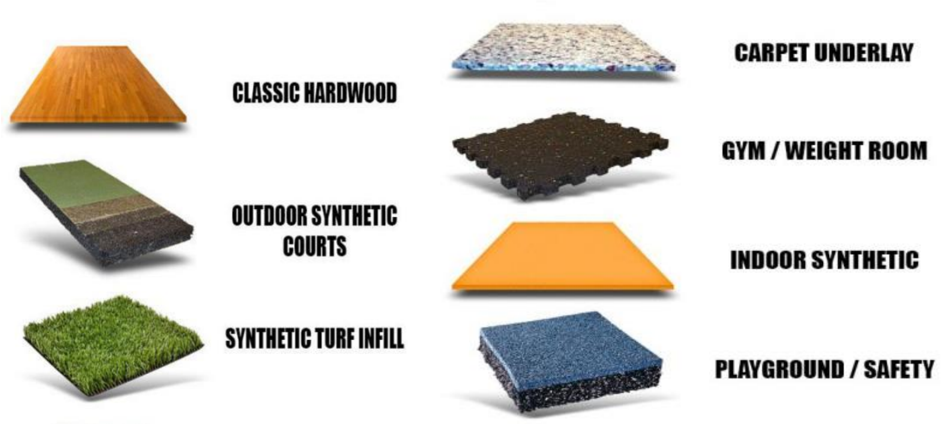
Also, different types of Nike's Grind can be seen below. There are basically three types of grind materials like Nike grind. They are made from footwear's outsole, Nike Grind Foam; made from footwear's midsole; and raw materials are made from recycled athletic footwears.

Picture 3.4. Nike grind; shoe's outsole is used
Source: Nike, Inc. 2008

Picture 3.5. Nike Grind Foam; types of midsoles are used
Source: Nike, Inc. 2008

Picture 3.6. Nike Grind Fiber; types of upper parts are used Source: Nike, Inc. 2008

Nike grind is a raw material made from recycled sports footwear parts, and it also has innovative and sustainable surfaces created from grind materials (www.nikegrind.com). Surface provides a high quality and safe surface for athletic excellence. "Nike grind materials have been incorporated into more than 1 billion square feet of sports surfaces" (www.nikegrind.com/ surface). Nike has helped more than 150 sport surfaces of communities around the world with its grind that is used for surfaces (www.nikegrind .com/ surface).



Picture 3.7. Samples of Usage Areas
Source: https://www.youtube.com/watch?v=Rq5EN3baTKg

Durability and environmental friendly materials are the advantages of the Nike grind materials. Moreover, a closed-loop cycle is created by using these Nike grind program. Nike states that their consumers are becoming more aware of the issues of sustainability and that they need to develop their business in a sustainable direction (Wennberg and Khudyakova, 2015). According to Nike stats, “Since its’ inception in 1993, Reuse-A-Shoe programme has recycled more than 16 million pairs of worn-out and defective sports footwear in total”. An example of Nike’s Reuse-A-Shoe system's collection box can be seen below;

Picture 3.8. Reuse-a-shoe System
Source:http://gottarunnow.blogspot.com.tr/2014/09/recycling-my-running-shoes.html

Another example of a solution to a current reuse and recycling approaches in the footwear sector can be seen in Figure 3.3

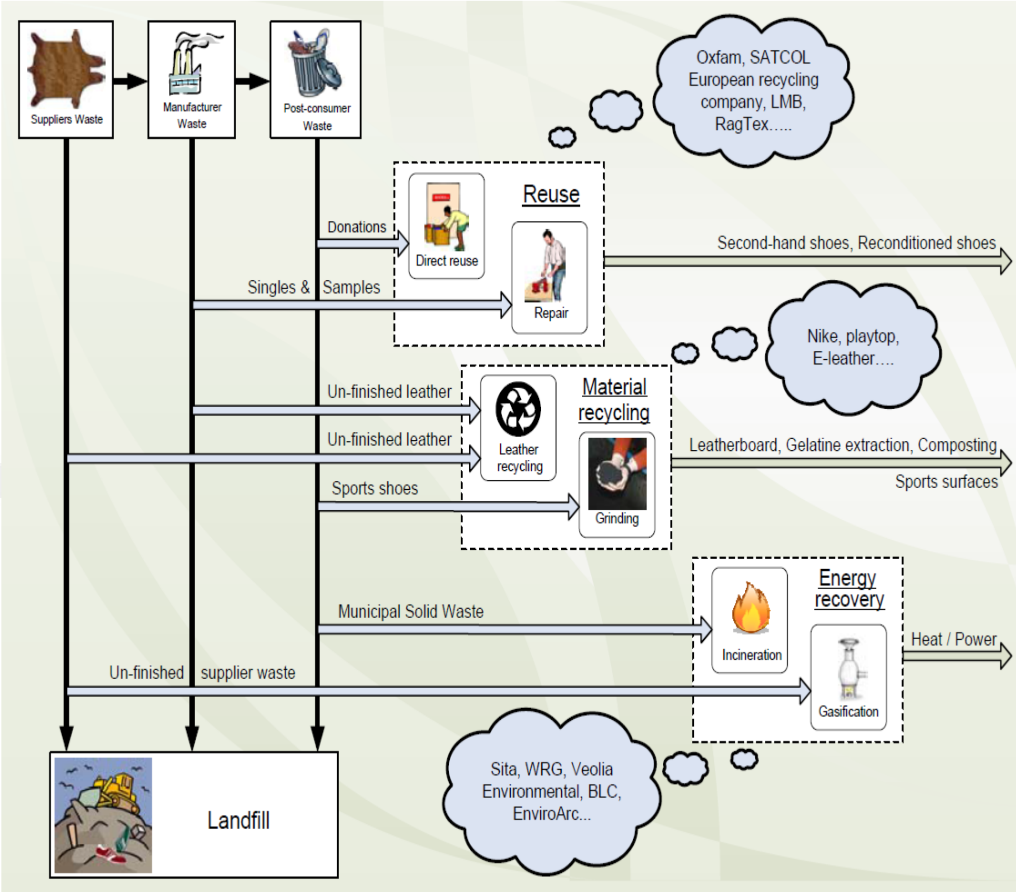


Figure 3.3. Current Recycling Solutions
Source: Staikos and Rahimifard, 2006

> The cost of such an environmentally friendly approach for footwear recycling may be higher than the cost of the present waste management method, but the new waste management system can become competitive in the longer term as new market opportunities (Staikos and Rahimifard, 2006).

Now, new waste management systems are being designed instead of old recycling systems. It was thought that these newly designed systems will be more beneficial than the old ones. The best example of this can be given from Staikos's and Rahiminfard's waste management system. Staikos and Rahiminfard have developed a renewed recycling system which supplies the technical feasibility for recycling the majority of the wastes of post consumer footwears. Hence, the figure below shows an alternative and innovative solution instead of current reuse and recycle approaches in the footwear sector. New recycling system can be seen in Figure 3.4

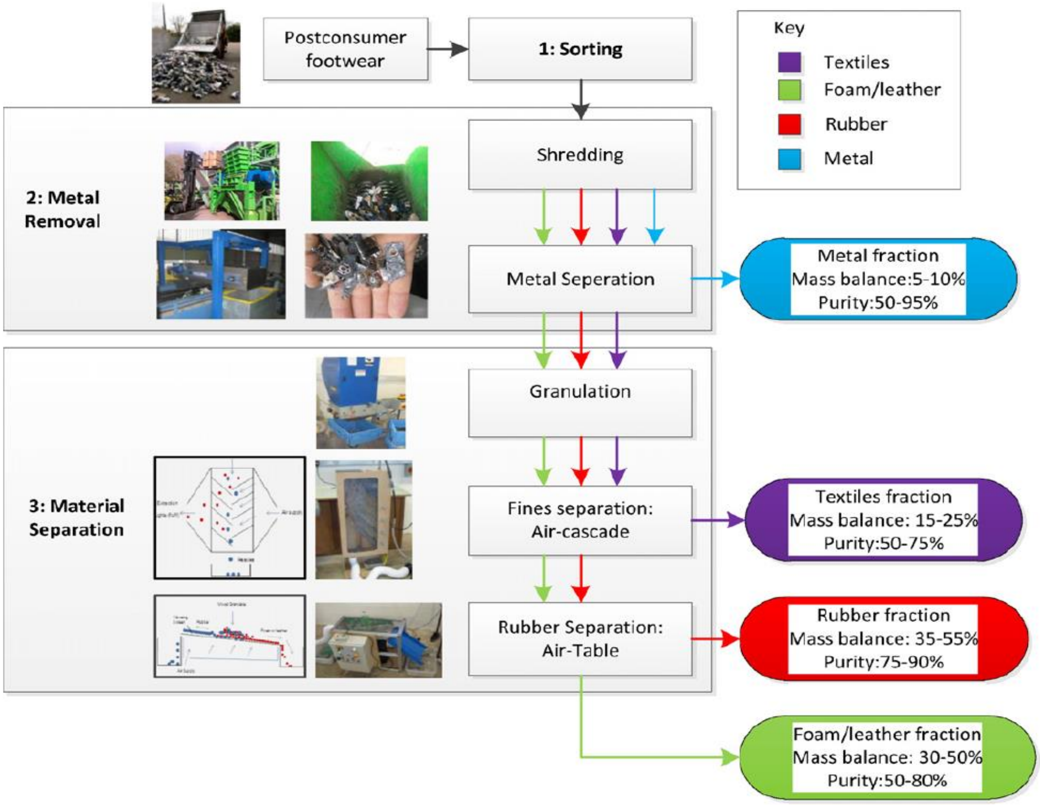
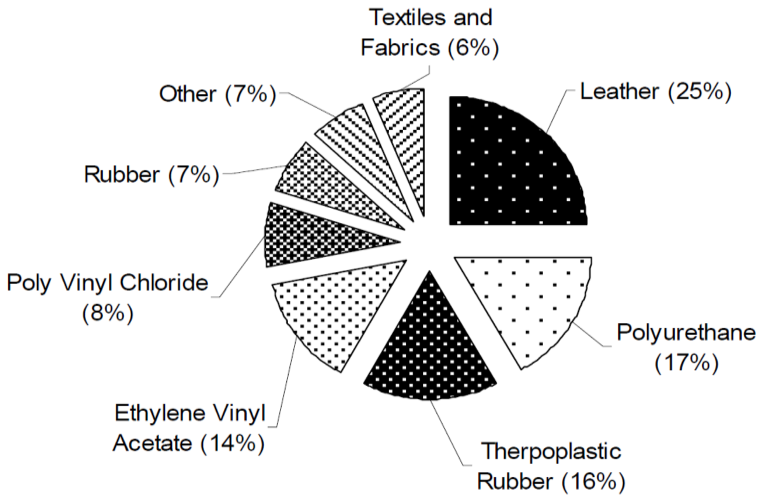


Figure 3.4 Recommended Footwear Recycling Process Flow

Source: Lee and Rahimifard, 2012

Sorting is the first step of this new approach, metal removal is the second step, and material separation is the third step. After using an automated recycling process after the shredding and granulation processes, the second step is separation process for post-consumer footwear pieces according to their densities and weights. For the separation process, separation devices are used which are; air based, liquid-based density, and magnetic eddy separation devices. These separation is based on a new recycling system used based on the materials physical qualities, densities, and weights (Rahimifard Staikos and Coates, 2007). About 40 different materials are used in the production of a sports footwear (Staikos, et. al., 2006). However, these materials differ both in their appearance and their physical qualities, and also in their service life and recycling and recovery options.

Besides, materials features also design and assemble techniques that are affected for their end of life options. Material Composition in Average Shoe which has been measured after grinding can be seen in Graphic 3.1.



Graphic 3.1. Different types of materials percentages after grinding
Source: Rahimifard et al., 2007

Picture 3.9. Grinding materials such as textile, foam and rubber
Source: Staikos and Rahimifard, 2010

An example of Sports footwear materials after grinding can be seen in Picture 3.9. As a result of information mentioned before, the benefits of an integrated waste management and sub-materials are as follows (Rahimifard, Staikos and Coates, 2007):

- Reduce the need for raw materials for preventing pollution, protecting energy, and decreasing greenhouse gas emissions.

- To provide protection for future generations by reducing the amount of waste

- To ensure that products are used throughout their entire life cycle with waste reduction and reuse, and to ensure the protection of public health through the management of safe disposal of potentially hazardous materials.

The unsustainable linear model has been transitioned to sustainable circular model for reducing the environmental impacts of the unsustainable cycle. In sustainable circular model, the new technologies and innovations in material, method, and production technologies have been adopted. Innovative materials have been started to preferred such as biodegradable materials. As a result of the conducted research, this material can be recycled with both organic and mechanical recycling processes and this material can be broken down into natural humus which can be turned to another raw material and also these materials are upcylable. Efficient recycling processes have been increased because the innovative materials which allow the creation of new materials of the same utility. Also, efficient recycling processes is an important subject for conservation of the natural sources and it is understood that, the recyclability of post consumer wastes are depent on the biodegradabilities of materials. Thus, there is no need to implement the incineration process. The biodegradable materials have the ability to compost at the end of life phase therefore, waste accumulation can be eliminated and also waste reduction can be provided in the circular model. Material recovery can be improved. The usage of these materials helps to create closed-loop model. Furthermore, in order to be able to talk about a sustainable system, the life cycle of a product should be closed-loop. In the circular model, the closed-loop model has been preffered instead of an open-loop model.

3.2. Material Innovation for Sustainable Footwear Design

This section includes three important sub-titles; Biodegration, InCycle process, and Boost materials. According to the first topic, terms of biodegrations and bio-based materials have been examined and it has been tried to determine how bio-based materials can affect an unsustainable cycle to produce a sports footwear. After then, why these materials have been preferred instead of conventional materials were analyzed. Also, these issues are discussed in relation to material improvement which is a proactive approach within the context of waste reduction. InCycle process which is the second important sub-title for the chapter three and first within the context of waste reduction, design improvements methods which is a proactive approaches, have been mentioned due to the InCyle process. Second, the role of the InCycle Process has been researched for producing a sustainable sport footwear and sustainable cycle. The last significant sub-title is Boost Materials. In this section, materials advantages related to the boost materials are researched. In addition, examples of these materials and technologies were researched in relation to the footwear designs. Finally, examples of sustainable sports footwears and footwear companies approaches related to applications of new materials and methods have been investigated to determine which factors are the most important for the sustainable production and consumption cycle.

3.2.1. Biodegration

In this section, the concept of biodegration, biodegradable materials, and bioplastics as an innovative materials for the sports footwear sector were researched. The main aim is to learn the effects of biodegradable materials on the unsustainable production and consumption cycle.

Moreover, learning of these definitions provides a better understanding of the subject of Biodegration. **Biodegradable** means can be consumed by microorganisms; compostable makes further specific demand whereby the object breaks down under composting conditions (Alshehrei, 2017). **Biodegration** is a bio-chemical process that refers to the degradation and assimilation of polymers by living microorganisms to produce degradation products (Alshehrei, 2017). **Biodegradability** is the disintegration of materials by bacteria, fungi, or other biological means (IUPAC Recommendations, 2012). **Decompose** is to separate or resolve into constituent parts or elements. **Compostable** is a mixture of various decaying organic substance, such as dead leaves or manure, used for fertilizing the soil. **Disintegration** is the act or process of decaying (www.dictionary.com).

According to environmental footprint, Carbon footprint is the largest environmental impact (55%) for the footwear production. Most especially, sports shoes in general have a heavy carbon footprint which results primarily from pollution, consumption of non-renewable resources, and waste (Subic et. al., 2012). In addition to this, material manufacturing stages are more important than the other life cycle stages of a sports footwear (Gottfridsonn and Zhang, 2015). According to literature review, most of the emissions are released during the footwear material processing (29%) (Cheah et. al., 2012). Also, there are too many environmental problems associated with material selection processes in unsustainable sports footwear production cycle. Therefore, material selection is significant for solving the problems. For this reason, traditional materials have been investigated in determining the environmental impacts through these critical subjects; toxicity, recyclability, disposability, waste, and biodegradability.

According to the raw material phase, the footwear industry employs a wide variety of materials to make a diverse range of different types and styles of footwears (Gottfridsson and Zhang, 2015). Due to the production of materials and dispose of the materials, some toxic substance can be emerged and there is an excessive amount of water consumption to produce these products. In the production phase of traditional materials, environmentally harmful chemical substances were used (Albers et. al., 2008). However, chromium is used for the leather material, and fertilizers and pesticides are used for the cotton materials;

thus these chemicals are highly toxic elements (Rivera Munoz, 2013). Also, toxic solvents and adhesives usage is the part of these problems. In addition, the production of petroleum-based synthetic materials contains toxic matters (Albers et. al., 2008), and these products are non-renewable and the use of petroleum fuels are generated by carbon emission resulting to environmental problems.

The world wide consumption of footwear is estimated at 20 billion pairs of footwears per year which illustrates an excess magnitude of the challenge when dealing with the disposal of footwears (Staikos et. al., 2006). There are some recycling approaches like; Nike grind, SOEX, and SMART's. Nevertheless, there are still traditional recycling systems and technologies that are inefficient and limited. There are not enough solutions for recycling process for post consumer footwear waste. Also, recycling processes are not effective for the disassembling of the mixed footwear products. Thus, less than 5% of end of life footwears are being recycled and, unfortunately, with 95% of post consumer footwear wastes being disposed of in landfill sites around the world (Lee and Rahiminfard, 2012). This situation results due to problem of overwaste. Moreover, these conventional materials cause greenhouse gas production after being thrown into garbage, which means that post consumer footwear waste is becoming a serious problem for the environment and human health (Rivera Munoz, 2013). Also, the conventional materials used in sport footwear resulted in serious environmental pollution of groundwater and rivers when disposed into the landfills. The production and consumption cycle has become unsustainable due to extreme waste problems which cannot be properly disposed of. Therefore, incineration method has been used for waste reduction and can be defined as the controlled combustion of solid waste for the purpose of converting it into heat. Nevertheless, it can be harmful to air emissions (www.law.berkeley.edu), and it still remains controversial due to environmental concerns over polluting emissions. It can be used for footwear post consumer wastes such as; PVC is used for footwear material when this material is burnt; organochlorine substance, which is extremely toxic and harmful in nature, may cause cancer, glues, allergies, disturbing and hormonal balance (Handel, 2012). According to Shahin Rahimifard from Loughborough Universitiy, "the vision of zero waste to landfill thus remains a major challenge for the footwear industry" (Staikos et. al., 2006).

Furthermore, the recyclability of post consumer footwear wastes are dependent on the biodegradability of the used materials. Also, conventional materials used in the sports footwear production remain in nature for a long time without deterioration such as; polyester, plastics, metals, and synthetics. Hence, the conventional materials do not contribute to sustainability. For example, about 320 million tonnes of plastic are produced annually, but, however, plastics remains in the environment for at least 100 years (according to ProBIP, 2009). On the other hand, it could take up to 1000 years for some types of plastics to degrade which take an extremely long time depending on the molecular weight of polymer (Alshehrei, 2017). So, the environmental impacts of sports shoes degradation in landfills are connected to the nature of the materials and when disposed in landfills, sport footwear can take up to thousands of years to decompose back to nature. In the footwear industry, it is understood that why the material selection is very significant to create a sustainable footwear, material selection is effected at the life time of footwears. Together with this, material biodegradation is the most important process for material selection and for producing a sustainable footwear.

Footwear producers are forced to decrease their impact on the environment due to increasing awareness of environmental problems by governments, international agreements, society and various stakeholders, and customers for developing their behaviour towards the environment choices. Afterwards, the producers began to move more environmentalist practices. Firstly, they used to change the conventional materials because of their inefficient features through the sustainability principles. As a result, they have begun to benefit from innovations that are needed to protect the environment and human health, and to get rid of the old problems of traditional materials. In order to make these changes, new solution proposals have been developed. According to awareness of environmental problems which are mentioned before, in regards to environmental ethics, companies, producers, and designers have been finding solutions to the following subjects (Ehren & Hoffman, 2013);

- Reducing the environmental impacts;
- Improving material recovery and recycling processes;
- Designing a sustainable production cycle;
- Producing a sustainable sports footwear and Developing alternative options for end-of-life management (Doppelt, 2001).

Primarily, producers have started to manufacture innovative sustainable materials instead of using the conventional materials in order to reduce the negative impacts of the conventional materials. Through this way, they can reduce their post consumer footwear waste, provide efficient recycling processes, and develop environmental properties of footwears. As a result of this, the consumption of water, energy, and toxic materials usage can be prevented. Then, if bio-based materials are used instead of conventional materials such as the most used synthetics which is petroleum based, waste problem can be reduced and the properties of sports footwears can be developed. Therefore, greenhouse gas emission can be reduced because, since biodegradable materials are made up of renewable materials, there are no obligations to use materials produced from petroleum-based materials.

In order to improve efficient recycling processes, closed-loop cycles instead of open-loop cycles were started. Moreover, the closed-loop cycle is provided to change the traditional linear model for creating a new sustainable circular model because circular model is more sustainable than the traditional linear model (Payne, 2015). In the circular economy, the circular supply chain introduces fully renewable, recyclable, and biodegradable materials. In addition, with the circular model, a closed-loop production cycle was used and innovative consumer approaches was also used. This approach includes *"bring back or take back"* approaches for closing the loop. Also, end users play a key role for the circular model because they can determine the end of life, as the period between purchase and return after use, and then they can close the loop. Nowadays, consumers have already become increasingly concerned with the environmental impacts of their consumption habits, and have increasingly demanded environmentally friendly products in a socially responsible way (Jahnke, 2000). For this reason, the shoe industry is becoming a zero-waste sector compared to the past. Thus, it is because it can produce sustainable solutions in the concept of circular models.

> Zero Waste is a goal that is ethical, economical, efficient and visionary, to guide people in changing their lifestyles and practices to emulate sustainable cycles, where all discarded materials are designed to become resources for others to use (Zero Waste International Alliance : ZWIA).

The vision of 'Zero Waste to Landfill' remains one of the major challenges of the 21st century in the footwear sector. This vision presents a very ambitious target as currently less than 5% of the 19 billion pairs of shoes produced worldwide every year is recycled or reused (Staikos et. al., 2006). However;

> It would have an effect on what materials and chemicals to use. It would be the solution to the mountains of waste because the products would never have to be discarded to the landfills anymore" (Fletcher, 2008, 108).

The advantages of zero waste concept are mentioned below;

- Design and manage products and processes for eliminating the toxicity of waste.
- Try to decrease waste; no waste is sent to the landfill or incinerator.
- Conserve and recover all resources, create sustainable cycle.

- Interest on all cycle and focus on supply chain and encourage the redesign of resources life cycles so that all products can be reused.

- Use low energy content materials and non-hazardous materials and use more renewable energy.

Today, bioplastics have been used as a biodegradable material in the footwear sector. The environmental features of footwear can be developed by the use of these bio-based materials. In this part, types of biodegradable materials, advantageous of biodegradable materials, and **Bioplastics** that is used in the footwear sector have been mentioned for the purpose of understanding the biodegradation issues in details;

- ***Types of Biodegradable Materials;*** There are several types of biodegradable materials that are being used by the footwear industry. These materials, firstly, include Natural Biodegradable Materials such as leather, natural rubber etc. Secondly, Biodegradable Polymers made from starchy crops such as maize and potatoes, developed as a "green" alternative to conventional petrochemical-based polymers such as Hybrids, for instance incorporating bio-polymer fibres (Staikos et. al., 2007). In addition, biodegradable materials can substitute conventional materials in order to improve the environmental properties of shoes. The two most important features that distinguish biodegradable materials from conventional petrochemical materials are their potential biodegradability or compostability at the EoL phase and the use of renewable resources in their manufacture (Staikos and Rahimifard, 2006).

- ***Biodegradable Materials Advantages;*** The choice of materials makes a big difference in building green, and the materials selection are very important with additional advantages. Today, biomass usability and functionality are the reasons for selecting bioplastic implementations

Biodegradation is the most important process for manufacturing a sustainable design and cycle. As a result, their potential biodegradability is very beneficial. This is because when these materials are used, post consumer shoe wastes are not accumulated related to this. In addition, environment problems can be decreased so that there is no need to use the incineration processes. Thus, this is based on the fact that there will be no excess waste and emissions can be prevented. The compostability at the end of life phase is the second important features of biodegradable materials. These materials are 100% compostable. Therefore, it can help to replace conventional materials with the ability to decompose at the end of life phase. Also, since the recyclability of traditional materials is inefficient, these materials can effectively change the recycling process and increase recyclability efficiency. These materials are easily recycled at the end of their life cycle such that they can be used again and again. In this way, raw material usage can be decreased. Renewability features is the third significant features of these materials. Emissions can be reduced compared to conventional materials through the production and end of life phase. And also, these materials are regenerative, reusable, and have low impact such as; bioplastics are non-toxic and it cannot pollute the environment. These materials are lightweight and they have high strength. Besides the fact that the materials was effectively implemented, the modules of elasticity and tensile strength increases by increasing the fibre content in composites through lightness, durability, and flexibility. Also, Biodegradable materials can be used for energy recovery and can increase the efficiency of resources through a closed resource cycle. The most important features is that the materials can be upcycled at the end of life phase (www.europen.bioplastics.org). Today, for the sustainable footwear designs, alternative materials are being used and the footwear sector has placed significant effort in improving material efficiency.

- ***Biodegradable Plastics/Bio-plastics*;**There are different types of bioplastics. So the materials properties are different according to their strengths, weaknesses and biodegradability, and also not all bioplastics are environment friendly. Most especially, common plastics are also called petrobased polymers which are made of petroleum. These petrobased plastics need more fossil fuels and it produces more greenhouse gases than the production of bioplastics (biobased polymers). These plastics remain solid for hundreds of years because Common Plastic biodegrades very slowly e.g. PVC. Conventional plastics such as PE, PET or PVC can be mechanically recycled in *existing recycling streams.* Bioplastics are the subject of numerous studies and have been increasingly present in the world today. Their applications are rapidly growing in all fields of human activities. As a material, bioplastics can be used for textile products and footwears. Bioplastics consists of three main groups; (non)Biodegradable, Biobased, and Fossil-based.

