Foot, footwear, flip flops and mass customization

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Introduction

The main aim of this study is to investigate, analyze and evaluate the foot and its different functions in order to understand how a pair of anatomic user friendly and absolutely tailor made pair of flip flops can be created. The main structure of the foot and its unique particularities as well as some basic ailments that can be partially cured by orthopedic footwear will be evaluated also. Thus the foot is analyzed mainly to understand how a pair of anatomic user friendly and absolutely tailor made pair of flip flops can be created. At the beginning we have a brief presentation of the flip flop history from ancient times until now while detailed historical facts and important milestones are also presented extensively. Afterwards, we move forward to evaluate and analyze the existing foot plantar pressure measurement and 3D foot scanning techniques. This way we can see how the up to date technology combined with traditional knowledge can contribute to a high quality accurate and totally personalized production flip flop design process. As a result, the mass customization applied in flip flop design and production consists of a major part of this study. In addition to this, mass customization is not the only major subject for investigation: another basic area for evaluation of the production of flip flops is the detailed analysis of the customer needs for footwear design. An analysis consisting of pure emotional and psychological evaluation of the user need not only for the designing and production process of the flip flop but for the whole marketing and promotion strategy of the product is essential. Thus, worldwide well-known methods of designing products according to the user’s emotional needs are being presented extensively along with famous examples such as kansei engineering and conjoint analysis. Finally, the study ends with a proposal for a tailor made 3D printed pair of flip flops. The proposal consists of views and recommendations for an accurate high quality 3D foot measurement of the foot and personal modifications customized to the user’s needs as well as material, color or pattern style and function customization for a more unique tailor made result on the flip flop. Last but not least, the procedure ends with the final fully personalized (“Tailor made”) product to be produced by the 3D printer. At the end, the product is packaged and ready for the end user.
Chapter 1

History of flip flop sandals

Flip flops are one of the oldest forms of footwear in modern history. The first flip flop ever made is estimated at around 1500 BC and is on display in the British Museum as the oldest recorded pair of flip flops. Furthermore, we can mention that the simplest form of a flip flop sandal originally appeared in ancient Egypt at around 4000 BC while flip flops is the oldest form of footwear still being worn.

Flip flops or Sagionares in Greek have been crafted with various types and qualities of materials throughout history. Thus, the main materials that have been used for the production of flip flop sandals are papyrus, palm leaves, straw, plastic and rubber. Here it should be mentioned that each tribe in modern history used her own materials for the creation of the sandals based on the raw materials of their homeland and the traditional knowledge of production methods. As a result, we can see that ancient Egyptians used papyrus and palm leaves mainly for their production, while the Masai of Africa chose rawhide (Pecheblu, n.d.). In India the main material selected was wood with the famous “Paduka” being the oldest and most exquisite example (Wikipedia, 2013). On the other hand, in China and Japan mostly rice and straw have been used due to the high amount of rice production in the area. In South America they have chosen the leaves of the sisal plant that provide twine for the production of their sandals. Finally indigenous populations of Mexico considered the Yucca plant as the best production material for their craftsmanship. In addition to this, we can mention that styles and forms were varying too from tribe to tribe especially with the different placement of the toe strap. As a result, we can see that Greeks used a strap placed on the big toe while Romans on the second toe. On the contrary, people from India have used the big and the second toe as well, while Mesopotamians have chosen the third toe.

In a basic research on the historical evolution of flip flop sandals, the Japanese Zori is considered to be a milestone. Zori is a form of flip flop with a thong held between the toes and is basically made out of rice straw. The first historical data for the use of Zori comes from Japan from at least the Heian period (794-1185). Years later in the 1950’s after World War II, American soldiers brought Zoris from Japan back to their country mainly as souvenirs. Thus Zori as worn by the Korean War soldiers has been considered as the precursor of the modern flip flop that really caught on during the 1950’s post war boom.

Later while flip flops were dominating the American “Pop culture” the product has been redesigned and transformed with the bright colors of the fifties design. As a
result, flip flops became famous examples of an informal lifestyle representing perfectly the latest Californian lifestyle and culture (Pecheblu, n.d.).

Another milestone in the historical evolution of the product was the creation of the famous “Havaianas” in 1962 from the Brazilian company Alpargatas. Havaianas has quickly become one of the most popular flip flop brands all over the world with sales of more than 150 million pairs per year. The Havaianas flip flops are inspired by the Japanese Zori and due to the high aesthetic adaptability to our times through the large variety of designs and color combinations, Havaianas has been placed among the best flip flop brands all over the world (Kathryn Cain, 2010).

On the other hand, the design of flip flops remains almost the same in the last decades and thus any product innovation relies on technology. As a result, we can see many flip flop companies cooperating with universities, podiatrists and medical associations producing together orthopedic flip flop sandals as an additional tool for curing various health problems such as chronic back pain, osteoarthritis, diabetes, plantar fasciitis and various other foot, leg or back pains. Finally, as recent studies have shown, even though flip flops are comfortable to wear in the short term, they are very dangerous for our health in the long run. Flip flops can cause damaging effects on your feet and according to the NHS of the United Kingdom injuries caused by the use of flip flops can cost up to approximately forty million pounds per year for medical treatment (Kathryn Cain, 2010). To sum up, we can see that flip flops are a broadly and commonly used means of footwear from ancient times through nowadays. Even though design and different forms have been created and various controversial arguments for their benefits and problems can be mentioned, flip flops were and still are an undisputable part of the global footwear design culture.
Chapter 2

Foot plantar pressure measurement and applications

Foot plantar pressure is a type of pressure field that interacts between the foot and the support surface which most of the times is the footwear insole. Most of the times plantar pressure is measured during everyday locomotor or sport activities depending on the nature of the foot problem. The obtained information derived from the various plantar pressure measuring systems is of major importance for various types of applications. Applications such as gait and posture research for diagnosing lower limb problems, injury prevention, sport biomechanics and footwear design as well. The main types of plantar pressure measurement systems are basically two, platform systems and in-shoe systems. Platform systems are made of: a flat rigid array of pressure sensing element positioned in matrix configuration on the floor to allow normal gait. Most of the times these type of systems are used for both static and dynamic analysis while there is the general protocol of the three steps for more accurate results. On the other hand, the second major type of foot plantar pressure measurement namely the in-shoe measurement system can be applied in a wider variety of studies due to the portability of the system. Flexible in-shoe sensors are embedded in the shoe in order to give us accurate results from the interface between the foot and the shoe. This system is highly recommended to evaluate orthotics and improve footwear design (Abdul Hadi Abdul Razan et Al, 2012). In addition to this, the measurement systems of plantar pressure identify and quantify foot areas of high pressure rates. In this way, the footwear designer has an accurate view of the root of the problem and as a result unique customized foot insole solutions can be given by many companies that are offering state-of-the-art technology in plantar pressure measurement systems. As a result, problematic foot areas can be pinpointed and cured by the appropriate insole design. Research has shown that plantar pressure can be reduced up to 50 per cent after the use of the right treatment. The whole procedure can be depicted through accurate high resolution images where areas of high and low pressure can be pinpointed in a clear color-coded display (Tekscan, n.d). On the other hand, we can now see that various systems and technologies have been developed from different companies in order to achieve high accuracy in plantar pressure measurement. Tekscan Inc. from South Boston, USA has developed various plantar pressure measurement systems. The f-scan system is an in-shoe plantar pressure analysis system that uses paper-thin sensors positioned inside the tested footwear in order to capture dynamic in-shoe pressure information unseen to the naked eye that can be easily summarized and quantified for a new product development. With foot pressure mapping systems
such as f-scan information can be given about the interaction between foot and footwear which can be very easily used for any scientific purpose. As a result, force, contact pressure distribution, and timing can be measured and quantified accurately contradicting the traditional visual observation of foot function and gait. Extremely thin and high resolution in-shoe plantar pressure measuring systems like the f-scan can provide high quality results and ensure accuracy of data for any scientific application. Applications vary from educational field to field and scientific area to area. As a result, we can discover that plantar pressure measurement can be applied to evaluate pathomechanics connected with foot dysfunctions and gait disorders. Of course, results can be helpful to enhance treatment outcomes and improve orthotic footwear performance in terms of design and quality of material improvements. Furthermore, detailed numerical data can depict the impact of orthotics on foot and gait biomechanics. This way, various leg, foot or other musculoskeletal problems can be prevented or partly cured.