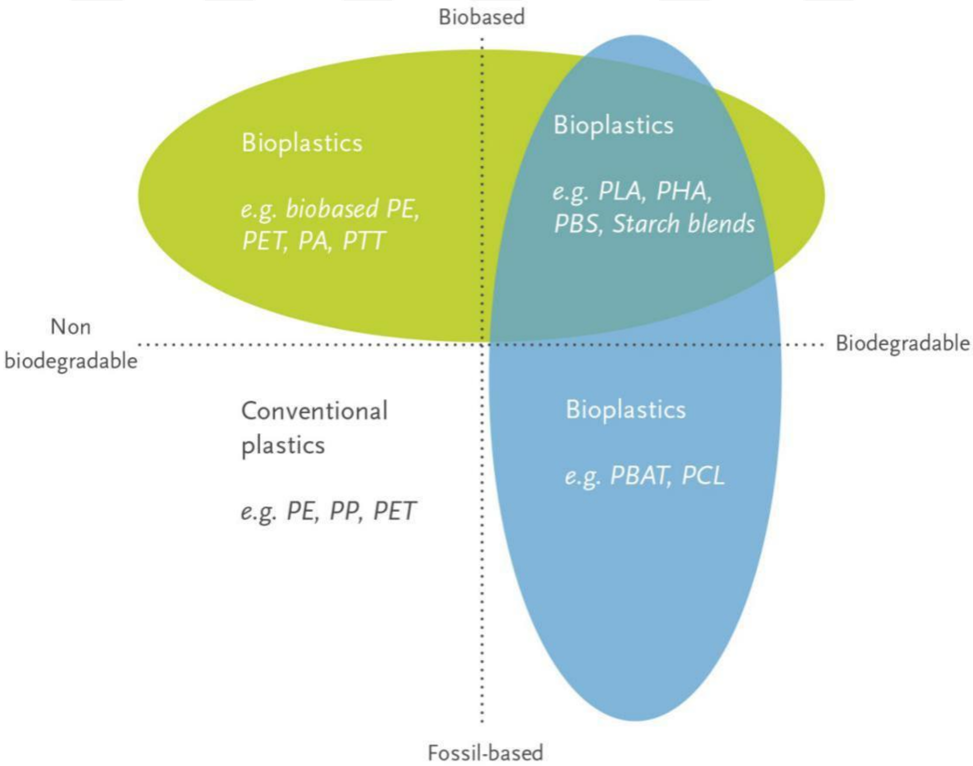


Figure: 3.5. Types of Bioplastics
Source: http://www.european-bioplastics.org/bioplastics/materials/

In the sports footwear sector before now, conventional plastics are generally used. They are both fossil-based and non-bioderadable. However, Bioplastics is being used as an innovative material for sustainable sports footwears. Also, bioplastics are both bio-based and biodegradable materials as can be seen in the figure above. “Bioplastics are made of renewable biomass sources such as vegetable fats or oils, corn, sugar derivatives such as starch, cellulose, and lactic acid” (Chua et. al., 1999). Nowadays, bioplastics are preferred to be used in the footwear sector because they are more biodegrade than traditional plastics and they have an important emission saving compared to traditional plastics (www.europen.bioplastics.org). Moreover, the approximate time taken for compounds to biodegrade in the environment is an important issue because only biodegradable materials do not show that the product is sustainable since all the materials are degrading in nature. Thus, it is important to be able to choose a time that is shorter than the disintegration time of these materials.

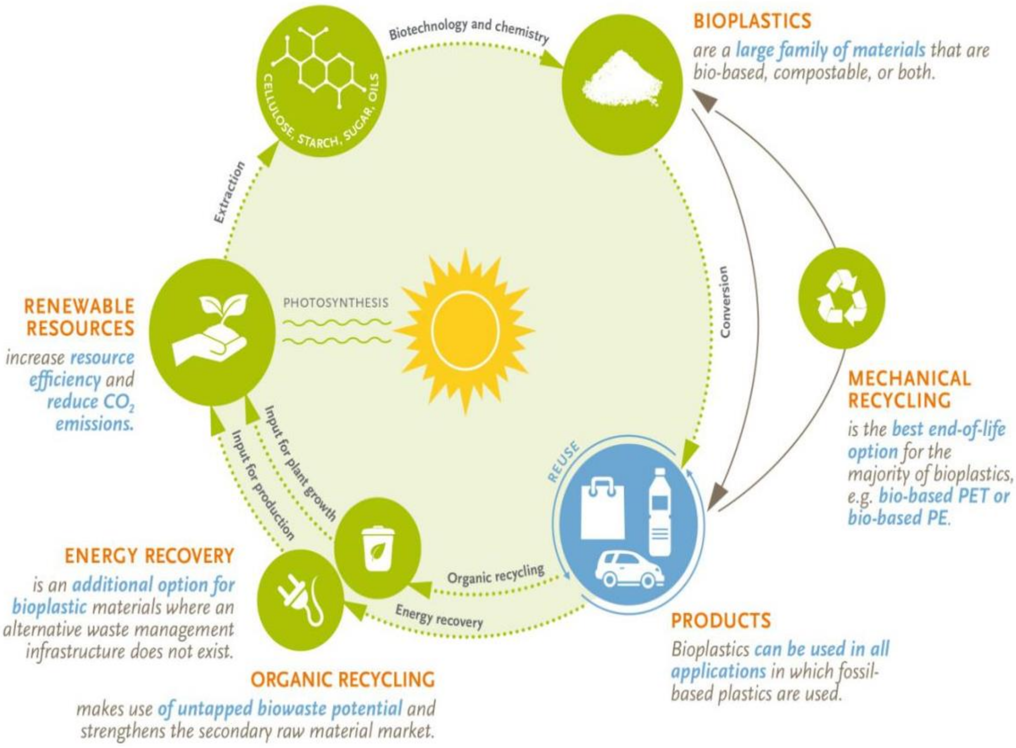


Figure:3.6. The process of Biodegradability
Source: Europen Bioplastics

Biodegradable technology is connected with the manufacturing science of biodegradable materials. It imposes a science-based mechanism of plant genetics into contemporary industrial processes. Scientists and manufacturing corporations can help impact climate change by developing a use of plant genetics that would mimic some technologies. By looking into plants of such a biodegradable materials harvested through photosynthesis, waste and toxins can be minimized (Alsherei, 2017).

In order to talk about a sustainable system, the life cycle of a product should be closed-loop. Closed-loop supply chain is definitely a more sustainable model than the previously used conventional supply chain (Payne, 2015). Also, in order to talk about a sustainable product material, method and technological innovations should be developed. Problems can be solved and improved with innovations so that a transition to a closed-loop system is possible. Also closed-loop systems are more sustainable to open-loop model. Besides this, the innovative materials can be a part of the closed-loop model (Payne, 2015). This closed-loop model provides the resource efficiency. Before, in the linear model, downcycling processes is used, but now, in closed-loop model, upcycling processes have been implemented according to the development in the recycling processes through innovative materials. Moreover, in this process, the quality of the resulting material is higher than the open-loop model.

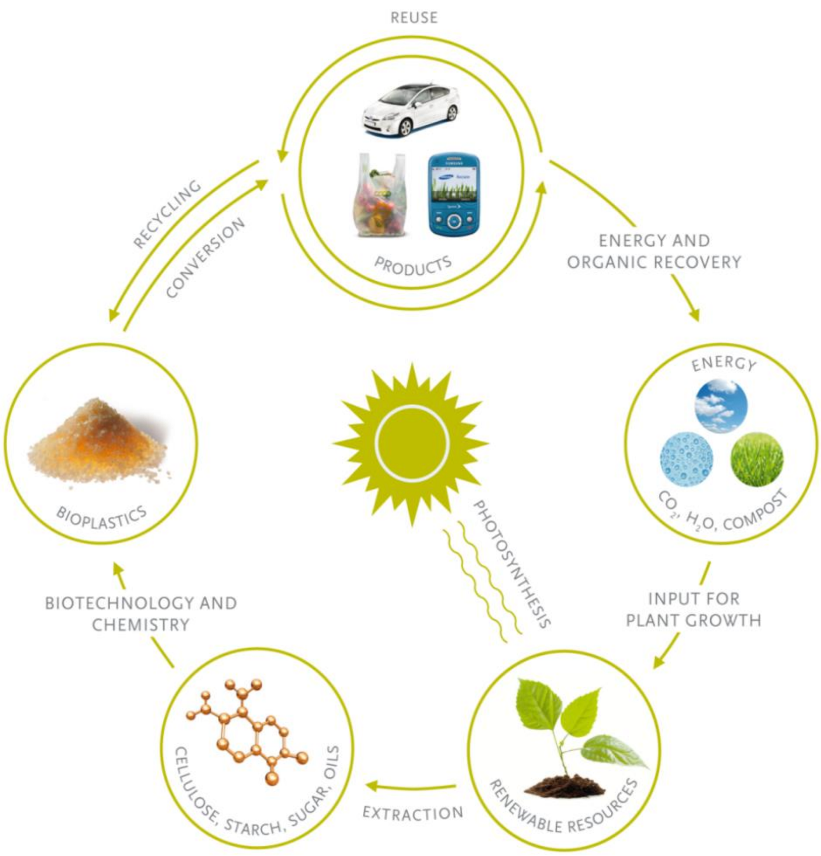


Figure:3.7. Life cycle model of bioplastics
Source: http://www.european-bioplastics.org/bioplastics/environmenterials

Biodegradable waste materials can also be treated using conventional methods, such as incineration and landfilling. Incineration may be a solution in the case of no available biological treatment. As with conventional plastics, the manner in which bioplastics waste is actually recovered depends on the type of product and bioplastics material used, the inherent quantities, and the recovery systems available. However, it is suitable for mechanical organic recycling and non-toxic.

According to Herva, Alverez and Roca (2001), companies should focus on making their products more sustainable. Examples of sustainable initiatives are investigated in details below;

> Sustainability initiatives was defined by Allen et al. (2012, p. 211) as: how companies enact their sustainability goals through their operations and practices "bring back".” Initiatives might include tracking and/or

reducing greenhouse gas emissions, designing sustainable products, or seeking to eliminate waste.

Picture: 3.10. OAT Sports Footwear
Source: http://www.jardinsflorian.com/products/oat-shoe-sneaker/ Leigh, 2014

The company called OAT has manufactured 100 percent biodegradable footwear since 2011 and OAT footwear was designed by Christian Mats. The footwear is fully biodegradable and Bio-Plastic is the main innovative material for the product also. Organic hemp, cork insole, and organic cotton flax are used as alternative natural materials for the sustainable footwear design (OAT Shoes, 2015). From a sustainable point of view, OAT footwears, firstly, have non-toxic materials and sustainable materials are selected for the eco-friendly footwear. Secondly for an OAT shoe, once buried, it takes them only a couple of months to degrade and for the plastic parts approximately 6 months (OAT Shoes, 2015). Production of OAT shoes has 33 percent less negative environmental impact and 25 percent less CO2 emission compared with similar canvas shoes made of cotton (Leigh, 2014). Not only can these shoes be buried in the ground after their useful life, but they turn into blooming flowers (OAT Shoes, 2015). In addition, OAT's ideology also includes local production. The footwear is made in Europe and sold in Europe (OAT Shoes, 2015). When consumers footwears wears out, they can be thrown into their garden. There, old footwear is broken down fully and they sprout flowers because there is a tiny seed packet sewn into each sneaker.

Another important example is Brooks sport footwears. Brooks engineered the biomigo midsole which is a smart material that degrades quickly. The midsole degrade into a non-toxic substance, and it can be used as nutrients for plants and animals. The midsole are made from unaltered petroleum products which can take up to a thousand years to degrade in a landfilly. By comparisons, a midsole made by biomigo midsole takes about 20 years to biodegrade which, therefore, is 50 times faster. Lots of microorganism, oxygen, and moisture are the ideal conditions for the biodegradable midsoles of the design. Biomigo is a faster degradation means and it produces much less waste that means smaller landfills. It also adds up to a more sustainable way of making midsoles that leaves a smaller well footprint on the planet. Brook is sharing the technology with other running shoe makers. By this way, they can all help in making a difference.

Picture:3.11. Green silence Sport footwear-running
Source: www. greenbiz.com

With traditional design method, it is designed in one-piece upper which have recycled materials. Thus, it uses water-based adhesive and green rubber for the midsole. Brooks introduced the biodegradable Biomogo midsole. Overall, 75 percent of its components are made with post-consumer recycled content and 3 percent contain post-industrial content, such as multiple pieces of the upper, laces, heel counters, and rubber outsoles. By weight, 52 percent of materials are post-consumer recycled and 7 percent are post-industrial recycled - yielding 60 percent of the total recycled content (Schweisguth, 2010). Biodegradable components include the BioMoGo midsole, insole and collar foams, and 30% more cushioning than standard midsole materials like gel or EVA (Schweisguth, 2010). Brooks was designed to possibly serve as a green issue. They wanted to have as little wastes as possible, and they are also grounded in frameworks such as Cradle-to-Cradle, Green Chemistry, and Design for Environment. From a sustainable point of view, the environmentally friendly footwear is composed of over 75% post consumer recycled shoe materials, with extensive cushioning, recycled rubber outsole, 100% post consumer shoe laces, and waterbased adhesive. The shoe has a slim eco-footprint, with half the pieces. Brooks reduced volatile organic compounds (VOCs) by 65 percent, and it uses low- and non-VOC materials and inks, and water-based adhesives. The sole is HPRGreen. However, it can be found in similar styles, improved durability, and extensive use of recycled and biodegradable materials. Brooks saved the equivalent of half a liter of oil and 41 percent of the energy used to make each pair

Picture: 3.12. The California Green Sneakers
Source: http://www.psfk.com/2012/06/gucci-eco-friendly-shoes.html

The Italian company “Gucci” developed special environmentally friendly men’s and women’s shoes both made from bioplastics, a biodegradable material sourced from compost. Natural biodegradable materials, such as leather and natural rubber, and biodegradable polymers made from starchy crops, such as maize and potatoes, was developed as a “green” alternative to conventional petrochemical-based polymers. Hybrids, for instance, incorporates biopolymer fibres. The men’s California Green sneakers - in a low or high top version - combine the bio-rubber soles with the upper part in genuine vegetable tanned black calfskin, biologically certified strings, and rhodium-plated metal details. Additionally, the green Gucci logo has been designed on a recycled polyester label. This new projects has a mission to interpret, in a responsible way, the modern consumer’s desire for sustainable fashion products. All the while, it focuses on maintaining the balance between the timeless values of style and utmost quality with an ever-growing green vision. This is the reason same improvements are not seen as widely and seriously, for example, among luxury brands and other lifestyle brands. Perhaps, it is because the other brands want to keep silent about these issues or they have not yet taken the steps towards changes that much. The reason might be attributed to the fact that the supplier factories of sports brands make more new material innovations and have possibility for that. The pressure might come as well from the hard competition in sports lifestyle area, especially when it comes to designing new kind of materials. Perhaps also, the sports customers are demanding and have awareness for good material qualities. As a result, the brands have to make new innovations all the time. The luxury brands have an important role because they lead the way for other brands for the consumers around the world. A lot of people are following their actions. The challenge is big for the textile companies and the suppliers to shift into new ways. Nevertheless, it is not impossible for biodegradable.

3.2.2. InCycle Process

In this section, features of the InCycle Process and the importance of the innovative materials used in the InCyle Process have been investigated. In addition, the differences between conventional recycling processes and InCycle Processes have been compared. Finally, examples of sports footwear have been examined in terms of sustainable variables such as; energy, water, raw material, emission and also, recyclability, compostability, and renewability.

Today, the sports footwear industry is unsustainable. As a result of unsustainable production, consumption and insufficient recycling processes, wastes have adversely affected the environment. Therefore, the industry needs to convert their business in a sustainable direction and follow the need technologies, methods, and innovations. According to increase in environmental problems, producers have begun to produce their products with sustainable principles. Bigger companies, designer or brand owners adopt alternative solutions for their sports footwear designs. For examples, Puma have developed an alternative system that can solve the increasing environmental problems for their sports footwears. Puma is a global sportswear company that has taken great steps in environmental and social aspects and has taken remarkable responsibility on their visions related to sustainability. According to Franz Koch, the former CEO of the company;

> The aim of the brand is to be the most desirable and sustainable sports lifestyle company in the world"; and "they thrive to look at things through different lens and want to break the convention using innovation and creativity (PUMA, 2013).

Additionally, they claim to reduce their waste through biodegradable and recyclable products (PUMA Business and Sustainability report, 2012). For example, they changed petroleum based materials with renewable bio-based materials based on the ability to compost at the end of the life phase. Since the sport shoe industry has many environmental impacts, the company is beginning to innovate for sports shoes. Moreover, the reason this company wants to develop a new system is explained in details below;

- To Provide Waste Reduction; waste is produced at every stage of production, consumption, and end of life phase. In addition, only 5% of wastes can be recycled because there are a lot of inefficient recycling processes and disassembly problems of sports footwears. Therefore, a waste accumulation can be a major problem, contributing to 95% of the post consumer footwear waste which is accumulated in the landfills; as a result, the company aims to provide waste reduction (Lee and Rahiminfard, 2012).

- To produce a sustainable circular model instead of conventionel linear model, the choice of materials, the development of the circular model, and the reduction of waste are the most important issues required to develop a sustainable production and consumption cycle for sports shoes.

- To produce a sustainable sports footwear.

- Try to get rid of negative environmental problems of the unsustainable system in footwear sector.

- Decreased raw materials, increased health problems and increased responsible consumer.

In addition to the environmental problems mentioned above, Puma noticed that their environmental impacts was 57% related to conventional materials such as leather, cotton, rubber, etc. The brand turned in making use of "clever raw materials" such as biobased materials, recycled and organic materials (www.ecouterre.com). The bioplastic material was created using the science of chemistry which is being used in the company's products in 2013. They started using this material in their sports shoes in the InCycle Collection. By using this material, a new sustainable sport footwear, a sustainable production and consumption cycle, and a new end of life approaches have been developed by the company. Also, a new business model which is a circular model is preferred instead of a linear model. According to Lorenzo Brunetti who is the Vice President-Marketing & Sales Director;

> In this way, they will foster the development of bio-sustainable production lines contributing to the creation of a culture of intelligent recycling and the use of biodegradable products which, at the end of their life, will be recycled using methods which are fully in harmony with the delicate mechanisms of nature (Brunetti, 2013).

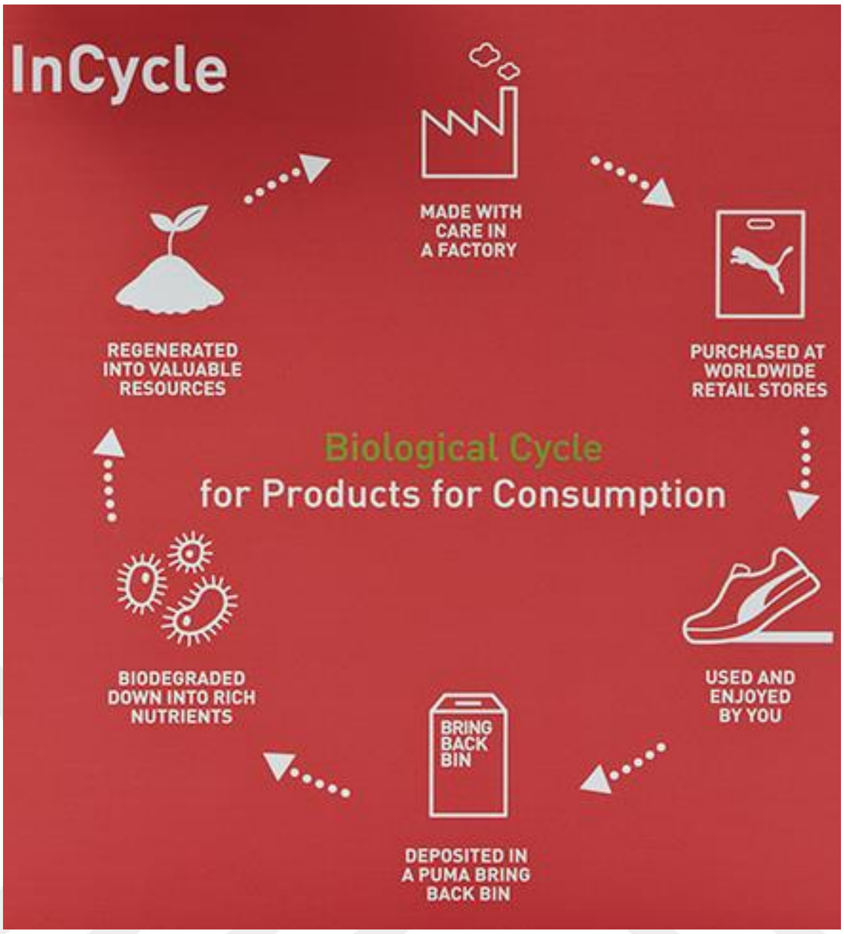


Figure:3.8. Biological Cycle/InCycle Process
Source:https://technabob.com/blog/2013/02/24/pumabiodegradableapparel/#ixzz3CHW1WX3H&

An alternative recycling process, which is named InCycle Process, has been developed by Puma by taking into consideration the negative environmental effects of conventional materials and the ineffective recycling processes. “Take back system is evaluated for consumer to return the old footwears back to reprocess when they reach the end of their lifecycle”. According to new InCycle Process. The post consumer footwear wastes or garbage can be returned under the company's "bring me back" program at the end of their life cycle. Therefore, the company is educating and encouraging consumers to return items for recycling. When collected through puma's "bring me back", the footwear will be shredded and transported to an industrial composting facility system, where its materials will be broken down into natural humus (www.ecouterre.com). At the same time, an innovative material recovery solution can be created for sports footwear recycling and, also, the product can be easily be separated. For this innovative recycling process, an innovative incycle material was used instead of using conventional materials.

In addition, innovative materials selection is very important to reduce the negative environmental impacts of the conventional materials (Puma Training Annual report, 2015). This is because production and disposal processes of conventional materials are very harmful to the environments. Thus, for conventional material production, various chemicals, toxic materials, and hazardous materials are used such as; chromium for leather, fertilizers and pesticides for cotton, in which they cause damages to nature and people both during the production phase and after consumption. Furthermore, increased water usage is an important problem of the production of conventional raw materials and dyeing processes. Also, synthetics are petroleum-based materials. During the disposal of these petroleum-based materials, green house gas emissions that are harmful to nature and harmful to the health of the living organism emerged.

Biodegradation is a significant subject for the material to be selected. This is because the recyclability of post consumer footwear wastes is dependent on the biodegradability of used materials. Also, conventional materials remain in the nature for a long time. Besides, material selection is effected in the life of footwears such as; in the production process, consumption process, and the end of life of footwears. Furthermore, the materials in the supply chain should be beneficial to the environment and to people.

Puma, therefore, play a key role in taking greater responsibility for the management of materials throughout their supply chains and across the product life cycles to ensure the greening of overall production process. According to recyclable and biodegradable collection, Puma improve environmental properties of sports foowear for their InCycle Concept. For this, innovative material and sustainable processes have been used. Puma introduced the concept that deals with material health assessment, which is the new process to upcycle the material (Capon and Go, 2012).

> The goal of the upcycle is a delightfully diverse, safe, healthy, and just world with clean air, water, soil and power-economically, equitably, ecologically, and elegantly enjoyed (McDonough & Braungart 2013).

Although downcycling, where materials of lower quality than the originals are obtained, is the most developed type of recycling in these industries, it focuses on upcycling which allows the creation of new materials of the same quality. The sports footwear produced with the Incycle concept are more sustainable than before because production and consumption processes and end of life phases are more sustainable than before.

> It needs attitude to concentrate not only on the present life of the product, but also on the facts of what happens after its first life cycle (Kupsala, 2013).

In the sustainable sports footwear design, innovative materials have been used and the footwear which is recycled back through technical process was composted as a biological nutrient (Seidel, 2013). These figures demonstres the degradation prcosesses of the bioplastic material in the below;

Picture:3.13. Compost at the end then Back to nature
Source: http://www.apinatbio.com

According to the features of sustainable footwear, organic cotton, linen, apinant-bio, organic cotton, and recycled polyester are selected as a raw material (www.ecouterre.com). It can be shredded into its component materials before being composted into natural humus. The sneakers are biodegradable when processed by modern composting facilities. However, it is designed to be returned to the industry for perpetual recyclability through Puma's "bring me back" program. Basket is a sports footwear which is an example of the first sport shoe in PUMA's closed-loop.

Picture: 3.14. Biodegradable InCycle collection, Basket Sneaker
Source: (left); http://newatlas.com/puma-incycle-recyclable-biodegradable/26273/

Also, the environmental impacts of sports footwears degradation in landfills are extricably connected to the nature of the materials and conventional materials used in the sports footwear when disposed in landfills. Sport footwear can take up to thousands of years to naturally degrade. However, in practice, the material is made up of renewable raw materials which is *Apinant-Bio* and it degrades by at least 90% within 6 months if placed in a compost (creativesustainabilitymarketing.wordpress.com).

Picture: 3.15. Biodegradable InCycle Collection
Source:https://gabistudios.files.wordpress.com/2013/08/2013-08-05-13-08-15-copy.jpg

Brands are becoming increasingly more interested in encouraging their suppliers to reduce the carbon intensity of production and consequently the impacts of manufacturing on climate change. PUMA, for example, has a goal of reducing the carbon intensity of its suppliers by 25% through the PUMA SAVE project (Footwear, Apparel and Accessories industry sustainability guideline volume: 1 energy). As a result of measuring their environmental impact in its annual report, the company noted that the incycle line had 31% lower environmental cost than conventional products. The report also noted the footwears trade at 12% higher retail prices. Also, the result shows that the incycle footwear impact to the environment is 31% which is less than the standart products. In addition, puma calculates that waste created during production and at the end of life for its conventional suede sneakers is almost 2/3 lower.

As an innovative biodegradable and recyclable material, Apinant-Bio is produced by the producer. APINAT, which is an environmentally friendly Italian Brand, is offering a variety of recyclable and biodegradable thermoplastic compound such as *Apinant-Bio*. Also, the brand, in collaboration with Puma and the company, introduces *Apinant-Bio* as an innovative raw material for their Basket Sneakers in InCycle Process. These materials have been involved in incycle process for the innovation of high performance biodegradables (www.apiplastic.com). It was the same bioplastic that Stella Mccartney used for the soles of her fall/winter 2012 footwear collection, apinant bio. Therefore, Apinant-Bio's features are listed below;

- The material is of high quality, low energy content, and it is non-hazardous; it does not contain any harmful chemicals.

- Biodegradable or potential biodegradability; it refer to remains in the nature at the end of life (EoL) phase. For the sustainable sports footwear, biodegradability for new material is 6 months with water and minerals. This is the implications of using biodegradable materials as a means of reducing the amount of end of life waste in the footwear industry. All components of the incycle line are biodegradable.