In addition to this, various medical case studies can be examined in order to evaluate the impact of foot plantar pressure measurement in the treatment of foot problems and disorders. For example, case studies which detect limb length differences can be used to determine the proper orthotic modifications. Or other case studies like diabetic long term non-healing ulcer treated with the proper footwear and orthotic modifications. Other applications of the foot plantar measurement for medical causes can be mentioned, applications such as identifying and correcting foot disorders like functional hallux limitus or measuring gait asymmetries can be areas of major scientific importance in the medical as well as the design or the materials engineering scientific field. Summarizing, we can see that digital foot plantar measurement systems is not for sure an unnecessary technological luxury. It is a major scientific tool absolutely necessary for designing ergonomic orthotic footwear for medical and not only applications (Tekscan, n.d).
Chapter 3

Footbed and insole design

Footwear and as a result flip-flops are probably the most important parts of the human apparel. High biomechanical pressures and human body weights are loaded on the footwear and especially the footbed. That’s why the footwear has to be ergonomically comfortable with high quality hygiene materials in order to produce happiness and feelings of comfort for the user. Furthermore, although comfort and quality are very important factors for a customer’s choice the most important one is aesthetics. Surveys carried out by various researchers such as Chong and Chan in Hong Kong has shown that style and comfort are ranked very high in the customer’s decision making process higher than quality, price, and function or brand (Chong and Chan, 1992).

In addition to this, the design of other parts of the footwear is also very important. Insole design for example is fundamental for the production of the footwear and the design methods are similar for the flip-flops. Insole is the separate interior part of a shoe that is inserted in order to be the in-between surface from the footwear and the human foot. Of course in case we are dealing with flip flops the upper part of the flip flop plays the role of the insole. That is the main contact surface between the foot and the footwear (flip-flop). As a result, it is very important to be well designed and manufactured with the appropriate materials. Different types of insole design are created for different purposes, purposes like odor control, moisture control, arch support, cushioning and reducing foot pain or foot realignment. Insoles and as a result flip-flop surfaces can be classified into three main categories. Prefabricated, customized and custom made (Gonetilleke, 2010).

1) Prefabricated or also famous as off-the-shelf insoles are not customized and are manufactured to cover the totally basic needs of the user. This type of insoles or flip-flops are sold almost everywhere. At drug stores, grocery or even retail stores. They are mass produced and can fit almost any size.

2) Customized or also commonly known as modified insoles are actually prefabricated insoles with some added features adjusted to each individual case. Some examples are the additional layer of cushioning along the length of the insole for individuals who spend long periods of time walking or standing on hard surfaces such as concrete or even adding heel lift to the rear portion of the insole for those with limp length discrepancy. Another common modification is the metatarsal pad that is added to the forefoot region of the insole to redistribute forefoot pressures. Furthermore, one other modifiable feature is the addition of a heel lift added to the
posterior region of the insole to correct for an anatomical, leg length discrepancy or to treat Achilles tendonitis or ankle equinus.