- Recyclability; the material is suitable for mechanical and technical organic recycling (Seidel, 2013). It can be broken down by microorganisms into biological nutrients. It is very important to include recyclable materials in the cycle to reduce post consumer waste.

- Regenerative, renewable and reusable; the materials are therefore upcycled materials which can be reused continuously without poor quality (Kupsala, 2013).

- The material is flexible, durable, printable, and is heat resistant, ease of operations and low cost.

- Easy to disintegrate in nature; compostable or potential compostability at the end of life phase in their manufacture (Staikos and Rahimifard, 2006).

These materials offer long term solutions to landfill pollutions. As a result, the company aims to decrease raw material, natural resource usage, and harmful chemicals usage of energy (Wennberg and Khudyakova, 2015). Also, decreasing emissions and pollutions also provides the use of efficient renewable energy such as solar, wind, and hydropower which are quality energy sources of fossil fuels and other non-renewable sources - renewable energy use.

Additionally, brand provided waste reduction. They minimize their own and consumers footprints by producing innovative sustainable products. Company reduced the accumulation of post consumer footwear waste which, therefore, leads to the prevention of problems according to the accumulation of waste in landfills. A sustainable product and circular model for their sports footwear was developed. Therefore, an efficient recycling process can be improved. These issues lead to the creation of a circular model and closed-loop cycle. The reuse of the product needs to be considered. Also, the designing phase of the product needs to be the starting point. The ingredients in the supply chain and manufacturing should be beneficial to the environment and people. Then they can be reused and reused over and over again without poor quality. This can be done by using appropriate materials, methods, and technologies with a minimal environmental footprint and design for longevity rather than obsolescence. According to Justin DeKoszmovszky, PumaVision Global Strategy and Program Manager innovation design experts created the industry's first biodegradable and recyclable collection at PUMA using the product certification process to realize their ambitious goals (www.csrwire.com). To talk about a sustainable system, the life cycle of a product should be closed-loop. Therefore, it is the first collection from Puma which comprises of a CLOSED-LOOP set of products, and Puma is now using the materials to manufacture its own product line (Kupsala, 2013). Puma aims at encouraging the recycling and reusability of sports footwears among consumers by providing a convenient and simple process.

The InCycle Process is used at Puma for encouraging designers to produce sustainable designs. The positive impact that puma's products have on the environment will put pressure on companies to follow their examples in making environmentally friendly choices in their production.

3.2.3. Boost Material

Sports footwear are clothing items which are exposed to various influences that are used in different ambient conditions and temperatures. Depending on the activities used, the desired base properties can be changed. Therefore, the soles of the sports footwears are one of the most important parts of the footwears. Generally, the desired characteristics of the sole of a sports footwear can be listed as follows: resistant to temperature variations, its durability, and comfortability. In addition, the other important features are; abrasion and slip resistance, elasticity, softness, and weight and also, recovery, recyclability, and disposal of materials are the most important subjects for the sports footwears soles However, in order to achieve these properties, it is necessary to pay attention to the properties of the materials used in the production of a sports footwear sole, such as; which manufacturing technologies are used during production and their relation to the environments are also significant factors to be considered.

When used materials of a footwear are examined historically, it is necessary to make mention of the German chemist, Otto Bayer. In 1937, Polyurethane material was invented by him; it was one of the greatest achievements that influenced the development of variable family of plastics for many years (www.bayer.com). The invention of this material has also affected the sport footwear industry because this material is being used as a sole material. It is relatively cheap and easy to produce compared to other sole materials.

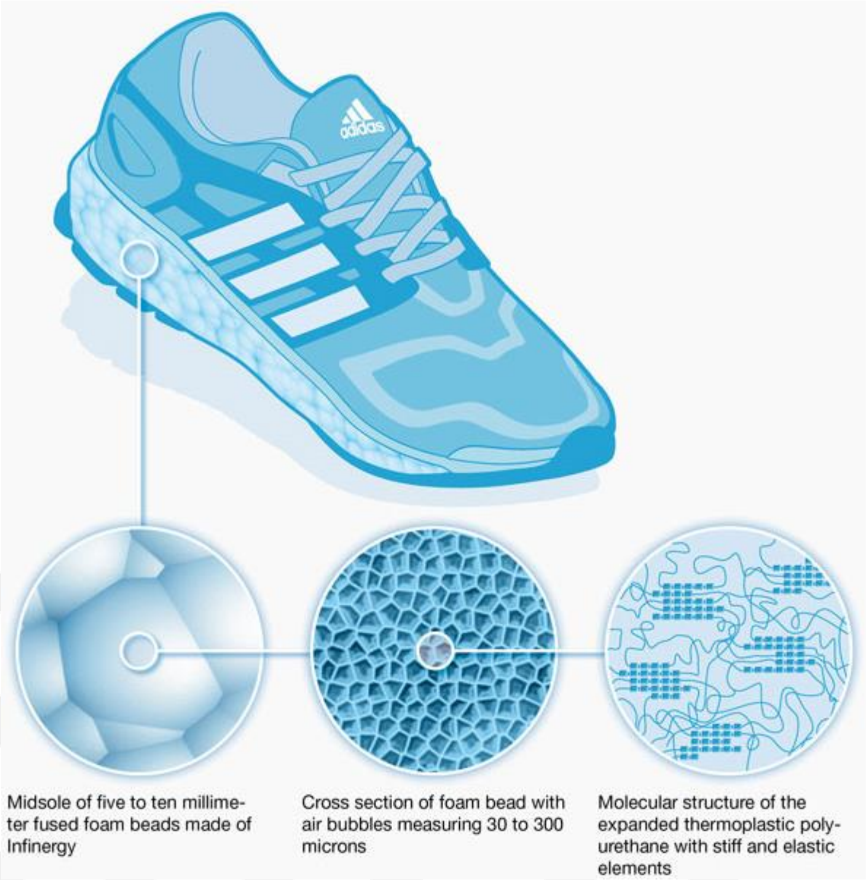
Polyurethane is a kind of a plastic which is a rigid polymer (Dombrow, 1957) but, unlike other plastics, they are formed by chemical processes in the mold. The polyurethane soles are the lightest footwear soles because they are in a spongy structure. Thus, they are soft and used for midsole cushioning and shock absorption. The tensile strength and melting points are increased using polyurethane which makes soles more durable (Bayer, 1947). Degradation with water, oil, and solvents ensures that they can be used instead of plastic materials (Saunders and Frisch, 1964). Since the 1950's synthetic base materials have begun to be used, many different materials used to manufacture sports footwear midsoles, such as foam, rubber, PVC, Poliamid and ethylene vinly acetate (EVA), have been the low cost choice of sports footwear midsole manufacturers. In the following years, new base materials have been developed in order to manufacture more sustainable products compared to previous materials. Therefore, the sports shoe industry and midsole formulators are looking for new solutions and options for footwear sole materials.

One of the latest technologies developed for sports footwear soles is the BOOST Technology which is Adidas's most innovative cushioning technology. It was unveiled in 2013 by Adidas Company. For this technology, Adidas and BASF company worked together to create the midsole material and the technology (www.plasticsportal.net). BASF Company, which is the largest chemical producers, provides raw materials for the producers and is also known as their ar-ge studies. The company used bio-degradable plastic material which is called thermoplastic polyurethane (TPU) for the midsoles based on the material's advantages. They improved polyurethane materials and then adapted these materials features to their own technology and they produced expanded thermoplastic polyurethane materials (E-TPU) called "INFINERGY"; thus this is the world's first expanded thermoplastic polyurethane (E-TPU) (www.reddit.com).

Picture 3.16. BASF's expanded TPU beads called the 'Infinergy'
Source: https://www.solereview.com/adidas-energy-boost-2-review/

INFINERGY, which is compressed under pressure for better shock absorption, instantly bounces back to its original shape. It is the material that is believed to have the highest energy return for running shoes in the market (www.jackrabbit.com). The midsoles is made from thousands of specially formulated foam pellets called "energy capsules." The process itself is used to produce a boost midsole such as a foam. The innovative materials help to produce soft foams with enhanced performance and processing for outsoles. During this process, the benefits of thermoplastic polyurethane (TPU) are retained, but to these are added the typical properties of foams. Being a particle foam, infinergy have a low bulk weight. This makes it the most elastic particle foam currently available on the market. The material is highly elastic over a wide temperature range, outstanding resilience, and is supersoft springy. Also, it has an excellent mechanical properties and good durability. Subsequently, the boost material can be formed and molded easily in every shapes and it is a material that can be melted and reused repeatedly when heated. This is important for the environment because it is reprocessed multiple times without losing its structural integrity. These materials are perfectly suited for regeneration because it is recyclable and can be reused easily without harming the environment (www.aldemirltd.com). It has become the most used material type in shoemaking. Another advantage highlighted by the shoe manufacturer is the great long-term durability of the material which, just like the other properties, is significantly better than that of conventional midsole materials in a wide temperature range. As Infinergy withstands temperatures of between -20°C (-4°F) and over +40°C (+104°F) without changing its functional properties, the footwear can be used at any temperature-whether in winter or in summer (www.plasticsportal.net). Other key features of the materials are; high abrasion and slip resistance and high tensile strength (www.plasticsportal.net).

Picture 3.17. Adidas Sports Footwear designed by Boost Technology
Source: https://www.solereview.com/adidas-energy-boost-2-review/



Picture 3.18. A look into the sole
Source:www.basf.com

One of the main features of infinergy is its excellent recovery behaviour and recyclability features. With this technology, material expertise and processing know-how were combined for creating an innovation ideas in sports footwear applications. In this way, high performance sports footwears began to be produced with innovative materials based on a sustainable process (www.reddit.com). This technology can be given as an example of bringing sports and science together in harmony. This is because in this technology, Adidas has benefited from the chemistry technology and has made it possible to develop materials that are used today and that are adapted to their own technology. With this technology, resources are protected and more sustainable process has been created.

3.3. Waste Reduction through Alternative Production Methods

In this section, proactive approaches have been focused on because this approach contains all measurements to take the goals of reducing or minimizing waste at the source. The waste reduction process is also an important issue for the sports footwear sector because it has a high waste rate. Thus, for reducing the need for raw materials, for preventing pollution, protecting energy and decreasing green house gas emissions and for reducing the amount of waste, there are alternative production methods for footwear production in regards to the sustainable principles. Furthermore, waste reduction methods can be seen at the beginning of the products design processes. For this reason, the effects of pattern productivity and dismantling methods, which can be used in the design phase on waste reduction, have been investigated. In order to better understand these issues, some examples in the sector have been examined.

Waste reduction is a waste management approach for footwears. Therefore, design improvements and material improvements are the two waste reduction options which are used before the sports footwears became post-consumer waste. As a solution to reduce environmental pollution of a product, products can be remedied without becoming waste. Designer can try to eliminate the environmental impacts of the design with a sense of ethic by considering alternative methods for decreasing environmental impacts. This is attributed to the fact that the design stage is the first step of the manufacturing. Also, 70% of a product's environmental effects were defined in the design stage (Ninimaki, 2010). For this reason, designers who have environmental considerations need to design in terms of sustainability and respect with the aim of creating alternative solutions for the environment and they also need to consider the next generations.

Eco-designs are produced for design improvements. Material substitution approaches are used for material improvements for waste reduction, resource protection, and sustainable environment. According to sustainable environment issues and resources, it is significant how wastes are generated after consumption and how these wastes can be disposed. For this reason, recyclability of post consumer waste is an important subject for the conservation of the natural resources as well as the conservation of the environment and sustainable development.

3.3.1. Pattern Efficiency Method

Waste reduction is being carried out to reduce the effects of environmental damages. For example, resources are gradually decreasing; water and energy consumption is increasing and the waste rate is also rising. Therefore, low waste design approaches can be used such as methods of pattern efficiency. For this method, nesting processes can maximize efficiency by fitting shapes closely together before die cutting them from raw materials. Subsequently, waste prevention is regarded as the most efficient methods for resources use. When less waste is produced, fewer resources will be used and, thus, less energy will be spent to recycle this waste.

Designers or manufacturers use this method to reduce the number of parts of the top of the footwears to create a single design. This is an important method because waste depends on the number of parts to be used and less material usage provides less waste. In this way, sports footwear designs can be made with fewer resources and, also, this process provides reduction in pollution (www.satra.com). Moreover, water, energy, and a lot of harmful substances will not be used because the reduced parts are not produced. Also, the recycling process will be facilitated because fewer materials are used. Finally, less energy will be spent on this process as less material is being recycled.

3.3.2. Disassembly Method

In this section, the disassembly method was emphasized and shoe samples which uses this disassembly method were searched.

Disassembly method is a process for designing products with ease of assembly, and it plays an important role in the recycling process. However, in the sports footwear sector, one of the most difficult elements of recycling is the issue of disassembly (Staikos and Rahimifard, 2010). Also, post-consumer footwear waste needs to be easily disassembled to be easily reused and recycled (Wennberg and Khudyokava, 2015). Nevertheless, they are difficult to recycle because of the way they are put together (Staikos and Rahimifard, 2010). This, therefore, is attributed to a large amount of adhesive typically used to join shoe parts together. Also, footwear is a multi-material product which can contain up to 40 different types of materials, many of which are stitched and glued together (EPSRC, 2013). Different types of materials such as rubber, textile, leather, and metallic pieces are used only for the same design. Additionally, disassembly of post-consumer waste depends on the importance of the material used, the number of parts to be used, and the production techniques and technologies to be used. This resulted to an over-waste problem and inefficient recycling process. Therefore, the importance of separation involves establishing a sustainability system. This is because when the waste enters the system again, the need for a new material will diminish. For this reason, post-consumer waste needs to be separated in an appropriate way. In fact, waste reduction methods need to be used before products become trash heaps. This method is a potential solution for the sustainable production of sports footwear. Furthermore, the methods have been found to reduce the amount of adhesive in the assembling of footwear components and it provides an easy separation process.

Manufacturing phase have the greatest environmental impact when all product life cycle stages are considered due to the amount of emissions which are released during the production stage (68 percent) (Cheah et. al., 2012). According to environmental impacts, most of the shoe production is released when creating shoe uppers (Gottfridsson and Zhang, 2015). This shows that footwear designers are able to focus on upper parts and materials for reducing environmental impacts and, therefore, the majority of the shoe consists of the upper part (Cheah et. al., 2013). Designer can design the product with fewer materials which makes it easier to separate a shoe for recycling. As a result, fewer materials which are used in its construction provide an increase recyclability of the product. Examples investigated in this subject are given below;

3.4. Innovation Manufacturing Technologies for Ecological Footwear Production

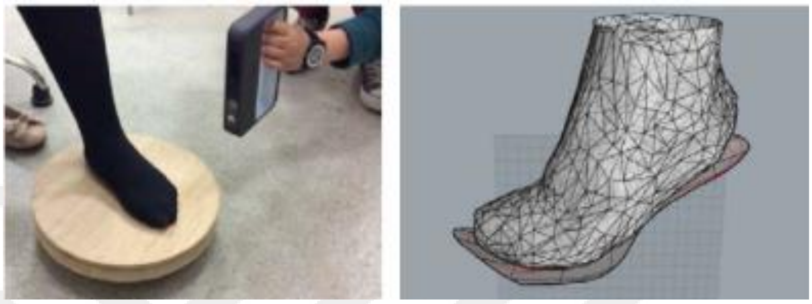
For this part, the technological innovations that are being used in the footwear sector have been investigated. Also, the development of sustainable footwear design and a sustainable production and consumption process have been tried to explore possibilities with making products and in reducing environmental impacts. For this reason, innovations in materials, production methods, and production technologies have been mentioned for sports footwear manufacturing with low or no impact. Therefore, 3D Print Technology, Dyeing Technology, and Knitting Technology have been investigated according to innovations in sports footwear sector. In regard to environmental ethics, companies are seeking ways to reduce the environmental impacts of products and they have started to think on the various answers to this problem. So, the sports shoes produced with these innovations have been examined in details. It has been tried for the purpose of determining which factors are the most important for the understanding of the design of the environment. In addition new approaches have been examined for comparing the differences between conventional and new developments for sports footwear and its cycle.

The footwear industry is unsustainable now. Therefore, the industry needs to convert their conventional business in a sustainable direction and follow the new technologies. The benefits of these innovations are; to create new solutions and to design more sustainable products and processes, and to reduce the environmental impact of traditional systems. Technology, design, and production processes can be considered together for the next generation sustainable industry for sports footwear. Technologies are opening up limitless possibilities for designer and companies who are able to follow the latest technical development standards in the field and be updated about it. After that, they can develop new sustainable products and new production technologies.

3.4.1. 3D Print Technology

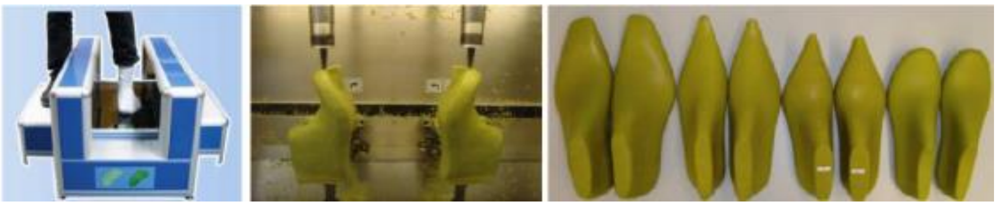
Additive manufacturing (AM) technology is called 3d printing which means the process used to form a three dimensional objects (Jon, 2013). Through this process, especially when basic concepts are designed, these designs are modeled with a computer-aided design program (CAD). After it is done, these 3D digital printable models are converted to stl format or additive manufacturing file format (AMF). According to the preferred production method, the appropriate 3D printer machine is selected (Çelik and Özkan, 2017). It is used for creating the item by adding material layer-upon-layer until a three-dimensional object emerges (Ford, 2014). In this technology, the variety of raw materials which are recyclable and reusable are increasing day by day and production is possible with different alloys; in addition, diversity is increasing due to new production methods (Çelik and Özkan, 2017). Usually, the preferred materials are thermoplastics, which mean they melt and mold easily. The corn-based eco-friendly plastic PLA is leading the way. It is a renewable type of thermoplastic material. PLA produces considerably less toxic emissions during the printing stage than others. Also, there is even less waste product with PLA when used as a filament for 3D printing. It is also better at the disposal stage at the end of a product's life cycle because PLA plastic is biodegradable (Bob Olson, 2013). Some printable polymers, such as acrylonitrile butadiene styrene (ABS), allow the surface finishing to be smoothed. ABS plastic is easily recyclable and reusable (Bob Olson, 2013). This is why it is currently, and will continue to be, the most popular choice over other 3D printing materials like ABS. Materials can be selected in terms of properties such as geometry, durability, conductivity, and the temperature resistance of the product to be obtained (Çelik and Özkan, 2017). Ceramics, plastics, metals and photopolymers and many other materials are also used for raw materials, and these can be in the form of a powder, liquid, or solid form (Ford, 2014). Moreover, additive manufacturing techniques are capable of using multiple materials in the course of constructing parts. In addition, 3D printable objects can be produced in all shapes and geometries (www.sculpteo.com). Initially, 3D-print technology was preferred for prototyping only. This is because of the potential benefits or advantages such as; determining the failures and problems before mass production. Consequently, prototyping is solving the problems related to the design and manufacturing processes. Whereas, with conventional methods, this production processes can be completed in several hours to several days, but rapid prototyping can reduce this time to a few hours (Çelik and Özkan, 2017). However, now it is being used to manufacture the final products. Thus, this is because it is an attractive alternative production method to conventional production methods (Ford, 2014).

The differences between conventional methods and 3D-print technologies will be mentioned in the next paragraph. Furthermore, different production methods are preferred for producing the 3D-printable objects. These preferences depend on the physical properties of the product, the amount of material to be used, the material properties, the surface quality of the product, and the production time (Ford, 2014). Most popular 3D printer technologies are; Selective Laser Sintering (SLS), Fused Deposition Model (FDM), and Stereolithography technologies. But, apart from these technologies, scan technology can also be used for producing 3D objects. 3D printable models can be created with a 3D scanner which is a device that analyses object to collect data on its shape and its appearance like colour. 3D digital models can be constructed with the collected data (Ford, 2014). It is also helpful with 3D printing and is wildly used for the relationship between foot and footwear because of the advantages in creating accurate models. With the accurate models, people can get shoes which fits into their feet appropriately (Lin and Chen, 2015). Firstly, the user's feet were scanned using a 3D modelling software. The 3D portable scanner was used. Secondly, the same form of shoes models were made respectively. CAD technology has become an important tool; Rhino is the main software in modelling for the advantages of dealing with surface and curve (Lin and Chen, 2015). Advantages of the scan technologies are; the scanned feet which help the precise measurements of individual consumers and fits the outline of foot and the arch of the foot. Due to the environmental impacts, it is able to control the number of prototypes produced. Therefore, the waste of the prototypes can be decreased through this way.



Picture: 3.19 (left) 3D Scanning; (righ) 3D Modeling
Source: (Lin and Chen, 2015)

According to Lin and Chen (2015), using 3D technologies to produce footwear prototypes is one of the techniques that are being used by the footwear industry. As shown in the above example, different types of footwear last can be created easily by using the scan and CNC technologies.

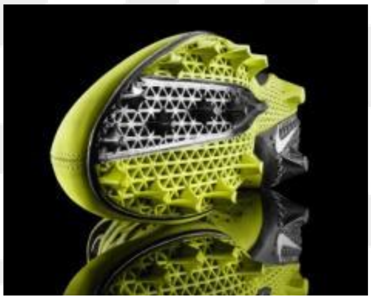


Picture :3.20. (left) 3D foot laser scanner; (right) CNC Machining, different types of shoe lasts
Source: Zhang et al. time

First of all, in order to better understand the 3D-print technologies and to understand how manufacturers can adapt this technology into their designs and also production processes, historical development process of 3D-printing technologies were examined before. According to the historical development of 3D printers, towards the end of the 1970's, these printers which are being used were very large and expensive at that time. Nevertheless, after 1980s, these devices and technologies became cheaper (Ford, 2014). In 1980s, the first 3D-print technology was developed by Charles W. Hull who is a physics engineer (www.epo.org). In 1984, he produced the first 3D-printed object and the first model of 3D-printer machine was created by him. This machine could perform in a matter of minutes what would normally take several weeks of moulding and casting (www.epo.org). Then in 1986, the process of stereolithography (SLA) technology was invented by Charles W. Hull and it is the first 3D-print technology which established the basis for all 3D-printing as it is well known today. Then the first patent for stereolithography machine was received by him. This machine was the first commercial machine for creating 3D-objects. According to Stereolithography (SLA) Technology, thermosetting materials are used for 3D printing material such as photopolymers which is in liquid form and ultraviolet laser which causes them to harden made layers to be created in such a way that the process continues in the same way such as adding material layer by layer (Çelik and Özkan, 2017). It is suitable for prototypes that require fine detail. Initially, 3D print technology was used for rapid prototyping of plastic (Goldberg, 2014). Today, every 3D-printer works is founded on the basis of Charles W. Hull's ideal; he opened up new applications across countless industries and today the possibilities appear endless (Hickey, 2014). A similar process was developed by Dr. Carl Deckard and Dr. Joe Beaman at the University of Texas at Austin in 1987. Dr Carl Deckard brought a patent in 1997 for the technology which is an additive manufacturing (AM) technique also called Selective Laser Sintering (Lonjon, 2017). SLS machine was designed by him (Deckard, 2018). Selective laser sintering is used for rapid prototyping and for printing functional, durable prototypes, and final products.

According to the technology, a carbon dioxide laser with very high power was used, and it is moved by using CAD software. This laser is used to melt the powdered materials by scanning cross-section and fusing them together. These materials are sintered to form a solid structure. Through this way, the first surface layer is formed and after then, the powder bed is lowered by one layer thickness (Çelik and Özkan, 2017). The same steps are repeated to create the next new layer until the 3D object is created. For this process, plastics, metals, ceramics, alloy mixtures, and composites are used according to the product's strength, durability, and functionality. According to Selective Laser Sintering (SLS) technologies, the advantage is that the diversity of materials allows the designer and the manufacturer to make more free and flexible designs. Besides this, the surface of the products is produced in a smooth manner because there is no supporting structure for product which is produced inside the powder. Also, the raw material usage has been reduced (Çelik and Özkan, 2017). Complex structures and geometries could be created easily with this technology. However, it is not possible to produce difficult structures without the print technology (Çelik and Özkan, 2017). In the following years, in 1988, Fused Deposition Modelling (FDM) technology was invented by Scott Crumb who is a mechanical engineer and it was patented by him in 1989. Also, the first FDM 3D-printer machine was created by him in 1992 (www.scuıpteo.com). Fused deposition modelling (FDM), which is the most popular and important printing technique, is one of the technologies that should be known in the 3D world. This technology is still used today. According to Fused Deposition Modelling (FDM), the melted materials are pushed out through a nozzle; then the melted materials are added to the other solid layer; and this process is repeated until the 3D-object appears (Gür, 2017). The preferred materials are generally acrylonitril butadiene styrene (ABS), termoplastik or polylactic acid (PLA) (Gür, 2017). The nineties have been very important years for the development of the 3D-print technologies. Therefore, this is because the expiration of the 3D-print technology patents is one of the significant reasons for this (Çelik and Özkan, 2017). The reason is attributed to the expiration of key patents, increase in sales, technological advantages, and new limitless applications of 3D-printing technology (Ford, 2014). After the nineties, Open Source applications are improved in relation to the technologies. And also, Open source applications are significant because there are lots of advantages about the process (Ford, 2014). First of all, it is important for democratizing production for everyone. For instance, open source 3-D printers enables the use of designs in the public domain easily and are economically made from readily available resources by local communities to meet their needs (Pearce et. al., 2010).

Secondly, it has a flexible structure because user can change the code according to his or her needs. It is possible to correct and update in case of any error. Open source codes are always adaptable, reliable, and transparent. However, other needs can be explored for free. Thus, it provides innovation and increase the popularity of these technologies (Ford, 2014). The expiration of 3D printing patents and open source applications has a significant effect on the growth of new applications. Later, this 3D-print technology was adopted at different usage areas and sectors in the world (Gür, 2017). For example, it has been employed in the footwear sector for several years to produce their products such as; Adidas, New Balance, Under Armour, Nike, etc. Midsoles which are created with 3D-print technologies are mentioned in Figure, first example is Nike Vapor Sports Footwear;



Picture:3.21. Nike Vapor Sports Footwear
Source:https://news.nike.com/news/nike-debuts-first-ever-football-cleat-built-using-3d-printing-technology

In 2012, Nike is using selective laser sintering technique for prototyping and producing their sports footwears such as Nike Vapor which is for the American football. With the 3D-print technology, Nike Vapor can be designed very lightly. It is just 158gr and, for the first time, cleats are printed for the footwear (http://nenws.nikeinc.com).

Picture:3.22. Zante Generate running footwear of New Balance
Source: https://www.newbalance.com/article?id=4041

Second example is New Balance's midsole; New Balance Running footwear model includes the company’s first 3D printed midsole. Nevertheless, most midsoles are made from foam through injection molding. However, this conventional manufacturing technique is expensive and wasteful. Also, the materials and processes are chemical in nature. New Balance have moved from making hard plastic parts with printing to soft durable cushioned flexible parts with 3D systems. The company makes use of selective laser sintering (SLS) technology. Midsoles are printed from a thermoplastic powder by laser consolidation. Products are both lightweight and extremely durable. Printed material for midsole can be recyclable.

Picture:3.23. Under Armour's new printed sports footwear
Source: https://www.kicksonfire.com/kof-live-under-armour-architech-trainer/

Third example is Under Armour's printed midsole; company's first 3D-printed midsole with the design lattice network. Adidas is another company that has adapted the 3D-print technologies for their designs. Adidas have continued to challenge the industry with its focus on innovation to improve the performance of athletic sports footwears. Their latest idea is about creating a developed midsoles with variable properties to improve shoe performance for different sports and, at the same time, creating their designs in a sustainable way. Therefore, Selective Laser Sintering (SLS) technology is adapted by Adidas for the manufacturing techniques for the futurecraft sports footwears midsoles.

Picture:3.24. Adidas Futurecraft, Sport footwear midsole
Source: https://www.carbon3d.com/stories/adidas/

Sustainable midsoles can be printed with this technology by Adidas Company. Adidas' sports footwear is produced in an environmentally friendly way. It is also a sustainable cycle because the powder material is recycleable and reusable. It is also important that it is produced in one piece, facilitating the decomposition steps in recycling. Moreover, some printing techniques require internal supports to be built for overhanging features during construction. These supports must be mechanically removed or dissolved upon completion of the print such as stereolithography (SLA) and Fused Deposition Modeling (FDM), which most often require special support structures to fabricate overhanging designs. On the other hand, SLS does not need a separate feeder for support material because the part being constructed is surrounded by unsintered powder at all times. This allows for the construction of previously impossible geometries. In 2015, Adidas and Carbon are creating the next breakthrough in athletic footwear, and they are developing futurecraft 4D. Adidas has collaborated with the Carbon Company which works at the intersection of hardware, software, and molecular science (www.carbon3d.com). Futurecraft 4D CLIP technology is used by the company. The technology combines innovations to create unique lattice structures in the form of adidas midsoles. It is allowed to print limitless geometric shapes for the midsoles in one piece.

Picture: 3.25. An adidas Futurecraft 4D midsole printing on a Carbon M-series printer to include varying lattice structures along the midsole in one piece
Source: https://www.carbon3d.com/stories/adidas/

A new developed 3D-print technology CLIP, which is called Continuous Liquid Interface Production, was adapted by Adidas to their midsoles for sports footwears (www.carbon3d.com). Clip technology is a photochemical process which is based on old stereolithograhpy 3D-print technology. Carbon's liquid resin platform uses digital light projection in combination with oxygen permeable optics to create the shape of the sole, and it then uses heat to set it (Sawyer, 2017). It is baked in a forced circulation oven because heat sets-off a secondary chemical reaction that causes the materials to adapt and become strengthen. Carbon's elastomeric polyurethane (EPY) 40 which is a printable, elastic and also recyclable material was used (www.carbon3d.com). With this technology, complex structures can be printed which gives producer access to geometries that were impossible with other manufacturing technologies (Gür, 2017). 3D printing is a good alternative to conventional methods. Joseph DeSimone who is the Professor of Chemistry at the University of North Carolina mentioned about the complex structures that: "Complex structures with interlinked connections cannot be produced by conventional production methods such as injection molding or compression molded in one piece" (Sawyer, 2017). Additionally, with traditional production process when midsoles can be assembled from multiple parts through a labor-intensive process, this introduces multiple potential points of failure. Thus, these complex structures can only be produced with 3D print technology in a sustainable way. Carbon’s rapid product development process enabled Adidas to iterate over 50 different lattices for the midsole before landing on the current design (www.carbon3d.com).

Besides making innovative shapes, Adidas is utilizing to open up new possibilities in shoe design (www.tth.com). Adidas is enabled to move into a new era of footwear manufacturing by producing and creating things in a clean and non-destructive way (Tolle, 2017). Depending on this technology, raw material usage can be reduced because it allows manufacturing without any waste, and this means producer during printing only makes use of that which they need (Çelik and Özkan, 2017). The process is extremely effective with the raw material usage to wastage ratio. Reducing material wastage usage is provided in decreasing production cost. It also involves casting, molding, and tooling processes which are consuming significant amounts of energy and producing hazardous industrial waste not applied in this CLIP technology (Ford, 2014). Producing midsole samples is cost-effective via traditional moulds production. According to fast fashion, the footwear models are changed continuously such that the molds need to be produced and changed again and again.

On the other hand, the waste of prototypes can be reduced by this print technology. Furthermore, footwear manufacturing process is changed using this technology before the process consists of design, prototyping, and production. This technology helps to prevent prototyping stages. By this technology, producer can print multiple designs on the same machine so that each product can be fabricated without the need of building a new assembly line (Ford, 2014). Furthermore, extraction and transportation of raw materials is a big problem. Thus, with this technology, production of the final products can be local based and, also, shipping and logistic problems of the materials can be decreased with this technology (Ford, 2014). Thus, cutting in carbon emissions results from savings in the distribution stage. The Clip technology is 100 times faster than conventional manufacturing methods and the final products features are; good tolerance, durability, and is functional and have high resolution surfaces. These techniques are able to print in multiple colors and color combinations simultaneously, and would not necessarily require painting. The importance of the 3D printing technologies seems to grow every year and this is a huge step for sustainable production until the technology evolves and producer are able to print in 3D with less damage to the environment. In addition, the additive manufacturing has a growing share of production in recent years compared to the conventional production methods. Therefore, this is due to the fact that it is a harmless form of production to the environment.

3.4.2. Dyeing Technology

In this part, conventional and new dyeing technologies have been investigated. The importance of these technologies in the production of sustainable footwear has been researched. Firstly, the dying process has been researched and the significant effect it has on the environment and the shoe production process was investigated."Dyeing is the process of adding color to textile products like fibers, yarns and fabrics." (www.thefreedictionary.com/dyeing).

In prioritizing, dyeing process was made with natural dyes and then the synthetic dyes are discovered by WH Perkins in 1856. A wide range of color fast and bright hues are provided with synthetic dyes. As a result, this dying application has become a massive industry today. However, this practice has resulted to a significant damage to nature and to life. Also, the processes are not environmentally friendly. This type of processed textiles is used in the upper part of the sports footwear. Every stage of the textile industry is made up of processes that will damage the nature. Most especially in this sector, a huge pollution has been created because it is one of the most chemically intensive industries on earth. These toxic materials can cause serious damage to the health of humans and other living organisms.

> More than 3600 individual textile dyes are being produced by the industry now, the industry is using more than 8000 chemicals in various processes of textile manufacturing including dyeing and printing (www.dyecoo.com).

In the conventional dyeing process, firstly, chemicals are involved in water resources in nature, and they are accumulated in nature. Therefore, it affects both natural life and agricultural activities and this creates huge pollution problems. Then the steam method is used to make the dyes permanent. Nevertheless, these chemicals evaporate and gets into the air. Furthermore, these chemicals damage the environment and the living organisms. Secondly, while the water scarcity is still going on, there is a lot of water consumption in the process for dyeing and printing.There is an excessive water use in many pre-treatment and finishing processes such as washing, scouring, bleaching, dyeing and finishing, and contaminated water can be used as a solvent in conventional dyeing processes. most of fresh water pollution in the entire industry is caused by textile treatment and dyeing". The Yeh Group stated that based on its experience, an estimated value of 100 to 150 litres of water are needed for processing 1 kg of textile materials (www.dyecoo.com). Thirdly, raw material usage and consumption of a great deal of energy are the negative environmental impacts of the process.

According to these environmental impacts, new technologies have been developed for the textile sector, especially the dyeing processes, taking into account the concern of these problems that harms nature and the environment. With the help of this new improved technology, DRYDIE technology has been improved. It is the world first chemical free and water free dyeing solutions (www.dyecoo.com) which was developed and implemented by Yeh Group. The company is an innovative and environmentally responsible knit fabrics producer. The Yeh Group is a Netherland-based polyester knit fabrics (www.dyecoo.com). The company says "It will eliminate the use of millions of litres of fresh water in dyeing fabrics using the new process" (www.dyecoo.com). In the new innovative dyeing process, supercritical CO_2 (SC-CO_2) has been used instead of water to dye garments without polluting the water and environment (www.dyecoo.com). Textile scientists, a team of specialized engineers, have developed a more efficient method of dying. However, it is the world's first ever industrial dyeing machines that uses supercritical CO_2 (SC-CO_2) replacement for water (www.dyecoo.com). When CO_2 is pressurized, it becomes supercritical, a phase between liquid and gas (www.dyecoo.com). It has a very high solvent power and it allows the dye to dissolve easily. Then it becomes gas at a certain temperature and pressure. At the end of the process, this CO2 in the case of gas is collected again at a certain point. Then this material is used repeatedly. 95% of the CO2 used is recaptured and recycled and then stored for reusing again. Therefore, it is a closed-loop system. At the end, the dyed fabric emerges from the vessel completely dry. “It saves more than 25 million litres of water; this means the equivalent of 10 Olympic sized swimming pools” (www.dyecoo.com). The benefits of the new technology were mentioned below;

- It is a sustainable technology and it is an eco friendly-process;

- Zero waste process and no waste water;

- Less energy intensive

- This clean technology is protected resources and it provides new design; for instance, different size of a single piece of fabric can be dyed in different colors or designs;

- Footprint can be decreased; no chemicals are used and auxiliary chemicals in dyes are eliminated (www.dyecoo.com);

- Sustainable dyeing without water usage;

- It is very cheap and does not harm human health;

3.4.3. Knitting Technology

In this section, Knitting Technologies and sustainable examples have been mentioned. This knitting technology which is a sustainable and innovative manufacturing process has been developed as an alternative industrial sewing technique to the production of shoe upper structures in a conventional manner. Tailored Fiber, Flyknit, Flywire and Premknit technologies are knitting technologies. However, the difference between these technologies arises from the use of different raw materials. For example; for the tailored fibre method, electrical wire are preferred for the embroidering, dumped plastic bottles are fuze down to manufacture new yarn for the flyknit method, steel yarns are used for the flywire method and lastly, premknit is a type of knitting technology, but the materials are different from the other knitting technology for this processes preferred materials are; rubber, thermoplastic yarn which are bio-degradable.

Sports footwear manufacturers have begun to move in a more sustainable way to remove the adverse environmental effects of the footwear production process. Because, the production of sports shoes is constantly increasing, but the excessive production causes high CO2 emissions, excessive water consumption, high toxic substance use. In addition, the environmental impacts of sports footwear degradation in landfills are connected to the nature of the materials. Conventional materials when disposed of in landfills sports footwear can take up to thousands of years to naturally degrade. However, it is very important to include recyclable materials in the cycle in order to reduce post consumer waste and improve environmental properties of sports footwear. Also, the environmental features of sports footwear can be developed by the use of recycled materials. Recovering materials reduces the need to produce those materials a second time around (Bolch, 2012). Therefore, decreasing negative environmental impacts, footwear brands are developing with waste-free knitting methods of manufacturing shoe uppers. It is an alternative sewing or embroidery techniques for sports footwear upper parts production. For this method; there is a growing of alternative textile fibres used in sports footwear that are eco-friendly and sustainable. They have started to use recycled fibre, yarn, fabrics and textiles in the development and production of new products (Payne, 2015). Today recycled materials are used such as synthetic fibres. These materials are recyclable, regenerative and reusable, man-made/chemical recycled materials. The reuse of synthetic outputs, such as polyester, pet bottles, plastics is come in useful to the environment not only because it consumes plastics waste, but also because reusing significantly decrease the plastic bottles that are shredded into small pieces through a process called polymerisation, they are converted into a new synthetic fibre that allows us to create new garments. Moreover, on this count, a new raw material is not reproduced.

With this technology, producers can create sustainable sports footwears and sustainable production cycle because this method can reduce environmental footprint of manufacturing. Furthermore, according to the environment point of view, the common advantages of knitting manufacturing technologies are mentioned below;

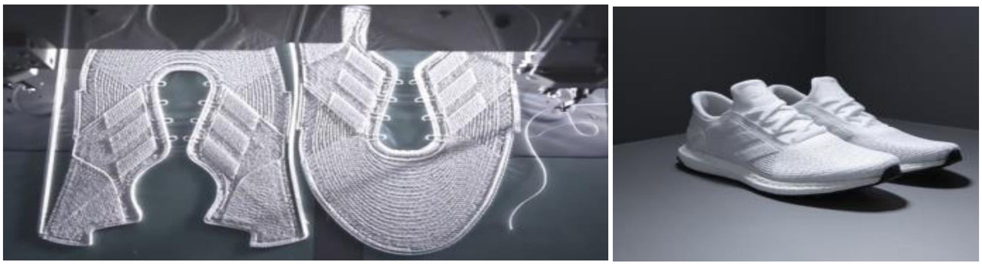
- With this method, it is possible to reduce carbon dioxide emissions, reduce water and energy usage.

- Manufacturing waste such as cutting waste and post-consumer waste generation can be decreased for the production of the upper construction.

- In the conventional production processes, more than one piece was used for upper parts of sports shoes, and these pieces were brought together by various joining methods. Adhesive was also used for joining parts, but the use of glue is not necessary as the knitting method is used for the upper parts. It is important that the upper part is produced in one piece.

- Knit construction allows a lightweight upper with fewer materials usage.

- A single piece of material is used which causes less material usage for the upper part. For this reason, this production process helps reduce wastes and facilitate recycling at the end of life stage, also, waste accumulation is prevented. The samples produced by knitting technology are examined in detail below;



Picture3.26: Tailored Fibre Sports Footwear
Source: http://conceptkicks.com

For Adidas Company, Alexander Taylor designed the Tailored Fibre Sports Footwear. Boost material is used for the midsole. The upper part is seamless because the upper material is embroidered in one piece and also as an alternative material electrical wire are preferred for the embroidering thus the design is durable and at the same time is lightweight.

Picture 3.27: Nike Flyknit Sports Footwear
Source: http://www.businessinsider.com

Nike uses this innovative knitting technology and they called this technology is flyknit. This technology for the goal of reducing waste and design incredibly light impossibly strong sports footwears. The idea and aim behind the flyknit were to create a running sports footwear that fit a second skin shape runners foot and to design a shoe with the feature of a sock, that has comfy to fit (http://www.businessinsider.com). An extra-light yarn is engineered in a knitted seamfree texture, with varied density layers giving indigenous elasticity levels to get featherlight, from fitting upper but, at the same time the footwear has high-performance standards. The sock liner is made from recycled materials, used water-based glues in the midsole and outsole to decrease the use of volatile organic compounds (http://www.businessinsider.com). Also, the upper was colored with water-based ink.

Nike uses "automated, high-tech knitting technology for the shoes upper into one piece instead of several pieces that are stitched together. This technology suggest well rounded occasions to significantly decrease waste associated with the production process. Thousands of tonnes of waste are generated every year, either going to landfill or being burned in incinerators which is not good for the air pollution. Due to the flyknit technology; dumped plastic bottles are fuze down to manufacture new yarn which is converted into fabric. Yarns are developed as high tech design materials which one diverted from lots of plastic bottles from landfills. Flyknit yarn, which to date has diverted more than 182 billion plastic bottles from landfills (Pospisilova, 2013).

Moreover, recycled polyester has been used, it is made from used beverage bottles, have lover energy less raw materials extraction and less waste compared to virgin polyester fiber (Pospisilova, 2013). Normally, plastics cause the emission of toxic substances when producing materials such as cobalt antimony from heavy metals (EPA 2001). And if these materials are not recyclable after use, they remain in the environment for a very long time without deteriorationbut, if it is used in this way with knitting production technology, petroleum based products will not be reproduced and used. In this case, the plastic materials are not buried in landfills, and the emissions produced during the disposal of these plastics are also reduced.

As a result, environmental impacts can be decreased. The material reusing process recover raw materials and decrease energy consumption. By the way, they improved recycling rates from the selection of materials using and production process. According to sustainable report FY14/15, Nike reduced its carbon emissions, improved its water efficiency by 18% percent per unit from the fiscal year 2011 through the fiscal year 2015 while revenue increased %52 percent during the same period. Nike forecasts that their flyknit technology decrease dump by about 60%, in comparison with cut and sew footwear and the technology cuts material usage by up to %20 (https://www.weforum.org).

Picture 3.28: Nike Zoom Victory 3
Source: http://store.nike.com

Jay Menchner and Morgan Stauffer designed the sports footwear. Flywire is a kind of knitting technology and steel yarns are used by Nike, these steels structures are support the footwear therefore, a lot of constrain stripes to make it stable, the stripes are sewing only where to be needed. A very sturdy yarn used in the construction of a steel vest is wrapped around the shoe so that the product is both very strong and very light. Without steel, recycled rubber and foam are the three main materials. The upper parts can be knitted in one piece. The aim of the flywire technology provides a sustainable lightweight designs with support and strength at minimal weight. It also allows for the weight of the shoe to be reduced by up to %50 (https://www.cleanenergy.com). Nike zoom victory/spike, Nike hyper dunk uses this flywire technology.

Picture 3.29: Adizero sports footwear/Adidas
Source: http://blog.adidas-group.com

Premknit is a type of knitting technology, but the materials are different from the other knitting technology for this processes prefered materials are thermoplastic yarn which are bio-degradable and recycled rubber with using embroidered method with using yarns. Sports footwears was made of thermoplastic fuse yarns, and first the upper part of the sports shoe is produced with knitting technology, then the parts are assembled and sewn then joined to the outsole. It is important that the upper part is produced in one piece which allows for less material usage for the design.

World is swamped with the synthetic product and it is really hard to get away from it. Companies typically used plastic products because they are cheap and the production process is quick but, according to eco-watch plastic constitutes, approximately 90% of all trash floating on the ocean surface with 46.000 pieces of plastic per square mile, as a result 100 marine mammals and 1 million sea birds are killed thousand every year due to the classic contaminating the surrounding waters it might seen that with increased use the effects of plastics on the environment might be impossible to reverse (https://www.ecowatch.com). However, Adidas and Parley, turning a thread that is destroying our oceans the ecosystems are turning that into a something positive into building material and making it a life thread Adidas is making sneakers out of literal trash.

In the 21th century, Adidas takes a lifecycle approachment across the value chain to appreciate its impact. Raw materyel manufacturing has a wide impact on the company's footprint. Life cycle analysis inform that it accounts for half of Adidas’ total impact and 68% of the company's whole water consumption (https://www.finchanbeak.com). Therefore, they focus on findings new ways to create products from waste materials. Adidas and Parley have begun their corporation under the ocean plastic program with a mutual aim; conforming marine plastic contamination into performance sports footwear, which decrease the sourcing of virgin raw materials and addresses waste in the value chain. As a raw material Adidas use new sustainable materials such as marine plastic. These marine plastic consist of recycled waste from the ocean or fishing nets.

Parley is the association network where designers, thinkers, eraders meet up to create awareness for oceans. Parley has improved its (A.R.I: avoid, intercept, redesign) strategy to temper urgent threats to marine wildlife, to decrease the use of virgin plastics in manufacturing design, producing and distribution and to decrease whole plastic use. Through this collaboration, the innovative concept of footwear made using recycled waste from the oceans was launched.

Picture 3.30: Adıdas / UltraBoost Footwear
Source: http://news.adidas.com

Adidas developed a sports footwear with the upper made from yarns and filaments recycled from ocean waste (Payne, 2015). Adidas started using new technologies to transform the recycle waste into yarn that will construct the innovative sports footwears. Adidas and Parley, to be come up is the environmental footprint of raw material manufacturing and cleaning up the ocean recycling with the target to manufacture one million pairs of Adidas shoes made with Parley Ocean Plastics in 2017.

UltraBOOST is also the first mass manufacturing footwear to be designed using Parley Ocean Plastic. Adidas designed one million pairs of UltraBOOST made with Parley Ocean Plastic by end of 2017. This designs part of a wider involvement by the brand to raise the use of more sustainable materials in its outputs and to make eco-innovation the new industry standard through application of the Parley A.I.R. Strategy, which goals to end the cycle of marine plastic contamination long-term it is just about creating awareness. It’s about taking action and implementing strategies that can end the cycle of plastic pollution for good. Eco innovation is an open playing field (http://news.adidas.com). Created using Parley Ocean Plastic, outputs are made from up-cycled marine plastic waste recycled via Parley interception and clean-up operations in coastal areas of the Maldives. The UltraBOOST Uncaged Parley, with 7,000 pairs available, the composition of the "upper" of the ultra boost unchanged running footwear is % 95 percent recycled plastic from deep-sea gillnets, from trashes and reused polyester (5%); the rest of the upper, laces, heel cap base material, heel webbing, heel lining and the sock-liner cover are also made of reused materials. Its design is inspired by ocean waves.

4. CONCLUSION

At the turn of the 21st century, the footwear industry has become to an unsustainable state due to the excess of production and consumption and this also effects the environment negatively. Sports footwear production and consumption are definitely rising because, sports footwears are no longer used only for the purpose of making sports and they are commonly used for daily necessities with fashion anxieties.

These shoes have become acceptable for daily wear because; they are the proper accessories for a new global style of casual clothing for speed and mobility for their comfort. Hence within the scope of this thesis, not only sports shoes which can be used for various sports activities but the shoes used by the amateur people for their daily life needs are mentioned. Like any other fashion item, sports footwear become a lifestyle product. However, this very fashion character of the shoes associates them with thrown away culture of capitalist consumption society instead of durability and permanence.

In addition, over production and consumption of the sports footwear leads to the high disposal rates and over-wastes and this unbalanced cycle lead to the depletion of natural resources such as material, water and energy. Besides, significant environmental problems arise due to the post consumer waste accumulation big amounts of post consumer wastes are disposed of in landfill sites around the world which caused over waste problem. The current approaches of recycling systems are inefficient and limited in particular regarding post consumer waste. Besides, recycling processes are also insufficient for the disassembling of the mixes materials of the post consumer footwear waste because, extensive variation of materials are provided for producing a various range of styles and several types of footwear such as leather, rubber, textile, fabrics and petrol-based synthetics, plastics. Moreover, according to biodegradabilities of conventional materials, they remain in the nature for a long time without deterioration.

According to these environmental problems mentioned above, the thesis topic was defined as; waste management in the sports footwear industry through designing sustainable life cycles. In the frame of this topic the research question determined as “what is the impact of innovations in materials, methods and production technologies on effective waste management to reduce the environmental impacts in the unsustainable production and consumption cycle? Sub- question is determined as; “what is the role of designer in accordance with these innovative design methods of sports footwear for waste management?” In the light of these questions the effects of innovations in material, manufacturing and production technologies in the sports footwear sector, are investigated in order to find the improvements of effective recycling processes and solutions are found out for reduction of environmental impacts in the conventional and linear production and consumption cycle a for creating sustainable products and processes. with a circular approach. insufficient recycling processes and waste problems occurring in all production and consumption processes of a sports footwear and the negative environmental impacts of these processes have been examined. In addition, innovations applied to materials, methods and production technologies that can provide solutions to these problems have been examined. Furthermore, it has been determined that environmental problems can be reduced by the critical decisions taken by the designers. These issues have been supported with examined sports footwear samples and alternative approaches about sports footwear.

In order to create a sustainable sports footwear and sustainable production and consumption cycle, first of all, the whole life cycle stages of the sports footwear need to be determined and then the alternative solutions could be considered by the designer. In particular, it has been understood from the literature view, the two life cycle phases have the most important effects rather than other phases. Because most of the emissions emerge in the raw material stage and production stage. There are too many environmental problems associated with the raw material selection and production processes in unsustainable sports footwear production cycle such as; chemical process, harmful chemicals, an excessive amount of water and energy consumption, hazardous materials, and waste can be identified major environmental impacts. Thus, most of the studies have been focused on these two life cycle stages. Improvement of raw material stage and manufacturing stage could be provided for decreasing negative environmental impacts of producing of a sports footwear. It was seen that most of the problems encountered in all life-cycle phases for sports footwear were related to conventional materials. For that reason, material selection has been determined as an important step for the creation of sustainable products and production stages.

The environmental impacts of conventional materials have been determined and these impacts are explained in detail under raw material stage topic in chapter two. it has been determined that alternative recycled materials and innovative biodegradable materials have been used to reduce the environmental impact of conventional materials, to prevent waste formation and to make recycling processes more effective. In addition, at the design stage, the role of the designer is important to reduce the environmental impact of the raw material and to reduce the environmental impact of the production processes. They use specific strategies from the beginning of the design process to ensure the sustainable solutions. Therefore according to the sustainable point of view; the environmentally friendly sports footwear should be composed of recycled and innovative materials.

The designer's instrumental role in developing sustainable sports footwear is not only defined through morphology and ergonomy of the of the design, but begins with selection of materials and continues with production and manufacturing in the production stage. Designer even feels responsible about the usage and post-usage of the product. Below the role of designer is given detaily in creating sustainable sports footwear with no waste production and consumption.

The material dimension and the sustainable manufacturing were determined as two main important roles of the designer in order to create no-waste life-cycle. The designer can eliminate the environmental impacts of the sports footwear with a sense of ethics by considering these issues.