3) Finally, custom made insoles or even flip-flops are fabricated from a partial or non-weight-bearing three-dimensional impression of the individual’s foot and require a prescription from a physician. Thus, custom made insoles are individualized for each patient and designed to change the function and the biomechanics of the foot during gait, or other discomforts caused by injury, overuse or disease. The final decision between the three categories of insole or flip flops is at the discretion of the health care provider and is dependent on a number of variables (Pedorthic Association of Canada 2008). To sum up, we can see that aesthetics and comfort are the two most important issues in the consumer’s choice for footwear (flip-flop) design. As a result, the three more basic categories of insole and flip flop design have been presented extensively in order to give the reader a wider view of the designing process of insoles and flip flops.
Chapter 4

3D Foot Scanning

Various types of surface 3D scanning systems that allow the depiction of the foot in a digital form are now commercially available. These type of systems can provide accurate 3D models of the foot shape and thus can be used in various scientific fields. Medical ergonomic and footwear development applications are the main fields of interest and due to low investment cost for the initial equipment it is easy to be acquired by almost every respectful institution or organization. As a result, rapid improvements and radical innovations can be made in the field of medical footwear through the creation of orthotic insoles while in the ergonomic footwear development new technologies and materials are used extensively. The rapid evolution of the 3D scanning systems provided our society the technological means for a new revolutionary way of designing and producing footwear products. Time consuming traditional ways of measuring the human body and foot especially have been overcome by foot 3D scanning. With the help of cutting edge technology 3D scanned anthropometric data bases have been created in order to depict and provide information about the human body and the foot especially and thus to be used in the designing and manufacturing process of the footwear. As a result, we can see surface 3D scanning systems playing an important role in the customized footwear market.

It is reasonable to mention the Finnish Left Foot company case. Left Foot Company is providing high quality mass customizing footwear. After extensive market research of the customized footwear we found that a custom made pair of shoes crafted by a shoemaker can cost from 1000 to 2000 euros per pair while a high quality mass produced pair of shoes can cost around 150 to 200 euros. Thus we can see that due to the fast technological evolution of the 3D scanner and printer there is plenty of space in the market for mass customization. Back in the Left Foot company case we can see that the company has chosen a mass customization strategy in order to have the production in Finland and fight Chinese low-cost products with a user centered strategy and improved quality. Furthermore, this way the company is avoiding the price competition by offering high quality exclusive services such as accurate and practical high quality fully customized insoles. Full footwear customization continues of course as another asset of the company. The customer can choose the color, the leather type, the outsole as well as the lining. Finally, a unique feature of the company is the opportunity of the client to have his name and customer number laser-printed onto the leather insole of the shoe. Considering the above results, it is obvious that the same method can be easily applied to any type of footwear and of course in our case to flip flop sandals (Sievanen et al, 2006). Going back to the 3D
foot scanning systems we can see that the applications of 3D scanning such as the customized ergonomic design of footwear and the foot orthotics and insoles have become widely available and relatively affordable. As a result, a surface scanning system can be acquired by an organization or institution with a price ranging from 5000 to 30000 euros. Furthermore the 3D digital models that are produced from the 3D scanners can be modified by a compatible software in order to correct and improve the foot form and as a result to create an appropriate foot orthotic or insole. In addition to this, the foot scanner and the 3D software as well, are totally compatible with the milling, CNC, 3d printer, rapid prototyping or any other computer controlled manufacturing system. As a result, it is economically viable, and strategically wise companies like the Left Foot company to create fully customized footwear solutions. 3D scanning systems can be separated into two main categories-scanners and digitizers. Scanning is the process where 3D images are converted to digital form using optical or video equipment while in digitizing the 3D model is traced and stored as digital codes on a computer. No other major differences between the two types lead us to analyze more. On the other hand, dynamic scanning is the scanning that is conducted in motion while static is conducted in a standing position.