4.1. Material Selection and Innovation

First of all, the desired characteristics of an upper and a sole parts of the shoe need to be considered by a designer. These features are depending on the activities used, resistant to temperature variations, its durability and comfortability and, the other significant features are; abrasion, slip resistance, elasticity, softness and weight and also, recyclability, reusability, durability, disposability and potential compostability and the biodegradability. Later, designer can used the innovative material such as bio based material and recycled material such as yarns which is composed of petrol-based synthetics for reducing the environmental impacts of the conventional material. However, sometimes engineering knowledge may be necessary; Thus, it is understood that the designers can work with scientists to change the properties and production methods of the materials they use. For example; In the biodegradable technology, the bio-based materials are created using the science of chemistry for reducing the environmental impacts of the sports footwear. It is understood from the researched examples that they have implemented innovations in materials, methods and production technologies to design a sustainable product and process also these examples are detailed in Appendix-1. According to the results of the literature findings, the positive impacts of selecting environmentally friendly materials are summarized in next page;

The carbon footprint of a sports footwear can be decreased because the use of conventional raw material has been reduced. Especially, petrol based conventional materials production can be prevented. Instead of unsustainable petroleum-based materials, alternative recycled materials can be used such as recycled yarns. Harmful materials such as pet bottles turn second yarn materials, wastes turns to the raw materials. In this phase, design thinking and sustainability issues can be considered together by the designer. According to literature, the choice of materials has affected the end of life of the sports footwear. For example, an implication of using biodegradable materials as a means of reducing the amount of end of life waste in the sports footwear industry, the waste problem can be decreased because of this innovative materials have with the ability to compost at the end of the life phase and the material's biodegradability is approximately 6 months. Furthermore, the materials are recyclable, regenerative, reusable and biodegradable, therefore there is no waste accumulation in the garbage and landfills. However, conventional raw materials remain in nature for a long time without deterioration. It has been determined that biodegradable materials can be recycled in accordance with both organic and mechanical recycling. This has been instrumental in effective recycling processes and prevention of waste generation. Selections according to the biodegradability and compostability of the material to be preferred has important effects on reducing environmental problems and waste generation and increasing recycling properties. it is the designer's responsibility to pay attention to these features in the design phase. Moreover, designer need to decide in terms of new fabrics, new materials and what kind of material they used and how they implement the idea it is the problem to solve.

4.2. Sustainable Production and Manufacturing;

In the production phase, every time manufacturer introduces a new technology however designer can decide which technology can be proper for the design. With the development of technology, computerized systems have been started to be used. In this way, it has been determined that cutting waste which is an important environmental impact can be reduced. Besides, energy saving is significant subject for the production stages thus renewable energies such as solar and wind energy should be used in this stage because these energies are much lower carbon footprint. In the production stage, decreasing the production processes will lead to reducing the carbon footprints of the product. Furthermore, the decisions taken by the designer in the production process, determine the post consumption processes of that product. For reducing waste problem recycling issues are important also, recycling issues of the sports footwear needs to be considered at the design phase which is a starting point. As it is understood from the studies, the recyclability of a product depends on the decisions of the designer at the production stage. In order to create an effective recycling process, developed sustainable methods have been examined. These alternative methods reduce the environmental impacts of the production process.

In the production processes, alternative production methods have been preferred in order to create sustainable products and processes, in order to reduce environmental impacts and to increase recyclability of post-consumer footwear waste and these methods which are proactive approaches have been used for waste reduction at source. Also, waste reduction is an important issue because it has a high waste rate in the conventional production and consumption cycle. These methods are disassembly method and pattern efficiency method.

4.2.1. The Issue of Disassembly;

In the sports footwear sector, difficult elements of recycling is the issue of disassembly. The designer has been used the disassembly method for designing products with ease of assembly because this method plays an important role in the recycling process. Disassembly of post-consumer waste depends on the importance of the separation process. And also, post-consumer waste need to be separated in an appropriate way for easily reused and recycled. A sports footwear is produced by assembling the upper part and the sole part of using various methods of attachment. Assembling of the pieces can be affected the recycling process. It is an important process because, it facilities the decomposition steps in recycling. In addition, too much adhesive is used for the assembly of the parts. But, adhesives can be created environmental impacts such as emissions when post-consumer footwear waste have been accumulated in the nature. Also adhesives damage the ozone layer and it is very dangerous for environment and human. For this reason, adhesive usage should be decreased and water based adhesives should be used. Besides adhesive usage which makes the process difficult.

4.2.2. Pattern Efficiency Method;

In the production process, lots of pieces are used for the upper parts of a sports footwear and a wide variety of materials are used at the same time. However, in this case the process of separation in the recycling processes have become difficult. In addition, waste depends on the importance of the number of the parts to be used. Thus, using less piece means produce less waste and also, waste reduction is being carried out to reduce environmental damages. As a result of research, the designer can eliminate parts of the upper with using pattern efficiency method. And also, the product can be designed with few materials. Therefore, the amount of conventional materials usage can be reduced by using these methods. It was understood that the separation process is facilitated by using this method and it can be provided to increase to the recyclability of the post-consumer waste easily. Therefore over waste problem can be prevented. Also, it has been seen that the upper parts of the sports footwear have been started to design in one piece upper. This leads to decrease the waste generated and increase the effective recyclable processes. The designer can try to eliminate the environmental impacts of the sports footwear with a sense of ethics by considering alternative methods for decreasing environmental impacts. designers and manufacturers may not be able to solve all the problems alone, so collaboration is required for all kinds of information in different disciplines. It is understood from the examples of sports shoes and literature that science and technology can be useful for alternative solutions and sustainable designs.

4.3. Making Use of Innovative Technologies

With the developed technologies, sustainable products and production processes can be produced. In the thesis, 3d print, knitting technology, and drydie technologies have been investigated as an innovative manufacturing technology. These technologies have been mentioned in chapter three and sustainable sports footwear examples have been mentioned in Appendix 1 in detail.

According to 3d print technologies and knitting technologies, parts can be produced in one piece. it is facilities the decomposition steps in recyclings. The used materials are recyclable, reusable and regenerative thus conventional raw materials usage can be decreased. Cutting waste is a major environmental impacts for this process. Also designer use less materials because they print what they need and moulding processes have been eliminated with this advanced technologies and the designer can quickly identify their mistakes in the production stage. Therefore they can find solutions and make alternative changes very quickly. In the past designer were sending out 2d blue prints and essentially asking their manufacturing partners to create a sculpture also these processes takes mounts, But, using 3d printing allowed them to build and visualized 3d models and then designer can revise and change up the problems easily. It is beneficial for technical precision thus designer prefer it. Furthermore, with using this technologies, lots of conventional production processes have been eliminated by this technologies. For example, in order to create upper pieces in the conventional production methods, cutting, stitching and gluing processes can be prevented with using knitting one piece upper design methods. Also for creating soles in the conventional production methods, midsole-outsole pressing processes, injection moulding processes, gel pouring processes can be eliminated with using the 3d print technology. Therefore, the elimination of the production processes can be reduced the carbon footprint levels, water consumption and energy consumption usage can be decreased because of the conventional materials usage are decreased. Instead of conventional material recycled, reusable and biodegradable materials have been preferred.

As a result of research, key companies have been adopted these technologies and have been created their design in a sustainable way and have been produced in an environmentally friendly way. It was seen that material and production methods should be considered together and these two processes were related to each other during the production processes. Related examples have been investigated in Appendix 1.

According to transition from Linear to Circular Design Model; the designer have been started to take responsibilities for their vision related to sustainability for breaking the conventional system through using innovations. With the development of technologies, innovations in materials, methods, and manufacturing technologies have helped to reduce the environmental impact of an unsustainable production system and these innovative production methods have been supported in the transition to a new sustainable circular model.

The unsustainable linear model has been transitioned to sustainable circular model for reducing the environmental impacts of the unsustainable cycle. In sustainable circular model, the new technologies and innovations in material, method, and production technologies have been adopted. Innovative materials have been started to preferred such as biodegradable materials. As a result of the conducted research, this material can be recycled with both organic and mechanical recycling processes and this material can be broken down into natural humus which can be turned to another raw material and also these materials are upcyclable. Efficient recycling processes have been increased because the innovative materials which allow the creation of new materials of the same utility. Also, efficient recycling processes is an important subject for conservation of the natural sources and it is understood that, the recyclability of post consumer wastes are depend on the biodegradabilities of materials. Thus, there is no need to implement the incineration process. The biodegradable materials have the ability to compost at the end of life phase therefore, waste accumulation can be eliminated and also waste reduction can be provided in the circular model. Material recovery can be improved. The usage of these materials helps to create closed-loop model. Furthermore, in order to be able to talk about a sustainable system, the life cycle of a product should be closed-loop. In the circular model, the closed-loop model has been preferred instead of an open-loop model. And also, more sustainable products and processes can be designed with using circular model.

It was also determined that, the usage phase affected the environmental problems in these processes. Unsustainable consumption caused a rised production of waste. However, user can help to close the loop by returning the product after consumption through a product take back systems. Also consumer should aware of the environmental problems and their responsibilities therefore, they should be a part of the sustainable system to provide a sustainable cycle. Consumer awareness is very important because sustainable awareness of consumer leads to changing for new standards of business especially in sports footwear. They can put pressure on producers. With the circular model responsible consumer behaviour have been increased through the collection section of the circular systems.

In the thesis, it has been found out that, the environmental footprint can be reduced by improvement of raw material extraction and manufacturing processes. These stages are provided for decreasing negative environmental effects of production of a sports footwear. Because, the raw material extraction stage and production stage are the most important stages about generation of greenhouse gas emissions. Besides, efficient recycling process lead to create a circular cycle and closed loop model. And also in order to be talk about a sustainable system, life cycle of a product should be closed-loop. Also, it has been seen that design is being used to reduce environmental impacts, not as a competitive tool.

As a result of the thesis, it can say that the innovations in material, method and production technologies can be reduced the environmental impacts of the sports footwear production and consumption processes and these innovative production technologies can be increased the effective recycling processes and also the major problem of the thesis is the waste problem can be reduced. In addition, these technologies help to establish a sustainable circular model. Therefore a sustainable sports footwear and sustainable production and consumption processes can be established. These suggestions can be mentioned for the future studies;

- In order to reduce the environmental impacts of the sports footwear, long-term thinking should be considered by designer.

- In order to be able to talk about a sustainable sports footwear material, method, and technological innovations should be developed

- Industrial design has an important role in achieving sustainable development; because people are closely concerned with what they use, what they consume, and what they do with the decisions that designers take when designing their products. Design plays an important role in building this system and scenario in a holistic way,

- Designers have a huge power on the sustainability issues in order to manufacture sustainable products. It is important to use the skills and abilities of designers in a way which helps people to have a better and equal life. However, It is up to the designer's discretion to reflect the design of issues related to sustainability. For every step of the design processes, they can be critical in terms of and product usability and post-production scenarios are considered by designers with a sense of ethic

- According to investigated examples demonstrates how the industry can rethink design and contribute to prevent conventional raw material usage and production. New approaches can be examined for comparing the difference between conventional and innovative sustainable sports footwear. Designer, producers have been adopted as an alternative solutions for their sports footwears design and its life cycle processes. key companies have been dveloped alternative systems that can be solve the increases problems for their unsustainable production line.

- The footwear sector is characterized by large volumes of production, high levels of consumption and short product life cycles resulting in high disposal rates and waste. According to waste manaement approaches a comprehensive design strategies is needed for preventing generation of waste The unsustainable processes can lead to depletion of natural resources such as water, energy and raw material. Therefore a sustainable design and design process should be created.

- For this reason design for environment, recycling concepts should be improved by the designers. Design thinking, understanding user needs are important. figure out how to implement need to thing all processes, and they need to decide the impact of every decision. They can interpret management of information in the production facilities and the technological updating information later they can determine the construction methods, implementing processes.

As a result of the study, with the development and help of technologies; examples and approaches have been demonstrated that the innovations in materials, methods and production techniques can reduce the the pee-consumption, production and post-consumption environmental impacts of sports shoes.

According to limitation of the Research**;** the thesis has been limited finding more literature related to the sustainable sports footwear production and consumption processes, innovations in materials, methods and production technologies, related case studies and applied works. Based on the importance of this thesis, limited academic research was specifically carried out on all the life cycle of the impacts of sports footwear. The literature describes only one of the processes or product life phases. Nevertheless, in order to talk about a sustainable system, all the processes and stages should need to be considered. It is the only source of all processes in the production and consumption of a sports shoe. In addition, the old sources refer to conventional materials and methods of production, but these sources refer to innovative material, methods, and production technologists.

Also, innovations in materials, production methods and production technologies have become an important subject in today's condition for finding solutions to the current environmental impacts in an unsustainable footwear sector. Therefore, the thesis will be a beneficial study for the designers, students and academics

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APPENDIX 1

Appendix 1: Examination of Sports Footwears Produced by Innovations in Materials, Production Methods and Technologies.

1.1. Table for Examples for Biodegration

1.2. Table for Examples for Incycle Process

1.3. Table for Examples for Boost Material

1.4. Table for Examples for Pattern Efficiency Method

1.5. Table for Examples for Disassembly Method

1.6. Table for Examples for 3D Print Technology

1.7. Table for Examples for Dyeing Technology

1.8. Table for Examples for Knitting Technologies

In the Appendix-1, examples have been examined within the context of sustainable production and design methods, and these examples have been categorized according to chronological order. These examples have been included through material innovation for sustainable footwear design, waste minimization through alternative production methods and innovative manufacturing technologies for ecological sports footwear production.

Table 1.1 for Examples for Biodegration

1.Sample	**Release Date:** 2010		**Manufacturing For:** Footwear Sole		
Image of the Sports Footwear					
Brief Informa-tion	Flexible, superlight.				
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Handmade**
	BROOKS	Green silence	Sport footwear	✓	
Materials (M)	**Recycled M.**	**Bio-degradable M.**			**Alter-native M.**
Preferred Materials	Post-consumer recycled waste Green rubber	Biodegradable BioMoGo			Eva
Method	Traditional method.				
Producti-on Process	Designers designed one-piece upper which have recycled materials, using water-based adhesive and green rubber for the midsole. Brooks introduced the biodegradable BioMoGo midsole, Overall, 75 percent of its components are made with post-consumer recycled content and 3 percent contain post-industrial content.				
Technology	BioMoGo Technology for midsole.				
Packaging	Cardboard; 100% post consumer recycled				
Aim	Designed to be as green issue as possible, they wanted to have as little wastes as possible, It's also grounded in frameworks such as Cradle-to-Cradle, Green Chemistry and Design for Environment.				
Sustainability	Environmentally friendly shoe, composed of over 75% post consumer recycled shoe materials, with extensive cushioning, recycled rubber outsole, 100% post consumer shoe laces, waterbased adhesive, The shoe has a slim eco-footprint, with half the pieces, Brooks reduced volatile organic compounds (VOCs) by 65 percent, using low- and non-VOC materials and inks, and water-based adhesives. The sole is HPRGreen, improved durability and extensive use of recycled and biodegradable materials. Brooks saved the equivalent of half a liter of oil and 41 percent of the energy used to make each pair.				
Source	https://www.youtube.com/watch?v=4CI-pXSZ7qo				

2.Sample	Release Date: 2011			Manufacturing For: Footwear Sole/Upper	
Image of the Sports Footwear					
Brief Information	The Oat shoes are made of fully biodegradable materials. You can plant or compost these sneakers when they're worn down and flowers can bloom from the seeds hidden in the tongue part of the shoes.				
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Handmade**
Christiaan Mats	OAT	OAT sheos		✓	
Materials (M)	**Recycled M.**		**Bio-degradable M.**		**Alternative M.**
Prefered Materials			Bio-plastic		Organic hemp Cork insole Organic
Method	Traditional footwerar production method				
Production Process	OAT Shoes are 100% biodegradable shoes, all the ingredients bio-plastic, organic hemp, cork insole, hemp, biodegradable plastic,flax, and organic cotton, which make them non-toxic.				
Technology	Traditional footwerar production method				
Packaging	-				
Aim	Wearing them for as long as you can				
Sustainability	Bio materials are used, For an OAT shoe, once buried it takes them only a couple of months to degrade and for the plastic parts approximately 6 months. Production of OAT shoes has 33 percent less negative environmental impact and 25 percent less CO2 emission compared with similar canvas shoes made of cotton.				
Source	http://www.jardinsflorian.com/products/oat-shoe-sneaker, (Leigh, 2014), (OAT Shoes,2015)				

3.Sample	**Release Date:**2012	**Manufacturing For:** Footwear Sole/Upper			
Image of the Sports Footwear					
Brief Information	The men's California Green sneakers in a low or high top version.				
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Handmade**
Frida Giannini	Gucci	The California Green sneakers	Sport footwear	✓	
Materials (M)	**Recycled M.**	**Bio-degradable M.**		**Alternative M.**	
Prefered Materials	Recycled polyester	Bio-rubber Bio-plastic		Vegetable tanned black calfskin	
Method	Moulding method				
Production Process	Combine the bio-rubber soles with the upper part in genuine vegetable tanned black calfskin, biologically certified strings and rhodium-plated metal details. Additionally, the green Gucci logo has been designed on a recycled polyester label.				
Technology	Moulding method				
Packaging	-				
Aim	This new projects conveys the House's mission to interpret in a responsible way the modern consumer's desire for sustainable fashion products, all the while maintaining the balance between the timeless values of style and the most quality with an ever-growing green vision.				
Sustainabiliy	Using eco friendly materials also recycleable and production process is without environmental impact. Bio-plastic, a biodegradable material in compost used as an alternative to petrochemical plastic. A shorter degradation process compared to traitional industrial plastic, without leaving any waste or environmental impact.				
Source	http://www.psfk.com/2012/06/gucci-eco-friendly-shoes.html				

Table 1.2 for Examples for Incycle Process

5.Sample	**Release Date:** 2013		**Manufacturing For:** Footwear Sole/Upper		
Image of the Sports Footwear					
Brief Information	Puma Introduces "Re-Suede" Vegan Sneaker Made With Recycled Materials, InCycle collection				
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Hand made**
	Puma	Re-Sued Vegan Sneaker	Sport footwear	✓	
Materials (M)	**Recycled M.**	**Bio-degradable M.**			**Alternative M.**
Prefered Materials	Recycled Rubber, Recycled PET Rice Rubber				Rice husks Latex synthetic Ultrasuede
Method	Incycle Process, Traditional footwear production method.				
Production Process	The Re-Suede which is a retooled version that comprises 100 percent recycled materials and a new outsole derived from rice husks. Compared with virgin materials, the synthetic Ultrasuede upper is said to reduce energy consumption and carbon emissions by 80 percent. The Double Rice Rubber outsole, which substitutes a portion of the latex content with a rice-husk filler, also saves fossil-fuel energy in manufacturing and agricultural resources, according to Puma. The upper of the shoe is a mix of organic cotton and linen while the sole is composed of APINATbio, a new biodegradable plastic that can be shredded into its component materials before getting composted into natural humus.				
Technology	closed cycle loop for materials usage, traditional footwear production method.				
Packaging	Puma's Clever Little Bag that uses 65 percent less cardboard than the traditional shoebox.				
Aim	Puma aims at encouraging the recycling and re-usability of sports products				

	among consumers by providing a convenient and simple process.
Sustainability	About the packaging; it could be folded into a smaller piece, weighs less in shipping and therefore occupied less space, transportation cost, gasoline use, and Co2 emission were decreased. They’ve saved 1 million liters of water and a total of 8.500 tons of paper. The materials they used were , of course, fully recyclable. Puma claims that this new design will save about 20 million Mega joules of electricity, 1 million litres of fuel oil, 1 million litres of water and 500,000 litres of diesel.The bag is made of non-woven polyester consisting of recycled PET, and eventually is also recyclable. PUMA helps to protect the environment, aspiring to eliminate waste by recycling used products to create new ones. This effort is one more step forward toward the long-term goal of transitioning to a closed cycle loop for materials usage.
Source	http://www.ecouterre.com/puma-introduces-re-suede-vegan-sneaker-made-with-recycled-materials

Table 1.3 for Examples for Boost Material

6.Sample	**Release Date:** 2015		**Manufacturing For:** Footwear Sole		
Image of the Sports Footwear	 				
Brief Information	Boost is a n adidas performance technology, boost is offered in over 20 different shoes on adidas.com, energy return is a universal language for any athlete. One piece of upper part.				
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Handmade**
Ben Herath	Adidas	Ultra - Boost	Sport footwear	✓	
Materials (M)	**Recycled M.**	**Bio-degradable M.**			**Alternative M.**
Prefered Materials		E-TPU:Infinergy thermoplastic polyurethane			Lycra yarns
Method	Boost cushioning for sole, Primeknit tech for upper part is a kind of embroidery method.				
Production Process	They improved polyurethane materials then adapted these materials features to their own technology and they produced expanded thermoplastic polyurethane materials (E-TPU) called "INFINERGY" for the sole part. A mixture of different colors are combined to make the primeknit upper, cutting out the lining and tongue, adding the labels to the shoe, assembly and stitching of the uppers with hand with using sewing machines, lasting the uppers, attaching the heel counter and outsole to the boost midsole with hand, joining the uppers with the sole. using less glue according to traditional methods. less harmful for the end of the production method is				

	de-lasting. Black rubber at the bottom of the boost is flexible and allows that stretching . Boost is very flexible material, it is very soft, at the same time it was highly elastic, during compression it gives it back. boost is a thermoplastic urethane and highly elastic, soft, can be formed and molded shapes. Boost is a supersoft springy. stretchy knit upper that adapts to the changing shape of user foot as they run.
Technology	Boost technology for sole
Packaging	Cardboard.
Aim	Style is important and they wanted to design and create a design that looks as good as its feels. when the materials come to gether they look beautiful
Sustainability	One piece of upper part can be decreased the waste level and provide to use use less glue when attaching the parts because we have one piece.
Source	https://www.youtube.com/watch?v=H9nlNnjRx9w,https://www.youtube.com/watch?v=4J_kxwT9zX4

7.Sample	**Release Date:**2017	**Manufacturing For:** Footwear Sole			
Image of the Sports Footwear					
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Hand-made**
	Adidas	AdidasUltraBoost Footwear	Sport foot wear	✓	
Materials (M)	**Recycled M.**	**Bio-degradable M.**	**Alternative M.**		
Prefered Materials	Ocean Plastic, Up-cycled marine plastic	E-TPU:Infinergy	Recycled polyester		
Method	The UltraBOOST for sole and knitting method and wastes are recycled to yarn				
Production Process	They improved polyurethane materials then adapted these materials features to their own technology and they produced expanded thermoplastic polyurethane materials (E-TPU) called "INFINERGY" which is the world's first expanded thermoplastic polyurethane (E-TPU) for the sole part. For the upper parts; created using Parley Ocean Plastic, products are made from up-cycled marine plastic waste recovered via Parley interception and clean-up operations in coastal areas of the Maldives. Features a knitted upper made from a mix of Ocean Plastic (95%) and recycled polyester (5%).				

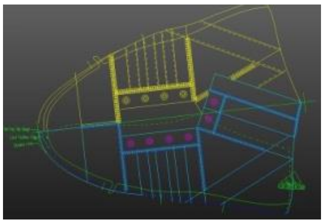
Technology	Boost technology for sole and Knitting Technology for upper
Packaging	Adidas Shoe boxes are Overall recycled content is 95% based on weight, most shoe boxes are made from 100% recycled fibre + clay coating/varnish; the ink used is soy-origin and water-based, between 38% and 60% weight reduction for shoe boxes since 2006 and no use of glues.
Aim	The aim of driving global awareness and comprehensive solutions to the threat of plastic pollution in the oceans.
Sustainability	Adidas creating one million pairs of UltraBOOST made with Parley Ocean Plastic by end of 2017. This designs part of a larger commitment by the brand to increase the use of more sustainable materials in its products and to make eco-innovation the new industry standard through implementation of the Parley A.I.R. Strategy, which aims to end the cycle of marine plastic pollution long-term it is just about raising awareness. It’s about taking action and implementing strategies that can end the cycle of plastic pollution for good. Eco innovation is an open playing field.
Source	http://news.adidas.com/Global/Latest-News/ALL/adidas-and-parley-for-the-oceans-unveil-first-performance-apparel-and-footwear/s/8c4261c6-1cdd-4d64-a7f3-3e2825980866

Table 1.4 for Examples for Pattern Efficiency Method

8.Sample	**Release Date:**2011		**Manufacturing For:** Footwear Sole/Upper		
Image of the Sports Footwear					
Brief Information	The NewSky is an everyday, around-the-house barefoot shoe from New Balance, It’s extremely lightweight, The design is stylish almost to the point of being elegant, at least for a sneaker. Promote the importance of recycling				
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Hand-made**
	New balance	The NewSky	Sport footwear	✓	

Materials (M)	Recycled M.	Bio-degradable M.	Alternative M.
Prefered Materials	Post-consumer recycled materials. Recycled PET, Pet bottles		Foam
Method	Pet bottles turn in for recycling are chopped up into flakes and processed into a non-woven material. Upper material is 95% recycled pet also created in one piece, NewSKY uses 73% less upper materials. Water based glue is used to assemble sole&upper.		
Production Process	Use of post-consumer recycled materials. The shoe's upper is fabricated using 95 percent post-consumer recycled PET bottles, and the outsole is held in place with a layer of water-based glue. On average, each pair of NewSkys uses the equivalent of eight 20-ounce PET bottles. The NewSky also uses the absolute minimum amount of material necessary to craft a piece of footwear, and ends up using 73 percent less material than the average New Balance running shoe. While traditional PET bottles are made from petroleum and other nonrenewable fossil fuels, PlantBottle packaging incorporates a blend of petroleum-based materials with up to 30 percent plant-based materials. The 100 percent recyclable package was designed with the planet in mind and is intended to remind people of the importance of recycling. For the consumer who is looking to maximize their style while minimizing their environmental impact.		
Technology	95% recycled pet also created in one piece		
Packaging	-		
Aim	The NewSky is designed to be worn as a minimalist recovery shoe, designed around the well know prenciples; reduce, reuse, recycle.		
Sustainability	The foam sole has a 4mm drop from heel to toe, similar to the New Balance Minimums and many other barefoot-style running shoes. Prior to receiving this pair of NewSkys, not having seen the design in person but knowing it's meant to be worn as a recovery shoe. Water-based glue, post-consumer recycled PET (Polyethylene terephthalate) bottles are used.		
Source	https://www.wired.com/2012/04/nb-newsky/		

9.Sample	**Release Date:** 2013		**Manufacturing For:** Footwear Sole		
Image of the Sports Footwear					
Brief Information	Its main features are: It has only 12 parts compared to 30 in an average running shoe				
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Hand-made**
	Adidas	Element Voyager	Sport footwear	✓	
Materials (M)	**Recycled M.**	**Bio-degradable M.**			**Alternative M.**
Preferred Materials	Recycled polyester Recycled EVA, Recycled rubber				
Method	Nesting method-pattern efficiency method.				
Production Process	It has only 12 parts compared to 30 in an average running shoe, a 60% decrease in the number of parts and 500g less waste per shoe. With 95% pattern efficiency; one of the many strategies used to increase pattern efficiency was "nesting" shoe pieces. This process differs slightly from more traditional shoe pattern creation methods in that the pattern makers consciously add cuts to upper pieces so they will "nest" together more efficiently on the cutting table				
Technology	Pattern efficiency method				
Packaging	Adidas Shoe boxes are Overall recycled content is 95% based on weight, most shoe boxes are made from 100% recycled fibre + clay coating/varnish; the ink used is soy-origin and water-based, between 38% and 60% weight reduction for shoe boxes since 2006 and no use of glues				
Aim	Aim to eliminate parts, the environmental impact of manufacturing those parts can be cut out of a shoe's carbon footprint.				
Sustainability	The Element Voyager is down to 5% waste, The complete Element Voyager shoe is made with environmentally preferred materials such as recycled polyester in the upper, recycled EVA in the midsole and recycled rubber in the outsole, which, coupled with the simplification of the shoe's design and it helps to decrease the amount of waste created during manufacturing**;** leftover trimmings from fabric and rubber can be avoided with more efficient pattern design or recycled. Secondly, less energy-intensive manufacturing processes or combining processes saves resources like water and energy. Lastly, by eliminating parts, the environmental impact of manufacturing those parts can be cut out of a shoe's carbon footprint. It is decreasing the emisions				
Source	http://blog.adidas-group.com/2013/07/applying-the-%E2%80%9Clow-waste%E2%80%9D-approach-to-a-running-shoe/				

10.Sample	Release Date: 2014		Manufacturing For: Footwear Sole		
Image of the Sports Footwear	 				
Brief Information	The Kayley shoe is another product manufactured by maximising pattern efficiency.				
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Hand made**
	Adidas	Kayley	Sport footwear	✓	
Materials (M)	**Recycled M.**	**Bio-degradable M.**			**Alter-native M.**
Prefered Materials	Recycled rubber				Textile
Method	Pattern efficiency method				
Production Process	Kayley low-waste shoe with more than 90% pattern efficiency, the Kayley shoe is another product manufactured by maximising pattern efficiency				
Technology	Pattern efficiency method				
Packaging	Adidas Shoe boxes are Overall recycled content is 95% based on weight, most shoe boxes are made from 100% recycled fibre + clay coating/varnish; the ink used is soy-origin and water-based, between 38% and 60% weight reduction for shoe boxes since 2006 and no use of glues				
Aim	"Low waste" is a design approach used in both apparel and footwear to reduce the environmental impact of manufacturing; making products with fewer resources.				
Sustainability	Reducing waste without compromising on style and performance.				
Source	http://www.adidas-group.com/en/sustainability/products/sustainability-innovation/#/reducing-waste-and-emissions-adidas-formotiontm-technology/				

11.Sample	Release Date: -	Manufacturing For: Footwear Sole
Image of the Sports Footwear		
Brief Information	The Duramo 6 footwear is streamlined and simplified.	