3D scanners are also used to evaluate the quality of fit between the foot and the insole of the shoe. As a result, various types of foot orthotics have been created according to traditional as well as technologically advanced methods. Technologically advanced 3d foot scanning methods have been dominating the market from day one of their use. Although the technologically advanced methods are faster, cheaper and often more accurate the traditional methods they have not been extinguished due to the high modification freedom that they are offering to the technician. The technologically cutting edge of 3d foot scanning methods can easily and comparatively be faster to create the positive shape of the foot directly in a digital 3D model by scanning the foot on a digital matrix which can be easily modified and afterwards produced by various totally compatible 3D software and manufacturing machines. Furthermore, a second alternative for the foot 3D modelling is the foam system. In this case, the foot is placed into a low density foam box in order to create a negative matrix. Afterwards, the box is filled with plaster in order to have the positive part created or 3D scanned to directly guide the machining of the orthotic. In this way we have a fast and low-cost method of producing high quality and accuracy foot orthotics. Finally, even though the previous methods have almost instantly replaced the traditional foot orthotic production, we can find some small companies and especially some individual technicians using the historic old-fashioned method again. According to the traditional method, customized foot orthotics are created with the help of a plaster cast that acts as the negative part of a matrix on which the foot’s shape is accurately depicted. By this procedure, a positive cast is created that can be altered by either removing or adding plaster according to the orthotic demands. All in all, the whole procedure gives us a
connection to the footwear production history in a very romantic way reminiscent of the classic footwear tradition. (Telfer and Woodburn, 2010).

Chapter 5
Analyzing customer needs for footwear design

General facts and examples

Footwear customization is becoming a trend as can be seen in the recent examples of the Nike ID and the Mi Adidas (Nike, 2013) (Adidas, 2013). Since there is no harsh price competition due to the fact that the footwear manufacturing factories and the prices of the raw materials all over the world are specific, we can see that the competition now relies on the added value features that meet the emotional and psychological customer needs (Halliday and Setchi, 2009). Furthermore, fit is considered the strongest asset of footwear with aesthetics and functionality coming next. Footwear customization of course is a rising market with great potentials and footwear designers and manufacturers are competing for a market share in a developing market. As a result, a clear understanding of the customer needs and a clever application of these needs in the footwear design is absolutely necessary for a footwear company in order to be viable.

In various marketing strategy meetings the phrase “we want something eye catching” for the design of the product is very common. That is totally reasonable since aesthetics are considered the No1 factor during the buying process of the footwear (Au and Goonetilleke, 2007). As a result, the buying process is mainly dependent on visual satisfaction. Aesthetics are so important in the buying process that people often sacrifice physical comfort for psychological comfort, even when the risk of physical harm is obvious (Slater, 1985). The most famous example is the women’s high heel shoes which, when overused can cause various types of problems in the legs and the lower back as well. On the other hand a survey on 420 European customers have shown that the 63.1 % of the females and the 61.7 % of the males stated that it is very difficult to find a shoe with the “right” design (Piller, 2002). Furthermore, Au and Goonetilleke (2007) again discovered that both comfortable and uncomfortable shoes that people own have good aesthetics. Obviously we can see the tremendous importance of the footwear design in the product development process.

The second most important issue in the footwear buying process is comfort. Comfort is the release from unpleasant feelings, a state of ease and enjoyment with a
perspective to make life easier and joyful. Comfort is also considered partly physical and partly psychological. It can be physical in terms of a tangible stimuli and it can be psychological in terms of inner joy and fulfillment. Psychological comfort also relates to the appearance and the quality of the product that crucially affects the users image (Slater, 1985).

But how do we apply psychological and physical comfort to the product design process? Most of the times user’s physical and psychological needs are vague and hidden. As a result, a well-structured method in order to quantify and qualify these needs is totally necessary for a well-designed and commercially successful product. There are various types of methods from various types of cultures which can be applied to the design process. To name a few, there are quality function deployment QFD (Anao, 1990), conjoint analysis (Green & Srinivasan, 1990), voice of customer (VOC) (Griffin & hauser, 1993), and Kansei engineering (KE) (Nagamachi, 1992) (Lockman et al, 2010).

Methods for customer needs analysis

**Quality function deployment**

Quality function deployment (QFD) is a systematic approach to design based on a close awareness of customer desires, coupled with the integration of corporate functional groups. It consists in translating customer desires (for example, the ease of writing for a pen) into design characteristics (pen ink viscosity, pressure on ballpoint) for each stage of the product development (Rosenthal, 1992) (Creative industries institute, n.d). The main goal of QDF is to translate subjective quality criteria into objective ones that can be quantified, measured and be used in the design and manufacturing process of the product. This is a complimentary method for choosing how and where high importance issues are to be applied on the product development process (Reilly, 1999). Developed by Yoji Anao in Japan in 1966, QDF in Anaos words “is a method for developing a design quality aimed at satisfying the consumer and then translating the consumers demand into design targets and major quality assurance points to be used throughout the production phase”. QFD is a way to assure the design quality while the product is still in the design stage (Anao, 1990) (Creative industries institute, n.d).

**Conjoint analysis**

Conjoint analysis is a famous marketing method. Marketers commonly use it to choose which features of a new product should be prioritized during the design process and how they should be priced. Conjoint analysis is very famous due to the fact that it is economically affordable and very flexible to address results. Let’s see
an example in order to explain the method. We assume that we have to market a new tennis ball. After a market research and conversations with tennis players we realize that the three more important product features are average ball control accuracy, average ball life and of course price. Combining all the three issues in a matrix we can have results for the ideal ball. After identifying the ideal ball we will try to find the most viable product which lies somewhere in the middle in the product features matrix. Furthermore, with this method if we analyze two product features conjointly we will discover the buyer’s tradeoffs on the product characteristics. In this way we have a very useful tool that provides for analyzing and evaluating the design of the product during the product development phase and still remains directly connected to the marketing strategy (Joseph Curry, 1996).

The voice of the customer (VOC)

The voice of the customer (VOC) is a method for elicitation of customer hidden and unhidden needs. The method creates specific sets of customer needs organized in hierarchical structures and then set into priority lists of importance and satisfaction with alternatives included. VOC has four aspects- customer needs, hierarchical structure, priorities and customer perception of performance. The method also consists of both qualitative and quantitative market research steps. The most common application of VOC is at the beginning of a new product process or service design project in order to deeply analyze and evaluate customer wants and needs. VOC can also be used as a previous step of quality function deployment. The method is of very high importance during the product development process resulting from the detailed analysis of the customer needs that can be directly applied to the product design process and thus new innovative products can be born (Gaskin, Griffin, Hauser et al 2011).

Kansei engineering

Kansei is a Japanese term and it is used to express someone’s impression towards an artefact, situation or surrounding. In Japanese dictionaries kansei is referred as sensitivity, feeling and emotion. In psychology, kansei is the mental state where knowledge, emotion and sentiment are harmonized (Lokman et al, 2010). Kansei is considered as a higher mental function of the brain and it is closely related to functions such as feelings, emotions and intuition (Harada, 1998). In simple words we can state that Kansei according to its founder is the psychological feeling that people have with a product, a situation or a place (Nagamachi, 2003). As a result, we can clearly see that Kansei cannot be evaluated easily, accurately and directly. Actually the real Kansei cannot be measured but only the causes and the consequences of Kansei. Thus Kansei can be measured only by measuring sense activities, internal factors and psycho-physiological behavioral responses (Harada, 1998, Nagamachi 2003, Ishikara et al, 2005). Sense activities can be measured by evaluating the impact of a sense stimulus on brain activity. Responses can be measured by electromyography (EEG), event-related potential (ERP), Functional
magnetic resonance imaging (FMRI) or expressive body or facial expression (Lokman et al, 2010). Emotional response to products is of crucial importance for any designer or marketer in Japan especially after World War II when they invested a lot in product quality and innovation. As a result with the establishment of the Kansei method by the Professor Dr Mitsuo Nagamachi in the 1990’s, the product development process became more structured in terms of product strategy. Thus, with the implementation of Kansei methodology implicit customer needs can be identified and directly applied to the product development process. The implementation of KE involves several steps using tools and methods from different applied scientific fields such as marketing, psychology and statistics. The Kansei method consists of both qualitative and quantitative research steps. While the main types of the method are eight. Category classification, KE system, KE modeling, Hybrid KE, Virtual KE, Collaborative KE, Concurrent KE, Rough sets KE (Lokman et al 2010).