<table>
<tr><th>Designer</th><th>Company name</th><th>Footwear Name</th><th>Footwear Type</th><th>Mass Production</th><th>Hand-made</th></tr>
<tr><td></td><td>Adidas</td><td>Duramo 6</td><td>Sport footwear</td><td>✓</td><td></td></tr>
<tr><td>Materials (M)</td><td colspan="2">Recycled M.</td><td colspan="2">Bio-degradable M.</td><td>Alternative M.</td></tr>
<tr><td>Preferred Materials</td><td colspan="2">Recycled rubber</td><td colspan="2"></td><td>Textile</td></tr>
<tr><td>Method</td><td colspan="5">Pattern-efficiency method, printing processes, nesting method</td></tr>
<tr><td>Production Process</td><td colspan="5">High pattern-efficiency, combined printing processes and fewer parts and colours all reduce waste, the main upper part of the shoe is built from only four pieces and designed to be fully computerstitched, while sole-glueing is automated, requiring less glue and making manufacturing quicker, incorporated environmentally preferred materials where possible. Less waste, fewer parts, more sustainable materials again nesting system is used that is a reducing the material that are used for upper parts.</td></tr>
<tr><td>Technology</td><td colspan="5">Pattern-efficiency method</td></tr>
<tr><td>Packaging</td><td colspan="5">Adidas Shoe boxes are Overall recycled content is 95% based on weight, most shoe boxes are made from 100% recycled fibre + clay coating/varnish; the ink used is soy-origin and water-based, between 38% and 60% weight reduction for shoe boxes since 2006 and no use of glues</td></tr>
<tr><td>Aim</td><td colspan="5">The Duramo 6 was designed as light as possible</td></tr>
<tr><td>Sustainability</td><td colspan="5">Requiring less glue, reduce waste, fewer material less waste and less environmental impact.</td></tr>
<tr><td>Source</td><td colspan="5">http://www.adidas-group.com/en/sustainability/products/sustainability-innovation/#/reducing-waste-and-emissions-adidas-formotiontm-technology/</td></tr>
</table>

Table 1.5 for Examples for Disassembly Method

<table>
<tr><td>12.Sample</td><td colspan="3">Release Date: 2007</td><td colspan="2">Manufacturing For: Footwear Sole/Upper</td></tr>
<tr><td>Image of the Sports Footwear</td><td colspan="5">
</td></tr>
<tr><td>Brief Information</td><td colspan="5">Po-Zu is an award-winning ethical shoe brand. Vegan Shoes which is exceptionally breathable and wicks away moisture quickly. It’s also naturally anti-bacterial, keeping user feet fresh, dry and comfortable.</td></tr>
<tr><td>Designer</td><td>Company name</td><td>Footwear Name</td><td>Footwear Type</td><td>Mass Production</td><td>Hand-made</td></tr>
<tr><td>-</td><td>Foot Mattrss</td><td>Vegan Shoes</td><td>Sports footwear</td><td>✓</td><td></td></tr>
</table>

Materials (M)	Recycled M.	Bio-degradable M.	Alterna-tive M.
Preferred Materials			Coconut Fibres/husk Natural latex Chrome-free suede
Method	Disassembly Method;upper part stitched (sewed) to the sole with butterfly suspension mechanism.		
Production Process	Layers of spiralled, naturally pliable coconut fibres linked together with high-elasticity natural latex and wrapped in soft, chrome-free suede and brand use a comfy eco-microfibre to cover user vegan shoes. Chrome-free suede for leather uppers, eco microfibre for Vegan upper, chir foot mattres; moulds to the shape of user foot and provide air circulation 60% coconut husk&40% natural latex then softens the impackts as the foot hits the ground made from natural latex.		
Technology	Disassembly Method		
Packaging	-		
Aim	Biomimicry design is based on the coconut husk's natural shock-absorber property. Its purpose in nature is to soften the impact		
Sustainability	Design for durability and disassembly, materials are recycleable. It has the glueles constraction.		
Source	http://po-zu.com/pages/foot-mattress , http://po-zu.com/pages/testimonials		

13.Sample	Release Date: 2012		Manufacturing For: Footwear Sole/Upper		
Image of the Sports Footwear					
Brief Information	Outer cage with tongue, inner sock, tongue, complete shoe , Lighter, Ultras are also very flexible				
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Hand made**
Asher Clark	Terra Plana	Vivo Barefoot-Ultra	Sports footwear	✓	
Materials (M)	**Recycled M.**	**Bio-degradable M.**			**Alterna-tive M.**
Preferred Materials	Eva, Nylon, Neopren and airprene ;kind of rubber				
Method	Disassembly Method; assembly method like logo, fully moulded lightweight running shoe.				
	User can slip them on and no tying required. Ultras have three parts: the outer cage, a sock-like piece and removable tongue. The sock has two				

Production Process	"buttons," a large hexagonal one on the heel and a smaller rectangular one on the top. These hold the sock in place; if you remove the sock then the tongue pops into place with the rectangular button. The sock is sort of a light neoprene mesh with a thin leather-ish sole.It also anti-bacterial so you can wear it without socks. The cage is made of latex rubber and has the Vivo Barefoot sole. The entire shoe is extremely light. Just over 100g. Back view of the Ultras, showing the hex-shaped "button." The sock can be inserted for cooler weather or just if you prefer the feel. user can pop out the tongue and other parts. It's made of molded ethylene vinyl acetate (EVA), a soft and flexible material that's resistant to both the abuses of running and potential damage from the elements. The sock liner — a combination of nylon, airprene and neoprene; is about 2mm thick.
Technology	Resisting layer sole technology, moulding method usage.
Packaging	Cardboard
Aim	Create lighter and eco-friendly running shoe.
Sustainability	Stichless parts the shoe have so designer don't use any kind of glues and also the shoe is proper for recycling about its material selection and assembling process.
Source	http://www.dunya.com/dunya/cevre-dostu-ayakkabi-harekati-haberi-260874 Didem Eryar Ünlü, Çevre dostu ayakkabı harekatı,

14.Sample	**Release Date:** 2015	**Manufacturing For:** Footwear Sole/Upper
Image of the Sports Footwear		
Brief Information	Lyf (love your footprint) shoes parts can be assembly and disassembly 100% cycling process it has. According to Aly, "in order to be sustainable in the real sense, designer have to make designs that can be divided into pieces. If glue is used, recycling operations become problematic".	

Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Handmade**
Aly Khalifa	LYF	LYF Footwear	Sports footwear	✓	

Materials (M)	**Recycled M.**	**Bio-degradable M.**	**Alterna-tive M.**
Preferred Materials	Cork		Textile

Method	Disassembly Method; assembly method like logo, It consists of assembling parts, without glue.
Production Process	Lyf is taking a modular approach to shoe making that combines recyclable materials, custom fabrics, 3D printing for sole part, Arduino microcontrollers Also Lyf's footwear is made from materials that can be easily recycled, such as the cork that makes up the shoes' insoles. When wearers have worn out a pair of their shoes, they can take their old pair in

	and get a 15% discount on their next pair. The shoes themselves are fabricated within a given retail shop and, when returned, the shoes are disassembled with the constituent components sent back to their manufacturers. The parts are upper, insole, performance plate, heel lock, siderail and sole. Shoes are made of 100 percent recyclable materials and do not use PVC or toxic adhesives that are needed in gluing together the upper part and sole of an average shoe. The shoes are assembled together without glue, which both makes it possible to recycle and manufacture them without toxics. LYF has conducted a CO2 emission calculation with the LCA tool. Compared to a typical comfort shoe made in China from the local materials, The LYF shoe's carbon footprint is 49 percent smaller. (LYF Shoes, 2015).
Technology	Disassembly Method , 3D printing,
Packaging	-
Aim	Design products for disassembly and costumazition also the business model aspires to cradle-to-cradle philosophies and will incentivize customers from the start to close the loop.
Sustainability	Avoiding toxic glues, and 100% recyclable materials, Lyf shoes are assembled on demand ideal for intimately meeting consumer needs with the lowest carbon footprint possible. Incenting consumers with a buy-back program, Lyf pioneers "Symmetrical Manufacturing" whereby each assembly facility also disassembles product, sending components back to OEM manufacturers, creating the industry's first "closed loop" shoe. Componenet designed for maximum fit and sustainability, each pair of shoes can stay out of the landfill and be re-cycled into a new pair. With detailed wear tracking built in, they can then offer the customer a better fitting pair, closing the loop with the customer and the planet.
Source	http://lyfshoes.com/

Table1.6 for Examples for 3D Print Technology

15.Sample	**Release Date:**2015	**Manufacturing For:** Footwear Sole
Image of the Sports Footwear		
Brief Information	The futurecraft concept would be that a customer would be able to actually walk into a special adidas store and have their soles printed, and the shoe is created, in that same store. The design reduces the time for costumers, also costumers will own their customize shoes which are lightweight. Adidas and Materialise are coordinated the collaboration	

Designer	Company name	Footwear Name	Footwear Type	Mass Production	Hand-made
	Adidas	Adidas Futurecraft 3D-Prototype	Sport footwear	✓	
Materials (M)	**Recycled M.**	**Bio-degradable M.**			**Alternative M.**
Preferred Materials	Recyclable Print material TPU				
Method	Sole manufacturing method, 3D printing technology				
Production Process	Futurecraft 3D is a prototype which is a combination of process and material in an entirely new way. It is cheap to just make soles via traditional moulds that it makes no sense the 3D print them, costumuzation and time are important through conventional moulding, at-least no where near as cheaply or quickly as 3D printing can. Materialise's 3D Printing software and solutions are helping sporting goods giant adidas unveil the future of performance footwear with Futurecraft 3D. Also, the midsoles were then laser sintered in TPU, the first durable fully-flexible 3D printing material to be used in a consumer product, through Materialise's manufacturing process.				
Technology	3D-printed technology/ Selective laser sintering				
Packaging	Adidas Shoe boxes are Overall recycled content is 95% based on weight, most shoe boxes are made from 100% recycled fibre, clay coating/varnish; the ink used is soy-origin and water-based, between 38% and 60% weight reduction for shoe boxes since 2006 and no use of glues.				
Aim	Technology that cuts timelines, allows for greater innovation in general at an affordable price. Decrease raw material usage, Increase recyclable material usage, Reduce the manufacturing time, Sole is produced in one piece.				
Sustainability	Selective laser sintering is an additive process; for this process raw material usage is decreased because producer only print what they need, and re-use the rest. They also don't have to pay a storage facility to house all their soles, because they only print what and when they need to. Extremely efficient with the usage to wastage ratio. Brands wants to reduce transportation needs between asia and the market so process turns to sustainabile.				
Source	https://www.youtube.com/watch?v=-9nuFJL5afo#t=178				

16.Sample	**Release Date:**2016		**Manufacturing For:** Footwear sole		
Image of the Sports Footwear					
Brief Information	Adidas/ the 3D-printed Ocean Plastic shoe; Adidas leverages 3D modeling and recycled materials to reduce manufacturing's environmental impact. The shoe is just a prototype Adidas and P**arley** are coordinated the collaboration				
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Hand-made**
	Adidas	The 3D-printed Ocean Plastic shoe prototype	Sport footwear	✓	
Materials (M)	**Recycled M.**	**Bio-degradable M.**		**Alternative M.**	
Prefered Materials	Ocean Plastic Gill net Recycled marine plastic debris			Better Cotton, Recycled Polyester	
Method	Sole manufacturing method, 3D printing technology				
Production Process	Upper; ocean plastic and a midsole which is 3D printed;recycled polyester and gill net content.				
Technology	3D-printed technology/				
Packaging	Adidas Shoe boxes are Overall recycled content is 95% based on weight, most shoe boxes are made from 100% recycled fibre, clay coating/varnish; the ink used is soy-origin and water-based, between 38% and 60% weight reduction for shoe boxes since 2006 and no use of glues.				
Aim	Together with the network of Parley for the Oceans Adidas have started taking action and creating new sustainable materials and innovations for athletes, Adidas with Parley want to bring everyone from the industry to the table and create sustainable solutions for big global problems. The shoe's midsole demonstrates how the industry can re-think design and contribute to stop Ocean Plastic pollution and The group shows their continual support of develop long-term sustainable manufacturing processes. reducing plastic waste in oceans, have collaborated to create a 3D-printed shoe made out of recycled ocean plastic.				
Sustainability	Adidas leverages 3D modeling and recycled materials to reduce manufacturing's environmental impact. The company's approach addresses water efficiency, quality and accessibility and **materials**; The adidas Group is committed to driving closed-loop solutions and extending the use of more sustainable materials such as Better Cotton, Recycled Polyester and Ocean Plastic. The company will continue to reduce its absolute energy consumption, transition to clean energy and				

	look into energy harvesting opportunities. 3D modeling and recycled materials to reduce manufacturing's environmental impact
Source	http://www.psfk.com/2015/12/adidas-sustainable-footwear-design-cop21-parley-for-the-oceans.html http://www.adidas-group.com/en/sustainability/products/packaging-and-paper/#/adidas/ https://www.youtube.com/watch?v=NDlnT1ZVHhc,https://www.youtube.com/watch?v=hVvpOWHcadI www.parley.tv, www.oceanplastic.com

Table 1.7 for Examples for Dyeing Technologies

17.Sample	**Release Date:**2013		**Manufacturing For:** Footwear Upper		
Image of the Sports Footwear					
Brief Information	Adidas running shoes, providing that when taking a different approach to product creation, a team can combine both performance and sustainability benefits.				
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Hand-made**
	Adidas	Element Soul	Sport footwear	✓	
Materials (M)	**Recycled M.**		**Bio-degradable M.**		**Alter-native M.**
Preferred Materials	Color recycled rubber (midsol, outsole)				Texti-les
Method	Knitting Method for upper part				
Production Process	Adidas conceived a shoe that weighs less than 200 grams, includes only water-based adhesives and even takes out the sockliner.				
Technology	DRYDYE technology for textile, knitting technology for the upper parts				
Packaging	Adidas Shoe boxes are Overall recycled content is 95% based on weight, most shoe boxes are made from 100% recycled fibre + clay coating/varnish; the ink used is soy-origin and water-based, between 38% and 60% weight reduction for shoe boxes since 2006 and no use of glues.				
Aim	The objective of moving towards a more natural run with less material between the runner and the run. Fewer parts, fewer materials and fewer adhesives.				
Sustainability	The textiles used in the shoe upper are environmentally preferred, there is recycled content in the mid-sole and the outsole is single-color recycled rubber. All of these elements lead to a more sustainable shoe that is not over-built. Adidas also use DRYDYE technology for manufacturing their				

	footwear products. According to drydye technology one million yards of water-saving with DryDye fabric. The technology eliminates the use of water during the dyeing process, but as well reduces the use of chemicals and energy by 50%. With DryDye, water can be saved, this technology; with major water savings in the dyeing process. 50% waste savings when compared to a traditional running shoe. Also, less energy and less water are needed at production. For the needed parts, they decided to increase the use of sustainable materials.
Source	http://news.adidas.com/global/Latest-News/every-piece-counts/s/126e36fe-cfa6-4799-9f60-1463d260254b

Table 1.8 for Examples for Knitting Technologies

18.Sample	**Release Date:**2012		**Manufacturing For:** Footwear Upper		
Image of the Sports Footwear					
Brief Information	With Nike's new Flyknit technology, unique sense of fit, comfort and lightness, fitting, sustainability and performance are important topics. Minimum waste manufacturing process.				
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Hand made**
	Nike	Nike Flyknit	Sport footwear	✓	
Materials (M)	**Recycled M.**	**Bio-degradable M.**		**Alternative M.**	
Prefered Materials	Recycled rubber, pet bottles Recycled polyester	TPU			
Method	Knitting technology for upper parts.				
Production Process	The use of knitted fabrics across the upper of an athletic shoe has unlocked completely new possibilities in footwear design. Designer enginereed an extra-light polyester yarn in a knitted seamless structure, with different density layers giving specific elasticity levels to obtain a featherweight, formfitting upper. Every stitch of an upper can be microengineered and changed according to individual needs of the athletes. New colors, new silhouettes, and of course the added comfort made Flyknit an instant hit. The shoe's one-piece Flyknit upper is now constructed with DWR (durable, water-repellent)-coated TPU yarn and a water-repellant internal bootie to keep the foot warm and dry. The laser-siped outsole pattern is now grooved to increase surface area, repel water and further maximize traction. The Flyknit Racer's laces are 30% recycled polyester, the upper is colored with water-based inks, and the sock liner is made from recycled materials. We also use 100% water-				

	based adhesives in the midsole and outsole to reduce the use of volatile organic compounds.
Technology	Nike Flyknit is a new technology; Nike uses "automated, high-tech knitting technology to 'weave' the shoe's upper" half into one piece, instead of several pieces that are stitched together. The technology reduces labor costs by up to 50% and cuts material usage by up to 20%, resulting in.
Packaging	Standard boxes made from 100 percent recycled paper, 80 percent post-consumer content Paper usage reduced by 16 percent by decreasing the depth of the hinged lid and size of the “rollover” or folding edge at the end of the box. Printed with water-based inks Contain no glues, coatings or staples.
Aim	Idea was to create a shoe with the characteristics of a sock, that is comfortable fit and light weight but, at the same time they want to reduce envronmental impacts of shoe manufacturing.
Sustainability	Knitting the shoe upper with individual strands of yarn, which drastically reduces manufacturing waste and materials compared to traditional cut-and-sew methods while providing strength and support where it’s needed most. This innovative approach prevents millions of pounds of waste from ever reaching the landfill. For makking the upper instead of cutting and stamping shoes out and having excess material with this technology the upper part of the shoe can be prepared in one time. Flyknit yarn, which to date has diverted more than 182 million plastic bottles from landfills. Construct a shoe such as upper out of single strands of yarn, resulting in a strong, lightweight upper that drastically reduces waste and materials and seek materials innovations that enable us to use only what is needed to create the lightest, best-performing products which new products are made of recycled polyester. Reclaimed, discarded plastic bottles are melted down to produced new yarn which is converted into fabric. This recycling process saves raw materials and reduces energy consumption by an estimated %30 compared to manufacturing polyester. Nike production leaves less leather and glue waste in the production process making it more sustainable then the previous method sneaker making, the material is build up rather than cut away it.
Source	https://www.youtube.com/watch?v=JUdNeFh2SDo, http://www.businessinsider.com/nike-saves-money-on-flyknit-2014-9

19.Sample	**Release Date:** 2014	**Manufacturing For:** Footwear Upper
Image of the Sports Footwear		
Brief Information	Primeknit, which employed a similar, “one piece” approach which made the footwear both lightweight and eliminated manufacturing waste. The upper would still remain a single one piece upper thats supportive and lightweight. adidas created 2,012 pairs of the adizero Primeknit knitted in the same red and white colors adidas athletes are competing in at these Olympics.	

Designer	Company name	Footwear Name	Footwear Type	Mass Production	Handmade
Alexander Taylor	Adidas	Adizero	Sport footwear	✓	
Materials (M)	**Recycled M.**	**Bio-degradable M.**		**Alternative M.**	
Prefered Materials	Recycled Rubber	Thermoplastic yarns			
Method	Knitting technology; embroidered method with using yarns is called primeknit method				
Production Process	While sport shoes are usually made from many separate pieces the Primeknit method digitally knits the entire upper in just one piece. Knitting fused yarn allows us to fine-tune the exact amount of flexibility and support needed in every part of the shoe. This means lightweight comfort that wraps seamlessly around user foot. It was made of thermoplastic fuse yarns which had been finished in a way that the glove was both flexible and stable. First the upper part of the sports shoe is produced with knitting technology, then the parts are assembled and sewn. The produced parts are molded to form, then joined to the outsole.				
Technology	Premknit Technology				
Packaging	Cardboard				
Aim	Design to produce less waste and create less piece. Increasing recyclability				
Sustainability	While sport shoes are usually made from many separate pieces, then the piece are adhesived one by one it is hard to reycled and disassambled. Whilst fewer materials produce less waste				
Source	http://blog.adidas-group.com/2012/08/how-primeknit-was-born-there-are-no-books-we-could-have-referred-to-for-this-project%E2%80%9D/,http://blog.adidas-group.com/wp-content/uploads/2012/08/PrimeknitFeature.jpg				

20.Sample	**Release Date:**2014		**Manufacturing For:** Footwear Upper		
Image of the Sports Footwear					
Brief Information	The world's first knitted football boot. High production values, smart design and an ethical approach, delivering new levels of flexibility and comfort.				
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Hand made**
	Adidas	Samba Primeknit	Sport footwear	✓	
Materials (M)	**Recycled M.**	**Bio-degradable M.**			**Alternative M.**
Preferred Materials	Recycled Rubber				Lycra yarns

Method	Knitting technology; primeknit embroidery method for upper parts.
Production Process	Designed by adidas with an upper that is fully knitted from heel to toe, the Samba primeknit provides a bespoke second-skin fit whilst retaining the strength of conventional football boots, the yarns used to construct primeknit offer stability and are treated with a high precision coating to guarantee water resistance even in the wettest conditions.
Technology	Prime knit embroidery method
Packaging	Cardboard
Aim	Decrease manufacturing waste and increase recyclability process
Sustainability	Part of the boot is constructed without any wastage of material so it makes it the brands most sustainable football boot, no material is wasted.
Source	https://12elfthman.com/2014/02/27/the-worlds-first-knitted-boot-is-here-adidas-sambaprimeknit/

21.Sample		**Release Date:**2015		**Manufacturing For:** Footwear Upper	
Image of the Sports Footwear					
Brief Information		The adidas Primeknit 2.0 is the latest update of the original Primeknit boot, launched and worn on pitch last year by Luis Suarez. Shapes perfectly fit user foot and provide sport			
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Hand made**
	Adidas	Primeknit 2.0	Sport footwear	✓	
Materials (M)	**Recycled M.**	**Bio-degradable M.**			**Alterna-tive M.**
Preferred Materials					Lycra yarns
Method		Knitting technology for upper parts.			
Production Process		Made from only one piece, the upper is creating using old knitting technology. Based on the construction insights gained from the Primeknit FS, the Primeknit 2.0 comes enhanced with “compression fit” technology. An all-new compression tongue includes lycra yarns designed to wrap around the midfoot area and create a maximum lockdown effect. The boot also features a new anatomical heel shape and design, following the natural shape of the back of the foot to provide optimum support. The “outer shell” of the Primeknit 2.0 comprises of a zoned knitted upper with a lightweight vacuum coated skin to protect the yarns and retain a soft surface, meaning the boot is at home in any weather, on any pitch. The			

	forefoot contains a knit structure specifically designed to aid control. The control knit structure offers 3D texture that combines ultimate ball control with unrivalled manoeuvrability
Technology	The upper is creating using old knitting technology and use lycra yarns.
Packaging	Cardboard
Aim	The forefoot contains a knit structure specifically designed to aid control.
Sustainability	The waste level is decreased.
Source	https://12elfthman.com/tag/primeknit/https://www.designboom.com/design/adidas-primeknit-2-0-football-boots-04-20-2015/

22.Sample	**Release Date:**2016	**Manufacturing For:** Footwear Upper			
Image of the Sports Footwear					
Brief Information	Adidas create sustainable solutions for big global problems such as plastic pollution. About 16.5 old bottles and 13 grams of plastic from gill nets go into a single upper on one of Adidas's new shoe. This shoes is made out of ocean plastic. Upper part is made of in one piece.				
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Handmade**
Alexander Taylor	Adidas	This Adidas x Parley running shoe	Sport footwear	✓	
Materials (M)	**Recycled M.**	**Bio-degradable M.**			**Alternative M.**
Preferred Materials	Ocean Plastic Gill net Recycled marine plastic debris Old plastic bottles	Boost material; thermoplastic urethane For sole			
Method	Knitting Technology for the upper part and sole manufacturing method is boost technology.				
Production Process	Its shoe upper made entirely of yarns and filaments reclaimed and recycled from ocean waste and illegal deep-sea gillnets which is recycled into the fibre, the usual synthetic fibres are replaced with yarns made from the recycledParley Ocean Plastic. Recycled materials will lessen manufacturing waste, as well as create more sustainable environmental practices. The green wave pattern across the uppers is created from recycled gill net, which was dredged from				

	the sea. One gill net can be used to make 813 pairs of shoes.
Technology	ocean wastes transform to yarns for knitting manufacturing.
Packaging	Adidas Shoe boxes are Overall recycled content is 95% based on weight, most shoe boxes are made from 100% recycled fibre, clay coating/varnish; the ink used is soy-origin and water-based, between 38% and 60% weight reduction for shoe boxes since 2006 and no use of glues.
Aim	This waste plastic is a growing concern among both environmentalists and designers, who have created products to help raise awareness of the problem and proposed a variety of solutions. Try to reduce plastik pollution. In 2017 the brand aims to produce 1 million pairs of footwears from more then 11 million plastic bottles eventually. This waste plastic is a growing concern among both environmentalists and designers, who have created products to help raise awareness of the problem and proposed a variety of solutions.
Sustainability	Designers will use to concept products through environmentally impactful materials. The Adidas x Parley shoe is made of two kinds of recycled plastic: PET, used most commonly for water bottles, and nylon from gill nets. Plastic is tangible, visual, and easier to quantify than, say, carbon emissions and with the right technology, you can turn old, bad plastic into new, good plastic. When supply chains become circular and self-sustaining the environment is protected from over exploitation and pollution.
Source	http://www.adidas-group.com/en/media/news-archive/press-releases/2015/adidas-and-parley-oceans-stop-industrys-waiting-game/

23.Sample	**Release Date:**2016			**Manufacturing For:** Footwear Upper	
Image of the Sports Footwear					
Brief Information	Adidas continues to push boundries with their creative, Futurecraft series. Upper part is made of in one piece.				
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Hand-made**
Alexander Taylor	Adidas	Tailored Fibre Footwear	Sport footwear	✓	
Materials (M)	**Recycled M.**	**Bio-degradable M.**		**Alternative M.**	
Preferred Materials	Waste plastic	E-TPU: thermoplastic polyurethane			Electri-cal wire
Method	Knitting Technology for the upper part / Tailored method such an embroidered upper material with electrical wire.				