**Category classification**

Category classification is a breakdown technique from a targeted concept of a new product to the associated subjective Kansei to the objective design parameters. A famous example of this category is the development of the Mazda Miata (Nagamachi, 1999).

**KE system**

A Computer Aided KE system comprises databases to support a computer controlled system that handles the process of applying the consumers feeling and emotion to a tangible well designed product.

**KE modeling**

KE modeling is used to handle logic of kansei that enables to form machine intelligence.

**Hybrid KE**

While hybrid kansei is the type of kansei that enables iterative process from design element to kansei evaluation. Hybrid kansei has been used in the study of high heel design (Chen et al 2008) and can possibly be used in our case of custom made flip-flops.

**Virtual KE**

Virtual kansei now consists of kansei techniques that give the consumer the opportunity to experience the product in a virtual world.
Collaborative KE

In collaborative KE, designers and consumers in different places utilize a mutual kansei database and collaborate through a network to develop a new product design.

Concurrent KE

In concurrent KE, representatives from different departments in a company join together and perform kansei evaluation and analysis. The procedure consists of a holistic approach to the product design process from all the aspects from engineering to product quality and marketing.

Rough sets KE

Rough sets KE is the best type to deal with vague and uncertain kansei data. A representative example is the beer can design (Okamoto, 2007).

Kansei also consists of a product design dimension a phase of choosing very important design elements such as color, size, and the shape of the product. The procedure can be performed by using empirical method or qualitative technique. With the empirical method the process begins with the collection of the data that have visible differences in design from the existing product in the market. Empirical observation is performed to evaluate design elements and finally a kansei product can be created. On the other hand in the qualitative method a group of experts decide on the design elements relying on their experience and their skills to achieve design for a predefined concept of a new product. Last but not least, we have the kansei product. The kansei product is the result from the qualitative and the quantitative implementation of the kansei engineering method. As a result, the kansei product consists of an amalgamation of design requirements and experience from skillful product designers. There are plenty examples of successful kansei products such as the Mazda Miata (Nagamachi, 1999), the Boeing 7E7 interior design (Guerin, 2004) and the Sharp refrigerator (Nagamachi, 2007).
Chapter 6

Mass customization

Mass customization a few words

The global trade system and in particular the footwear industry has changed rapidly during the last decades. Price competition has been minimized and the competitive advantages of the products nowadays rely more on design and comfort for the individual user. A constantly increasing pressure for lower price competition deriving from the new market circumstances has as a result products of high quality provided at a low price especially from countries of the Far East and China. Thus as a result in order to have a reduced production cost major shoe and flip flop companies were obliged by the low cost competition to reduce production costs by splitting the production processes, outsourcing several production steps to the areas with lower labor cost and finally by organizing a global production and supply chain network. Secondarily an upcoming trend of the footwear industry deriving from the fashion industry driven by a few multiproduct oligopolies is offering except for comfort a clear high fidelity reflection of the personal identity of the user. As a result, more fashion conscious and clearly personalized shoe models have been identified in the footwear market (Piller and Muller 2004). In addition to this, shoe providers must develop new market strategies and try to invent new radical and innovative business models in order to achieve and maintain a clear competitive advantage. On the other hand, shoe and flip flop producers must focus more on the product quality improvement, the innovation in the design of the product and the use of the appropriate materials. Furthermore, it is equally important to focus on the consumers personalized hidden needs and quickly respond to dynamic fashion trends by offering fully customized high quality affordable products than simply offering goods. Thus mass customization follows heterogeneity among different customers in order to precisely meet individual consumer needs. This is also clearly indicated through the definition of mass customization itself: “the technologies and systems to deliver goods and services that meet individual customers’ needs with near mass production efficiency” (Tseng and Jiao 2001). The definition obviously indicates the two major goals of mass customization. On the one hand, providing products of high quality which is considered as satisfying consumer’s individual needs, and on the other hand, keeping the cost of the product as close as possible to mass production. Finally, with the elicitation of the individual needs of the customer by an interactive process, the specific information about customer’s hidden needs and desires is transformed into a real product or service (Zipkin 2001). Furthermore, with the interaction and configuration toolkits, the customers are able to express their expectations from the product and can also help in the product configuration process by pinpointing the product requirements on the physical product model. As a result, the customers can be considered as co-designers (Tseng and Du 1998).
Mass customization methods: style, comfort and function customization