Production Process	Tailored Fibre is a flexible and efficient embroidery technology, which consists of a primary yarn stitched down by a smaller secondary yarn. The highest-performance fibres and filaments are engineered, adding to the textile toolbox accessible to the brand. In a single process, the technology allows the creation of all the required functionality, including flexible forefoot, supportive mid-cage and rigid heel counter. Infinergy is called expanded thermoplastic polyurethane materials E-TPU.
Technology	Embroidery technology, Tailored Fibre Technology, Boost technology (for sole)
Packaging	Adidas Shoe boxes are Overall recycled content is 95% based on weight, most shoe boxes are made from 100% recycled fibre + clay coating/varnish; the ink used is soy-origin and water-based, between 38% and 60% weight reduction for shoe boxes since 2006 and no use of glues
Aim	To search out and propose new alternatives appropriate for the future of manufacturing product .
Sustainability	Requiring less glue, reduce waste, fewer parts, more sustainable materials again nesting system(pattern efficiency) is used. Upper part is made of in one piece.
Source	http://conceptkicks.com/process-adidas-futurecraft-tailored-fibre/

24. Sample	**Release Date:**2016		**Manufacturing For:** Footwear Upper		
Image of the Sports Footwear					
Brief Information	Flywire technology will be built into several sneakers including the Nike Zoom Victory, the Nike Zoom Victory Spike, and the Nike Hyperdunk. Ultra light shoes with less materials. structers are support the footwear.				
Designer	**Company name**	**Footwear Name**	**Footwear Type**	**Mass Production**	**Hand-made**
Jay Menchner/Morga Stauffer	Nike	Nike Zoom Victory 3	Sport footwear	✓	
Materials (M)	**Recycled M.**	**Bio-degradable M.**		**Alternative M.**	
Preferred Materials	Steel, rubber	TPU			Foam
Method	Knitting technology for upper parts				

Production Process	The shoe is stronger then any shoes it also is lighter, a lot of constrain stripes to make it stable the stripes are sewing only where to be needed. These yarns are fixed on the upper part of with shoe machine. Only one seamless upper part can be created, so glue is not used for glueing.
Technology	FLYWIRE technology; It is a new technology produced by nike used steel yarns then with embroidery technology sewing this yarns for the upper part in one piece.
Packaging	Cardboard
Aim	Designed to provide athletes with increased support and strength at minimal weight. To search out and propose new alternatives appropriate for the future of manufacturing product .
Sustainability	The production of the upper part in one piece is the least of the waste formation. In addition, when not using different materials, it provides convenience for recycling. Requiring less glue, reduce waste, fewer parts, more sustainable materials again nesting system(pattern efficiency) is used. Upper part is made of in one piece.
Source	http://store.nike.com/us/en_us/pd/zoom-victory-3-unisex-racing-spike/pid-11156092/pgid-11287291

APPENDIX 2

APPENDIX 2: Table for Literature Review

In this study, a literature review was used, specific key words were determined such as; sports footwear, environmental impact, life cycle assessment, waste management, sustainable design, design for recycling, innovative design, material, footwear design, innovative material/ method/manufacturing technology, recycling, design, sustainability were scanned in databases.

Table 2.1: Key Words; Waste, Waste Management, Environmental Impacts, End of Life Management, Recycling

Table 2.2: Key Words; Life Cycle Assessment, Eco Design, Sustaibability, Sustainable Design, Designer, Eco Friendly Design, Ethics, Sustainable Manufacturing

Table 2.3: Key Words; Innovative materials, innovative methods, innovative manufacturing technology

Table 2.4: Key Words; Footwear, Footwear Manufacturing, Sports Footwear

Table 2.1: Key Words; Waste, Waste Management, Environmental Impacts, End of Life Management, Recycling

REFERENCES OF THE STUDY	**YEAR**	**NAME OF THE STUDY**	**KEY WORDS OF THE STUDY**	**AIM OF THE STUDY**	**RESULTS OF THE STUDY**
Toptaş, A	1993	Deri Teknolojisi	Leather, Chemical Materials, Waste Management	The purpose of this book is to provide information about leather technology and chemical wastes	Environmental impacts of leather
Wilford, A	1997	Environmental Aspects of Footwear and Leather Products Manufacture	Leather, Leather products, Footwear, environmental impact, waste	The review is intended to cover the environmental impacts and health issues of the footwear and leather goods industries with particular reference to solid waste, air pollution and chemicals.	This report considered to be a starting point for pollution control problems of the tanning industry and included such components to its technical assistance projects implemented in developing countries.

Table 2.1: Key Words; Waste, Waste Management, Environmental Impacts, End of Life Management, Recycling

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Vatan, C.	2002	Recycling of Plastic Material: Examples From Automotive Industry	Plastic materials, responsibilities for environment, LCA, recycle.	In this study, plastic materials recycling, which has the environmental and economic values, discussing with the other countries studies and automotive industry applications is included.	It is determined that the study to make the individuals become conscious and attend the recycling program should be done.
Staikos, T Heath R. Haworth, B Rahimifard, S	2006	End-of-Life Management of Shoes and the Role of Biodegradable Materials	End-of-Life Management, Shoes, Biodegradable Materials	The study discusses the implications of using biodegradable materials as a means of reducing the amount of end-of-life waste in the footwear industry and how this proactive approach compared against traditional end-of-life management approaches.	The paper reviews the trends in the footwear sector regarding the amount of end-of-life waste produced and ways in which it is tackled. Existing reuse and recycling activities in the footwear sector are examined, and the use of biodegradable materials is investigated.

Table 2.1: Key Words; Waste, Waste Management, Environmental Impacts, End of Life Management, Recycling

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Rahimifard, S. Staikos, T. Coates, G.	2007	Recycling of Footwear Products	Waste, End of Life, End of life waste, foowear sector, Landfill Restrictions	'Design for recycling' methodology ease of disassembly and separation and to reduce the overall cost of shoe recycling.	The study provides an overview of the scale of post-consumer footwear waste, legislative requirements, existing recycling solutions and the key factors influencing the establishment of a nationwide footwear recycling scheme in the UK.
Staikos, T.	2007	The realisation of end-of-life product recovery to support a zero waste to landfill approach in footwear industry	End of life product, waste management, footwear industry, Biodegradable materials in shoes.	Aim to investigate the variant end-of-life options for footwear products and to generate a multi-criteria decision making model to aid the selection of the most appropriate product recovery and recycling treatment option for a particular end-of-life footwear product.	The research has concluded that, the multi-criteria decision making model and tool can provide support for the implementation of shoe recovery and recycling procedures in footwear industry.

Table 2.1: Key Words; Waste, Waste Management, Environmental Impacts, End of Life Management, Recycling

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Staikos, T., & Rahimifard, S.	2007	An End-of-Life Decision Support Tool for Product Recovery Considerations in the Footwear Industry	Shoe Recycling, End-of-Life Management	The study highlights the potential benefits of developing a footwear product recovery methodology and an associated software tool to support decision-making to determine the most suitable manner in which to treat post-consumer shoe waste.	This methodology could be used to find optimal product recovery and recycling procedures for footwear products based on the combination of material content, recycling feasibility, recycling application and cost, and social–technical and environmental considerations.
Staikos, T., Rahimifard, S.	2007	End-of-Life Management Considerations in the Footwear Industry	End of life management, waste management, footwear sector	The paper provides a brief review of the trends in the footwear sector regarding the amount of end-of-life waste produced together with existing reuse and recycling activities	The environmental properties of a product can be improved by simply choosing different materials. Material improvements, under certain circumstances, can achieve significant reduction of waste.

Table 2.1: Key Words; Waste, Waste Management, Environmental Impacts, End of Life Management, Recycling

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Staikos, T. Rahimifard, S.	2007	Post-consumer waste management issues in the footwear industry	End-of-life management, shoe recycling, product recovery, footwear industry	The latter sections present an integrated waste management framework for shoes and discuss the challenges in establishing end-of-life product recovery procedures for post-consumer shoes.	The paper provides a brief review of the trends in the footwear sector regarding the amount of end-of-life waste produced, together with existing reuse and recycling activities establishing end-of-life product recovery procedures for post-consumer shoes.
Lima, P. R. L., Leite, M. B., Santiago, E. Q. R.	2010	Recycled lightweight concrete made from footwear industry waste and CDW.	Ethylene Vinyl Acetate (EVA); construction and demolition waste (CDW); mechanical behavior; recycled aggregate; lightweight concrete.	The goal was to evaluate the influence of the use of these recycled aggregates, as replacements of the natural coarse aggregate, upon density, compressive strength, tensile splitting strength and flexural behavior of recycled concrete.	The EVA waste results from cutting off the EVA expanded sheets used to produce insoles, innersoles of shoes in the footwear industry. It is possible to use solid wastes of the footwear industry, the construction industry as aggregate for the production of conventional and lightweight concrete, The density of recycled concrete was reduced

Table 2.1: Key Words; Waste, Waste Management, Environmental Impacts, End of Life Management, Recycling

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Rahimifard, S., Blackhouse, C.	2010	Minimisation of End-of-Life Waste in Footwear Industry	Post consumer shoe waste, global footwear market	Aim of this study is to minimize the amount of post-consumer footwear waste send to landfill and bespoke recycling processes that underpin the realization of a sustainable product recycling chain for the footwear sector	The study has developed an economically feasible automated material recycling process for mixed post consumer footwear waste.
Doğan, Z.	2012	Tekstil Sektöründe Atık Ekolojisi Uygulamaları	Textile Waste, Waste Ecology, Recycle	The purpose of this study, to reveal the cycle of rapid change in our country and the world in recent years which have revealed the amount of solid waste in the textile sector, the suitability of this waste to recycling and disposal rates.	The research study area of waste ecology and environmental awareness on the textile industry to date is thought to attract attention to the importance of ecological applications.

Table 2.1: Key Words; Waste, Waste Management, Environmental Impacts, End of Life Management, Recycling

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
MEGEP	2012	Deri Atıklarını Değerlendirme 524KI0278	Leather, Leather waste, Leather Waste Management	This module was prepared with the aim of giving information about raw leather waste, splitting leather waste, processed leather waste.	At the end of the module students are expected to learn methods of evaluating raw skin wastes.
Lee, M. J., Rahimifard,S.	2012	An air-based automated material recycling system for postconsumer footwear products	Material recycling process, post consumer, footwear, waste	The study discusses the development of an economically feasible automated material recycling process for mixed post consumer footwear waste.	According to the study, experimental studies with three different types of post consumer footwear products show that it is possible to reclaim four usable material streams; leathers, textiles, foams and rubbers. For each of the reclaimed materials there are a variety of applications such as surfacing materials, insulation boards and underlay products.

Table 2.1: Key Words; Waste, Waste Management, Environmental Impacts, End of Life Management, Recycling

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Endress, K., Neuber, N.	2013	Phase Out of Long-Chained Fluorinated Chemicals	Zero Discharge Hazardous Chemicals, environmental impacts	Study aims to explain to decrease the environmental impact of our products.	In the study it has been explained that PUMA has published its first Restricted Substance List for harmful chemicals (RSL) in PUMA products in 1999 and has defined clear standards that follow the strictest international legislation and best practice industry standards.
Karakehya, N.	2013	Tüketim Toplumunun Çevresel Etkileri	Environmental Effects, Consumerist Society	The aim of the study is to examine the environmental effects of the consumer society.	According to the study, it is now necessary to adopt a mode of production in which the environmental consequences are taken into consideration before profitability, a serious sustainable development policy

Table 2.1: Key Words; Waste, Waste Management, Environmental Impacts, End of Life Management, Recycling

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Sah, N. K.	2013	Greener approach to leather techniques	Chrome tanning, eco-friendly tanning, leather waste, membrane process, NF, UF, use of ultrasound, vegetable tanning	The main purpose of this study was to find out greener and more ecological methods of leather tanning	. The realization of a toxic, hazardous and polluting free tanning process by using and establishing technical environmental friendly innovations is setting the fundaments for a sustainable growth.
Goonetilleke, R. S.	2013	The Science of Footwear	Footwear, Footwear industry, waste minimization	Chapters discuss the issues of customization with a view to minimizing waste, enhancing overall performance, and delighting customers.	The book is useful for who strive to incorporate the biomechanical and ergonomics principles into footwear to enhance performance, safety, and comfort and to reduce injury.
Gajewski, R., Ferrer, J., Martinez, M. A., Zapatero, A., Cuesta, N., Gajewski, A.	2014	FOOTWEAR CARBON FOOTPRINT IN FOOTWEAR INDUSTRY (CO2SHOE)	Environmental impact,Carbon footprint, footwear industry,	This paper presents the work carried out in the European project (Footwear Carbon Footprint), which aims to create a carbon footprint calculation tool specific for the footwear sector.	According to the results of the study, the most effective method to encourage the manufactures to improve their pro-ecological attitude is to use intermediate factors.

Table 2.1: Key Words; Waste, Waste Management, Environmental Impacts, End of Life Management, Recycling

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Rajamani, S. G.	2014	Growth Of Leather Sector In Asian Countries And Recent Environmental Developments In World Leather Sector	Asian Leather, environmental effects of leather	The recent technical developments to meet the environmental challenges with specific reference to Asian countries, Europe and Latin America are dealt.	According to the Study, innovative tanning processes which will greatly reduce the water and chemical usage and minimize solid waste generation are needed together with overall environmental planning and management.
Resta, B., Dotti, S., Pinto, R., Bandinelli, R., Rinaldi, R., Ciarapica, F. E.	2014	Practices for Environmental Sustainability in the Textile, Clothing and Leather Sectors: The Italian Case	Environmental sustainability, Textile Clothing and Leather (TCL) sectors, Practices, Italy, Content analysis.	In this paper, a theoretical framework for mapping practices for environmental sustainability implemented in the fashion system is presented.	As a general result, Italian TCL companies do not seem very interested in sustainability activities, or at least only a few percentages of them has already undertaken some practices on this area.

Table 2.1: Key Words; Waste, Waste Management, Environmental Impacts, End of Life Management, Recycling

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Piñeiro P.	2016	Footwear Carbon Footprint Calculation	Carbon footprint, ISO StandartS, environmental impact	To develop a carbon footprint calculation tool specific for footwear to quantify the green house gas emissions of a pair of shoes to improve the environmental situations of the footwear	It has been created a calculation tool which has been verified that allows the specific calculation of the carbon footprint of footwear
Anonymous	2017	DERİ ENDÜSTRİSİNDE KİRLİLİĞİN kontrol altına alınmasında EM TEKNOLOJİSİNİN kullanılması	Leather, Environmental impacts	Aim to reduce leather manufacturing environmental impacts	According to the study, EM Technologie has been really successful in the purification of Cr element especially in wastewater and waste sludge

Table 2.1: Key Words; Waste, Waste Management, Environmental Impacts, End of Life Management, Recycling

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Laurenti, R., Redwood, M., Puig, R., Frostell, B.	2017	Measuring the Environmental Footprint of Leather Processing Technologies	Environmental footprint, industrial ecology, leather processing	The aim of this study is to survey key environmental footprint metrics of two different leather-tanning technologies to improve understanding of their environmental impact among tanners, their customers, and regulators.	According to the results, no significant differences were found in the footprint of vegetable and chromium leather processes, but these are only indicative findings and need confirmation in further studies.

Table 2.2: Key Words; Life Cycle Assessment, Eco Design, Sustaibability, Sustainable Design, Designer, Eco Friendly Design, Ethics, Sustainable Manufacturing

REFERENCES OF THE STUDY	**YEAR**	**NAME OF THE STUDY**	**KEY WORDS OF THE STUDY**	**AIM OF THE STUDY**	**RESULTS OF THE STUDY**
Anonymous	2001	LCA and Eco-Design Guidelines - European Commission	Life Cycle Assessment, Eco Design Guideline	The IPP conference has shown that eco-design guidelines and life-cycle assessment (LCA) are important parts of any IPP.	Prior to the workshop, it was clear that an overview of existing LCA data is still missing and that the diffusion of existing data and the business community has to be improved. Similarly, the use of eco-design guidelines needs to be promoted.
i Canals, L. M.Domènèch, X. Rieradevall, J. Puig, R. Fullana, P	2002	Use of Life Cycle assessment in the procedure for the establishment of environmental criteria in the Catalan Eco-label of Leather.	Catalan eco-label; cradle-to-gate; cradle-to-grave, descriptive LCA, eco-label procedure, environmental criteria, impact assessment; leather industry, leather, Life Cycle Assessment	The study was intended to serve as a guide for future applications of LCA to the establishment of environmental criteria for the Catalan Eco-labelling Programme.	In relation to the impact categories, the tannery is important in most of the impacts considered.

Table 2.2: Key Words; Life Cycle Assessment, Eco Design, Sustaibability, Sustainable Design, Designer, Eco Friendly Design, Ethics, Sustainable Manufacturing

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Germani, M. Mandorli, F. Corbo, P. Mengoni, M.	2004	How facilitate the use of LCA tools in SMEs-a practical example	Life cycle assessment, Life cycle inventory, product model, feature technology	The aim of this study is focused on data migration of digital models containing product and process information, and life cycle inventory systems.	In this study, a framework based on the definition of LCI Features has been developed to provide efficient and well-structured data retrieval of LCI-relevant product information.
Kayhan, Ö.	2005	YENİ ÜRÜN GELİŞTİRME SÜRECİNDE TASARIM İŞ TANIMI: TÜRKİYE'DEKİ UYGULAMALARIN İRDELENMESİ	Industrial design, product deveopment, design stage, design process, design brief.role of designer	The aim of the study is to investigate the existence and usage of “Design Brief” in Turkish Design Industry.	The findings of the study show that design definition is very important factor in determining the success of the product development stage. And design definition becomes even more important as the design service is generally outsourced to different firms.

Table 2.2: Key Words; Life Cycle Assessment, Eco Design, Sustaibability, Sustainable Design, Designer, Eco Friendly Design, Ethics, Sustainable Manufacturing

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Oygür, I.	2006	ENDÜSTRİYEL TASARIMCI-KULLANICI İLİŞKİSİNİN TÜRKİYE BAĞLAMINDA İNCELENMESİ	Industrial designer, User, Relationship Empathy role of designer	In the study, eight products which were designed, developed and produced by Turkish designers and engineers are investigated with the help of interviews and surveys to examine designer-user	According to the results of the study, users are not investigated in a systematic manner in the product development process in Turkey; user oriented design methods are not used.
Maxwell, D. Sheate, W.	2006	Enabling Sustainable Development through sustainable consumption and production	Sustainable Development, Sustainable Consumption and Production (SCP), Sustainable Product and Service Development (SPSD), eco-design; Life Cycle Management.	The aim of the study is to describe the factors to enable SCP as a reality and whether SCP can deliver on the Sustainable Development agenda	The research conclusions highlight recommendations for a wide range of stakeholders, policy makers, researchers, industry, consumers, NGOs, etc.

Table 2.2: Key Words; Life Cycle Assessment, Eco Design, Sustaibability, Sustainable Design, Designer, Eco Friendly Design, Ethics, Sustainable Manufacturing

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
ISO	2006	Environmental management — Life cycle assessment — Principles and framework	Life Cycle Assessments, ISO	The increased awareness of the importance of environmental protection	One of the techniques being developed for this purpose is life cycle assessment (LCA) for sustainable environment
Kumar, S. Malegeant, P.	2006	Strategic Alliance in a closed-loop supply chain, a case of manufacturer and eco-non-profit organization	Closed-loop supply chain, Reverse logistics, collection, eco-non profit organization, strategic alliance, industrial ecology, environmental management, life cycle management	The aim of the paper is tend to show that manufacturers can create valuable by implementing a partnership with an eco-non profit community organization in the collection process of used products for the closed-loop supply chain.	According to the result of the study, it is said that, a strategic alliance between a manufacturer and an eco-non-profit organization in the collection process of a closed-loop supply chain is a good strategy that benefits the manufacturer. And it is said that closed-loop supply chain creates value for the stakeholders.

Table 2.2: Key Words; Life Cycle Assessment, Eco Design, Sustaibability, Sustainable Design, Designer, Eco Friendly Design, Ethics, Sustainable Manufacturing

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Turan, F.	2007	Çevre Dostu Şirketler: Yeşil Göz Boyama mı Çevresel Üretim mi?	Green Consumer, Green washing, Environmentally Friendly Products	This study explores recent multinational companies' efforts about the green claims.	On the basis of the two samples examined it was seen that the green washing was painted and the people holding the power determined the discourse.
Bici, E.	2007	Aynı Ürün İki Farklı Disiplin: Endüstri Ürünleri Tasarımcıları Ve Moda Tasarımcılarının Ayakkabı Tasarımına Yaklaşımlarının İncelenmesi	Industry, design, fashion, shoes, craft Designer, process, method, approach the role of designer	In this research, the approaches of industrial l designers and fashion designers who design the same product which is 'shoes', are compared.	As a result, the context of industrial design for 20 years while it is in the context of fashion design for centuries. The existing shoe design today is being defined and described by the concepts and the terminology of fashion design, aesthetics considerations are more prior to the other considerations.

Table 2.2:Key Words; Life Cycle Assessment, Eco Design, Sustaibability, Sustainable Design, Designer, Eco Friendly Design, Ethics, Sustainable Manufacturing

REFERENCES OF THE STUDY	**YEAR**	**NAME OF THE STUDY**	**KEY WORDS OF THE STUDY**	**AIM OF THE STUDY**	**RESULTS OF THE STUDY**
Albers, K. Canepa, P. Miller, J.	2008	Analyzing the Environmental Impacts of Simple Shoes A Life Cycle Assessment of the Supply Chain and Evaluation of End-of-Life Management Options	Life Cycle Assessment, Materials of shoe, Supply Chain Management Options, End of Life Management	The goal of the study was to compare the environmental performance of four products. To accomplish this, we performed a comprehensive Life Cycle Assessment (LCA), supply chain analysis and End-of-Life (EOL) evaluation.	The results of the study indicate that traditional footwear materials are the most significant source of environmental impact within the supply chain.
Subie, A., Mouritz, A., Troynikov, O.	2009	Sustainable design and environmental impact of materials in sports products	Sustainable design, sports product, environmental impact, composite textiles	The aim of the study is to provide a detailed discussion of the main issues associated with the use of advanced materials in sports products and a review of the contemporary research, highlight the key technological challenges and opportunities facing the sporting goods industry in its quest to embrace the sustainable design paradigm.	According to the results of the study, sustainable design of sports equipment poses significant challenges to the sporting goods industry.

Table 2.2: Key Words; Life Cycle Assessment, Eco Design, Sustaibability, Sustainable Design, Designer, Eco Friendly Design, Ethics, Sustainable Manufacturing

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Malya, G.	2009	Sustainable Product Design Education: An International Review	Sustainability, product desing education, design	The aim of the thesis is to express the importance of sustainable design among our lives, to articulate the reality, that education creates the basis of sustainable design at both an academic and professional level.	Results of the survey were explained in details in order to explore sustainable product and service design departments at international scale.
Abbey, B., Chang, A., Coltellaro,C Lovely, B., Weitmann,D.	2009	The Zero-Waste Loafer	Footwear, footwear materials, footwear parts, Sustainable LCA Leather footwear	The study is try to design a model about zero materials waste in manufacturing,Zero toxic waste or emissions, and Zero air pollution.	In conclusion, it is said that the design eliminates material waste for all processes except the procurement of leather
Arcenas A., , Holst J., Ono, T., Valdin, M.	2009	The Development of a Standard Tool to Predict the Environmental Impact of Footwear.	LCA:Life cycle assessment, sustainable shoe brand, Environmental Impacts of Shoe Production, GaBi , I-Report	The goal of this project is to create a model that can be used to evaluate the environmental impact of shoes prior to production.	According to the study, by creating a model, Deckers will be able to design shoes with minimal environmental impact.

Table 2.2: Key Words; Life Cycle Assessment, Eco Design, Sustaibability, Sustainable Design, Designer, Eco Friendly Design, Ethics, Sustainable Manufacturing

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Fornasiero, R., Tescaro, M., Scarso, E., & Gottardi, G.	2009	How to increase value in the footwear supply chain.	Supply Chain, Footwear Supply Chain life cycle	The study aims to analyses some relevant issues emerging for Italian firms operating in the footwear industry in a specialized regional cluster.	In the analyzed industrial footwear cluster,.each shoe producer can play the role of catalyst for its Supply Chain and propose improvements for the benefit of all tiers.
Schaber, F.	2010	Socially Responsible Design: Breadline Shoes for Children in India.	Appropriate technologies, footwear, live project, India, socially responsible design	The aim of the study is to explore the role of Design students in industry and research collaboration ultimately benefiting the poor.	The roles of students, researchers and educators in the project and the benefits derived from an association with multiple partners in the teaching of socially responsible Design
Derrig,A. King,P., Stocker, J.Tinson,E. Warren,L., Winston, E.	2010	Sustainability Assessment of Nike Shoes	Nike, Sustainability, Sustainability Assessment	The aim of the study is to look into the sustainability assessment of Nike shoes.	The methods used by Nike, researchers were given an idea as to some of the basic methods of all shoe production and what it takes to make a sustainable, stylish shoe product.

Table 2.2: Key Words; Life Cycle Assessment, Eco Design, Sustaibability, Sustainable Design, Designer, Eco Friendly Design, Ethics, Sustainable Manufacturing

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Jacques, J., Agogino, A., B. M. Guimarães, L.	2010	Sustainable Product Development Initiatives in the Footwear Industry Based on the Cradle to Cradle Concep	Footwear industry, Cradle to Cradle Concept life cycle	The study aims to investigate and discuss how a traditional, linear production system could be transitioned into a more sustainable model following strategies based on the *cradle to cradle* concept, which seeks to close the production and consumption loops.	In the study, it has been characterized the sustainable product development initiatives currently being carried out in footwear industry
Hervaa M., Álvarez A., Roca, E.	2011	Sustainable and safe design of footwear integrating ecological footprint and risk criteria	Ecodesign, Ecological footprint, Environmental risk assessment	In the Study, a sustainability assessment methodology, ecological footprint (EF), and environmental risk assessment (ERA), were combined for the first time to derive complementary criteria for the ecodesign of footwear.	According to the results, the ecological footprint (EF) is a suitable screening indicator to assist the assessment of the sustainability of an ecodesign proposal and the EF does not consider the risk derived from hazardous substances in its evaluation.

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REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Karalar, R. Kiracı, H.	2011	Çevresel Sorunlara Karşı Bir Çözüm Önerisi Olarak Sürdürülebilir Tüketim Düşüncesi	Sustainability, ecology, sustainable development, sustainable marketing, sustainable consumption	In this study, sustinable consumption concept was explained.	then scope of sustainable consumption notion was mentioned and finally, given place to stakeholders and deficiencies of sustainable consumption.
Boer, P. van Heeswijk, J., Heideveld,A. den Held, D. Maatman, D	2011	Inspired by Cradle to Cradle: C2C practice in education	Cradle to Cradle, education, LCA	Development and design of materials, products, production processes and entire systems are based on the principles of natural ecosystems, where the quality and effectiveness of material and energy flows are central features.	According to the book, it can be said that educational evolution has already started. A campus is not yet a Cradle to Cradle world. But things appear to be changing. With the introduction of competence-based education and didactical concepts like trans disciplinary education, some of the required changes have been made.

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REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Subic, A., Shabani, B., Hedayati, M., Crossin, E	2012	Capability Framework for Sustainable Manufacturing of Sports Apparel and Footwear	Sustainable manufacturing framework; capability assessment; sports products	The study aims to describe outcomes of a research project conducted in collaboration with a global sporting goods manufacturer that focused on the development of relevant capabilities across their supply chain for sustainable manufacturing of sports apparel and footwear.	The study presents the developed sustainable manufacturing framework and capability assessment results obtained for selected companies within the supply chain of this global manufacturer in Asia.
Gürcüm, H. Yüksel, C.	2012	Moda Sektörünü “Yavaşlatan” Eğilim: Eko Moda ve Moda’da Sürdürülebilirlik.	Sustainability in fashion, Eco Fashion, Green Textile, Slow Fashion, Product Design.	In the study, three dimensions of sustainability: non toxic, eco efficient and cyclic fashion concepts have been mentioned in the ecological dimension and	The dye stuffs, chemicals found in the garment construction damage the human health by reacting with the skin or by breathing. to ensure social sustainability in the selection of production processes, raw materials, chemicals.

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REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Anonymous	2012	ASICS Drafts Sustainability Strategy toward 2015	Sustainability, eco, environment, footprint, green, materials, recycled, asics	The aim of the article is to explain Asics' project about minimize carbon footprint	ASICS was able to reduce the environmental impact from production of shoes while maintaining high performance. Kayano 18 running shoe based on the project results.
Brugnoli,F. Kráľ, I.	2012	Life Cycle Assessment, Carbon Footprint in Leather Processing (Review of methodologies and recommendations for harmonization)	Leather raw materials, Life Cycle Assessment, Carbon Footprint	Aim of the report is to provide a robust overview of State of the Art publications, standards and papers references for the calculation of the Product Carbon Footprint of the product	Analyzing generic and leather specific background knowledge on Life Cycle
Arena, A. Civit, B. Piastrellini, R.	2013	5th International Conference On Life Cycle Assessment, CILCA, Sustainability Metrics From Cradle to Grave	Sustainability Metrics, Cradle to Grave	The aim of the proceeding book is is to bring together the declarations presented in the conference on sustainability metrics and life cycle assessment.	

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REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Atalay, D.	2013	THE ROLE OF DESIGN IN THE FORMATION OF AN ETHICAL FASHION SYSTEM	Fast Fashion, Fahion consumption, Ethical Fashion, Sustainablity, Design	This study explores the role of design in becoming a potential agent for transforming production and consumption strategies of the conventional fashion system towards a more responsible and ethical direction.	Thus, it is aimed to make a contribution to the pursuit of design in defining a new identity and way of becoming for itself.
Öç, B.	2013	Sürdürülebilir tasarım: Ürün Tasarımı ve Üretimi Temelinde Malzemelerin Geri Dönüştürülmesi	Product Design, Sustainability, Sustainable Design, Industrial Product Designer, Produce	The purpose of the thesis is to analyze sustainability, sustainable product design, recycling and recycling materials while researching the importance producers and industrial designers give to sustainable design.	Although the knowledge level on sustainability and education of the producer survey (PS) participants were less than those of the participants of industrial product designer survey (IPDS), it was observed that they were more conscious of applications of sustainability.

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REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Muñoz, Z. R.	2013	Water, energy and carbon footprints of a pair of leather shoes	Product life cycle, Environmental aspects, Footwear industry, Sustainable design	The aim of this study is to analyze and improve a pair of leather shoes, including materials selection and end of life strategies to lower environmental pressure due to water and energy use and CO2 equivalent emissions.	The analysis showed that three important potential areas for eco-shoe development are the shoe sole, the inside textile and the paper packages. the best way to fulfil their roles and the least impact on the environment, considering also all auxiliary processes
Kupsala, H.	2013	ECO-EFFECTIVE FASHION THEORY, How to implement the Cradle to Cradle concept into fashion and clothing design? The designer's professional, economic, social and environmental role	Fashion-ology (fashion theory), eco-effectivity, designer's role, Cradle to Cradle concept	The purpose was to determine the innovative materials such as bio-based materials and their features	The results that the companies and designers want to make a positive difference through Co2 design.
Hvass, K. K	2013	Exploring Business Model Innovation for Closed Loop Fashion.	Models for footwear, sustainable design process	The aim of the study is to explore the relationship between business models	paid towards building a closed loop supply chain for fashion garments. And a framework was created.

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REFERENCES OF THE STUDY	**YEAR**	**NAME OF THE STUDY**	**KEY WORDS OF THE STUDY**	**AIM OF THE STUDY**	**RESULTS OF THE STUDY**
Deselnicu, V., Deselnicu, D. C., Vasilescu, A. M., Militaru, G.	2014	EU Policy For Sustainable Consumption And Production-Ecolabel For Footwear	Ecolabel, footwear, sustainable development,	The paper provides a brief overview about EU Ecolabels with special emphasis on EU Ecolabel for footwear product group	EU Ecolabel logo is designed to encourage businesses to market products and services that are kinder to the environment, as well as providing guidance for people seeking safer and more sustainable consumption.
Deselnicu, D. C., Crudu, M., Ioannidis, I., Brugnoli, F	2014	EnvironmentalAspects For Leather From A Life – Cycle Perspective. PartI: Methodology	LCA, chrome tanning	The goal of this paper is to quantify the environmental impact of new pre-tanning technologies	Environmental impacts were caused by chrome tanning technology
DESELNICU, V., CRUDU, M., ZĂINESCU, G., ALBU, M. G., DESELNICU, D. C., GUȚĂ, S. A., ... & CHIRILĂ, C.	2014	INNOVATIVE MATERIALS AND TECHNOLOGIES FOR SUSTAINABLE PRODUCTION IN LEATHER AND FOOTWEAR SECTOR	Innovative materials wet white, FOC leather, waste valorization, cosmetics, soil remediation, sustainable development	The aim is to obtain wet white leather by an organic tanning process in order to reduce chromium in tannery effluent.	The scientific and technical objectives of the project initiate a new area of research in leather processing-Knowledge-based Tanning Agent,

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REFERENCES OF THE STUDY	**YEAR**	**NAME OF THE STUDY**	**KEY WORDS OF THE STUDY**	**AIM OF THE STUDY**	**RESULTS OF THE STUDY**
DESELNICU, D. C., VASILESCU, A. M., PURCAREA, A. A., & MILITARU, G.	2014	SUSTAINABLE CONSUMPTION AND PRODUCTION IN THE FOOTWEAR SECTOR	Footwear, sustainable development, sustainable consumption, Ecolabel	The objective of this paper is to present consumers' perception regarding Ecolabel for footwear.	Aspects concerning ecological leather, footwear produced from such leather and Eco-label are not yet very popular and familiar to Romanian respondents,
Aminata, J., Grandval, S., Sbihi, A.	2014	Energy efficiency in production process: A case of footwear trade development	Sustainablity, Energy, Efficiency, Footwear, Retail, Production, Warehouse,	The meaning of energy efficiency gives influence for profit and competitiveness level to keep sustainable the footwear industrial development. One of the strategies in their method is how to apply efficiency approach at any level of business activities, precisely the energy efficiency approach.	Energy efficiency that shows an amount of saving, total emission reduction and cost effectiveness will take important role in global supply chain that stimulates trade structure and international trade flows.

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REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Gottfridsson, M., Zhang, Y.	2015	Environmental impacts of shoe consumption-Combining product flow analysis with an LCA model for Sweden.	Shoe consumption, LCA, MFA, product flow analysis, Sweden, LCA, environmental impact of shoes.	The aim of the master thesis is to assess the environmental impact from the consumption of shoes in Sweden based on the net inflow.	An increase in consumption of some shoe groups such as leather shoes might then generate higher impact than others. The results show that material production corresponds to the highest impact with 80% of the total life cycle.
Hietala, H.	2015	Eco-business: What, Why, How and Who?: A study on Eco-friendliness of Footwear Companies.	Footwear, eco-friendly, sustainability, eco-business	The purpose of the thesis was to study eco-friendliness of footwear companies. The guiding research questions in the thesis were whether eco-friendly footwear companies exist and if eco-friendliness is profitable.	Timberland, Nike, OAT Shoes and LYF Shoes, studied closer. The conducted research showed that eco-friendly footwear companies do exist, but they are not absolutely environmentally friendly.

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REFERENCES OF THE STUDY	**YEAR**	**NAME OF THE STUDY**	**KEY WORDS OF THE STUDY**	**AIM OF THE STUDY**	**RESULTS OF THE STUDY**
Mahdi, H. A. A., Abbas, M., Mazar, T. I., George, S. A.	2015	A Comparative Analysis of Strategies and Business Models of Nike, Inc. and Adidas Group with special reference to Competitive Advantage in the context of a Dynamic and Competitive Environment	Strategy, Sustainable Competitive Advantage, Business Model Perspective	The study attempts to find out the relevance of the strategies adopted by these companies, which are globally successful athletic apparel companies in the context of Bahrain	The findings of the study pointed that Nike's strategies which focus on innovation market Segmentation Strategy and Closed-Loop strategy. The Adidas strategies focus on the broad differentiation, innovation, trying to produce new products, services and processes in order to cope up with the competition.
Guta, S. U., Albu, L., Bostaca, G.	2016	Applications of Life Cycle Assesment To Leather Industry- An Overwiew and A Case Study	Life-cycle assessment, leather processing, carbon footprint	study aims to reveal the environmental impact of leather processing activities in the form of CO_2 emissions	The resulting values of the study, fall into the ranges of the ones published world wide in various studies and publications.

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REFERENCES OF THE STUDY	**YEAR**	**NAME OF THE STUDY**	**KEY WORDS OF THE STUDY**	**AIM OF THE STUDY**	**RESULTS OF THE STUDY**
Curran M. A.	2016	Life Cycle Assessment	Life Cycle Assessment	In this article, an overview of LCA methodology is given.	In the study, LCA applications and future outlook are addressed.
Dabija, D. C., Pop, N. A., Postelnicu, C.	2016	Ethics of the garment retail within the context of globalization and sustainable development.	Ethical principles, Sustainable development	In order to outline the means by which fashion, sportswear and footwear retailers transpose within all activities of the value chain ethical norms, as well as sustainable development principles,	The results disclose a mastery of the ethical principles and the implementation of several measures that can be encompassed to sustainable development within the value chain.
Wakulele, S. R., Odock,S., Chepkulei, B. N, Kiswili, N. E.,	2016	Effect of Eco-design Practices on the Performance of Manufacturing Firms in Mombasa County, Kenya	Green supply chain management, Life Cycle Analysis, Design for Disassembly, Design for Environment, Design for Recycling	The purpose of this study was to establish the effect of adoption of Eco-design practices on organizational performance of manufacturing firms in Mombasa County, Kenya.	Findings show that Eco-design practices have positive influence on organization performance with greatest impact being on environmental impact reduction and financial performance

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REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Dunn, J. C.	2016	Comparing Subnational Ecological Footprints for the United States, 2010	ecodesign, input-output, demographic analysis, population composition, household consumption	In this paper, the first complete demographic analysis of Ecological Footprints within the United States using 2010 National Footprint Account data in order to examine environmental burden allocation at the subnational level.	According to the results it can be said that by selectively targeting industries with high Footprint intensities, policy makers will be able to reduce the intensities of the products that people consume and reduce per capita Footprints.
Altun, Ş.	2016	Üretim ve Kullanım Atıklarının Geri Kazanımı, Çevresel ve Ekonomik Etkileri, Uşak Ticaret ve Sanayi Odası Raporu	Sustainability, Environmental issues, waste management	With this report, it has been tried to be determined that the recycling sector is gaining economic and environmental sense, and the problem of the sector and the solution suggestions.	environmental problems caused by textile will be reduced. As you can see, the recycling sector is an important aspect of "sustainable production and development" and must be supported absolutely

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REFERENCES OF THE STUDY	**YEAR**	**NAME OF THE STUDY**	**KEY WORDS OF THE STUDY**	**AIM OF THE STUDY**	**RESULTS OF THE STUDY**
Aydın, H., Ünal, S.	2016	A study on the effects of the consumer lifestyles on sustainable consumption.	Sustainable Consumption, Lifestyle, environmental problems, environmental pollution and consumer behaviour	In this study, it is aimed to examine the impact of consumers' lifestyles on sustainable consumption trends	According to result of survey which has been done at Erzurum/Turkey on 350 people, it has been determined that consumers' life styles have an impact on their sustainable consumption trends.
Roy, V., Singh, S.	2017	Mapping the business focus in sustainable production and consumption literature: Review and research framework	Systematic literature review, Sustainable production and consumption, Sustainable Development, Business environment	This paper reviews the growing literature on sustainable production and consumption (SPaC) for characterizing the prevailing business focus.	The outcomes of this review provide an organization to further strengthen the business focus in SPaC literature. In the future, it would be also important to map the business focus prevailing in the standalone views of production and consumption.

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REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Dabija, D. C., Pop, N. A., Postelnicu, C.	2016	Ethics of the garment retail within the context of globalization and sustainable development.	Ethical principles, Sustainable development	In order to outline the means by which fashion, sportswear and footwear retailers transpose within all activities of the value chain ethical norms, as well as sustainable development principles, the authors have conducted a qualitative, exploratory research, within the Romanian business environment.	The results disclose a mastery of the ethical principles and the implementation of several measures that can be encompassed to sustainable development within the value chain.

Table 2.3: Key Words; Innovative materials, innovative methods, innovative manufacturing technology

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Luximon, A., Goonetilleke, R. S., Tsui, K. L.	2001	A fit metric for footwear customization.	Footwear, Fit, Comfort, 3D foot scan technology, customisation.	In this paper, the 2-D methodology has been extended to 3-D. First, the foot and the last outlines were aligned.	In this paper, a method based on dimensional differences is proposed to quantify footwear fit.
Sharif, M. I. Mainuddin, K	2003	Country Case Study on Environmental Requirements for Leather and Footwear Export from Bangladesh	Leather Footwear, Leather material, Global trends of Leather goods trade Leather Sector in the Economy of Bangladesh, Leather Sector	The aim of the study is to create a Draft Study on Environmental requirements, Market Access and Export Competitiveness for Leather and Footwear in Bangladesh	According to the study, given the highly polluting nature of the leather industries, their dependence on the European market
Richie Jr, D. H, Pribut, S	2006	What's New in Running Shoe Technology? Computers, hi-tech materials, and design changes have led to improved footwear	New Technologies, Footwear	The study revives three new technologies currently found in the running shoe market.	According to the study, it can be said that the recent trends in running shoe technology has potential direct repercussions on the way podiatric physicians treat the foot with custom orthoses.

Table 2.3: Key Words; Innovative materials, innovative methods, innovative manufacturing technology

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Zerenler, M., Türker, N., Şahin, E.	2007	KÜRESEL TEKNOLOJİ, ARAŞTIRMA-GELİŞTİRME (AR-GE) VE YENİLİK İLİŞKİSİ.	Competition, Global Technology, Research and Development (R&D), Innovation	The main determinant of competitiveness is AR-GE and innovation-driven high and sustainable productivity increase. Technological innovations can lead to changes in competition and product and process, as well as changes in the markets.	Fast and radical changes in our lives leave no choice but to be innovative in their operations; which in turn causes businesses to attach importance to research and development activities at the strategic dimension.
Ashby, M. F	2009	Materials and the Environment Eco-Informed Material Choice	Materials, environment	methods for thinking about and designing with materials when one of the objectives is to minimize environmental impact — an objective that is often in conflict with others, particularly that of minimizing cost.	The book is written for students of engineering and materials science , the background and tools required for the materials csientists or engineer to analyze and respond to environmental imperatives.

Table 2.3: Key Words; Innovative materials, innovative methods, innovative manufacturing technology

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Belso Martinez J.	2010	Outsourcing Decisions, Product Innovation and the Spatial Dimension: Evidence from the Spanish Footwear Industry	Product innovation footwear industry	outsourcers in mature industries with competitive problems, particularly in southern Europe. The study attempts to fill the gap by investigating the distinctive traits of firms located in the most important Spanish footwear industrial districts.	According to the study, it was found that size, design and product innovation, prior institutional networks and location in specific industrial districts favour the development of outsourcing strategies.
Jacques J.J., Guimarãesb L. B.	2012	A study of material composition disclosure practices in green footwear products	İnnovative productionSustainable product development, sustainable production, footwear industry	This study is based on the study of pioneering sustainable product development initiatives, and the analysis was guided by the cradle-to-cradle concept	According to the study, The use of hazardous materials and chemicals in shoe manufacturing, can pose serious risks to human health and the environment.

Table 2.3: Key Words; Innovative materials, innovative methods, innovative manufacturing technology

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Grancarić, A. M., Jerković, I., Tarbuk, A.	2013	Bioplastics in textiles	Bioplastic materials, environment, polymers, textile	The bioplastic production cost is one of the major factors that determine the effectiveness of their implementation.	bioplastics will become cheaper, particularly as consequence of the development of new technologies and by achieving the required economy.
Watkins, P.	2013	Fibres & fabrics	Consumption, Fabrics, Sustainability	The aim was to show fashion designers and buyers the variety and quality of sustainable fabrics, and that it is possible to make highfashion clothing with a low environmental impact.	According to the study, with such large numbers and as populations grow, the pressure to source more raw materials for textiles is intensifying – which makes it even more crucial to source sustainably, and to get that message across to both retailers and consumers.

Table 2.3: Key Words; Innovative materials, innovative methods, innovative manufacturing technology

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Cheah, L., Ciceri, N. D., Olivetti, E., Matsumura, S., Forterre, D., Roth, R., Kirchain, R.	2013	Manufacturing-focused emissions reductions in footwear production	Manufacturing vs. Materials, Uncertainty, Footwear, Carbon footprint environmental impact	One purpose of the study was to determine the carbon footprint, or life cycle GWP of a pair of running shoes and to suggest strategies to reduce the product's impact. thereby contribute to carbon footprinting methodology.	This study analyzed the carbon footprint of a familiar consumer product, a pair of running shoes. It was determined that most of the emissions were released during shoes material processing (29%) and manufacturing phase (68). product.
Pantazi, M., Vasilescu, A. M.	2014	Assesment Of Leather And Leather Substitude Waste Biodegradability Under Aerobic Conditions In Liquid Environment	Biodegradation , material chrome-tanned leather	The aim of this paper is to comparatively study biodegradation under aerobic conditions	As a result of this study, it was found that vegetable-tanned leather has a biodegradation capacity of 84.6%.
Hanchevicia A. B., Albu L. Macovescu G., Coara G., Bucur E., Popescu, M.	2014	Pollutants Minimization and Innovative Monitoring Techniques Toward A Sustainable Leather Industry	Innoavtive technology, footwear industry, lca	In this paper, The new innovative technological and monitoring system for pollutants minimization, presented	Reduce the pollutants, facilitating the implementation of the EMS.

Table 2.3: Key Words; Innovative materials, innovative methods, innovative manufacturing technology

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Lin, L. Y., Chen, C. H.	2015	Innovation and ergonomics consideration for female footwear design.	footwear design; ergonomics; 3D printing; 3D scanning, Ergonomics consideration,	The intent of this study is to explore the potential of 3D printing female shoes and try to change the manufacturing procedure	3D scan is also helpful with 3D printing, the advantages to create accurate models. Compare to traditional manufacturing, 3D printing can provide a new process to produce footwear and decrease the producing cost and especially the producing time.
Hasan, I. Rashid, T., Arefin, S.	2015	An Analysis on the Sustainability of Different Soling Materials During Shoe Flexing Using FEA Method.	Outsole materials, Sustainability, Material properties	The study tried to introduce the Finite Element Method (FEM) into the shoe design process	it was found that TPR was the most sustainable soling material among them with high displacement magnitude, high strain von Mises and low stress von Mises
Richie Jr, D. H. Pribut, S.	2016	What's New in Running Shoe Technology? Computers, hi-tech materials, and design changes have led to improved footwear.	New Technologies, Footwear, sports footwear	This article will review three new technologies currently found in the running shoe market.	the recent trends in running shoe technology has potential direct repercussions on the way podiatric physicians treat the foot with custom orthoses.

Table 2.4: Key Words; Footwear, Footwear Manufacturing, Sports Footwear

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Boër, C. Dulio, S. Jovane, F.	2004	Editorial: Shoe design and manufacturing	Shoe, shoe design, shoe manufacturing,	The aim of the study is to explain the desing and manufacturing in mass production in footwear industry.	The project has led to a research effort that encompasses the development for each of life cycle phases, and of all the relevant critical technologies.
Özkan Hafızoğlu, Ö.	2005	A RESEARCH ON FOOTWEAR AND FOOT INTERACTION THROUGH ANATOMY AND HUMAN ENGINEERING	Foot, sportfootwear design, foot-footwear interaction, human engineering, comfort and performance	The main purpose of this thesis is to examine the footwear design from the human engineering point of view.	According to the result of the study, it is said that compared with the traditional design, human engineering considerations could be even more complex
IBISWorld Industry Report	2010	Global Footwear Manufacturing: C1321-GL	Foot wear industry	The report aims to provide statistical information about the global footwear industry.	According to the report, it can be said that consumers are less influenced by pricing and are more concerned with quality design, materials, finishing and brand image.

Table 2.4: Key Words; Footwear, Footwear Manufacturing, Sports Footwear

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Zhang, Y., Luximon, A., Pattanayak, A. Zhang, M.	2011	Shoe-last design exploration and customization Footwea r production	Customized shoe-last; parametric design; e-commerce; mass-customization; shoe-last design; custom footwear	This study proposed a system to enable shoe-last design changes, exploration and eventually enable mass-customization	Results of the study can be used to create a system for shoe-last design exploration and mass-customization system for individual designs in a cost effective manner
Sterzing, T., Lam, W. K., Cheung, J. T. M.	2012	Athletic Footwear Research by Industry and Academia	Athletic Footwear, Functional Footear Innovation, Science and Research Interaction Sport footwear	innovative structures, materials, smart technologies, and manufacturing methods have been used. *Science and research* takes a specific role prior and within the in-line product cycle as being capable to support the other departments at all stages of the product creation process.	Thereby, valuable benefits due to routine and specific interaction with science and research are pointed out. Athletic footwear research and testing is carried out at industrial and academic institutions with mutual interaction steadily increasing..

Table 2.4: Key Words; Footwear, Footwear Manufacturing, Sports Footwear

REFERENCES OF THE STUDY	YEAR	NAME OF THE STUDY	KEY WORDS OF THE STUDY	AIM OF THE STUDY	RESULTS OF THE STUDY
Ma, X., Luximon, A.	2013	Design and manufacture of shoe lasts.	Shoe last, design, manufacture, bottom pattern.	This aims to give a complete introduction to a shoe last. A shoe last is an aid model used in shoe making. Shoe technology in the modern footwear	The relationships between different parts of the foot and the shoe last are then explained.
Gillinov, S. M., Laux, S., Kuivila, T., Hass, D., Joy, S. M.	2015	Effect of minimalist footwear on running efficiency: a randomized crossover trial.	Sportsfootwear Running biomechanics; traditional shoes; minimalist shoes; foot strike; ground contact time,	When compared with running in traditional, cushioned shoes, both barefoot (socked) running and minimalist running shoes produce greater running efficiency in some experienced runners, with a greater tendency toward a midfoot or forefoot strike and a shorter ground contact time.	This study suggests potential immediate biomechanical benefits of minimalist footwear over traditional, heavily cushioned shoes in adolescent cross-country runners. By improving running biomechanics, minimalist footwear may improve running efficiency and performance.