Footwear and as a result flip flop customization can be divided into three different dimension categories, style customization, comfort customization and function customization (Boer and Dulio 2007).

Style customization

Style customization in footwear focuses more on the satisfaction of the various customer needs. As a result, issues like aesthetics and self-identity expressed by the style and the type of footwear are evaluated extensively during the style customization design process. In addition to this, the style and the design of the footwear and in our case flip flops is considered as a first class way for the customer to express his personality. Moreover, footwear in general can be considered as a key signifier of the wearer’s identity, individualism, ethnicity and personality. Furthermore, some types of “classic” footwear and also some “classic” flip flops often become “art” items for various users and sometimes even a social trend. Obvious examples are the all-time classic Converse All Star shoe model and the traditional Havainas flip flop model. All Star and Havainas as well have been a social trend in order for people and especially young adults and teenagers to express themselves. But expression and creativity isn’t limited only in the color and the style of the product. We have seen many times best friends or couples exchanging one shoe from a pair of All Stars or Havainas of different colors in order to indicate an emotional connection. Or even better we have seen many pairs of All Stars having written quotes and poems or even painted with drawings of personal interest in order to express the inner personality of the person. These examples are examples of footwear becoming a form of art and social communication, a role for a shoe or flip flop far beyond the traditional conservative way of thinking for a pair of footwear. Style customization expresses a customer’s personal interest and current fashion trends. It also offers to the customer the freedom to select the desired footwear or flip flop among a list of possible products based on the standard shoe design (Boer and Dulio 2007).

The style customization strategy is widely well-known and used by many large footwear producers due to the fact that it requires a very small amount of effort from both producers and customers. Style customization consists of high in design sales on the one hand but affects very little the manufacturing and production costs on the other. Most of the times style customization is conducted online through a footwear configuration process controlled by the customer. Very large footwear companies, such as Nike, Adidas, Selve etc. provide various different features in style customization with a similar participation on the part of the customer. In most cases, the customer chooses the customization among different styles, features, patterns and colors through a digital computer configuration toolkit either from the website of the company or in some specific cases from a physical retail store with the
contribution of a computer. The toolkit in most cases provides customers the opportunity to create their own unique version of the shoe model by changing colors, by adding patterns, graphics, text or simply by changing the materials on specific parts of the shoe. On the other hand, there is a major problem with the website method that most companies face. The sizing/fitting problem for example- if a customer is buying a shoe or a flip flop from a company for the first time it is very common to have a fitting problem since the same size can have differences from company to company. In order to avoid this phenomenon some websites are providing an extra feature with the sizing info in centimeters. This way the client can measure his foot on his own in centimeters and then choose online the right size to avoid sizing differences among footwear companies. Finally after the customer completes the configuration process and the customized model is fulfilling his emotional needs, an online purchase order can be made and then directly transferred to the manufacturer in order to have the production process start. Most of the times style-customized shoes can be delivered to the customer within a week or two and for hand-made customization even longer. As a result, delivering time is the final factor that can be improved in the style customization process (Ravindra S. Goonetileke 2013). Here we can add the example of the custom styled Havaianas where various designs, styles, colors and logos can be identified in order to fulfill any individual need even from the most demanding customer (Us.Havainas 2013).

Function customization

Function customization has the purpose to create footwear and as result flip flops also for every individual customer. This way and by maximizing every parameter in terms of techniques and materials the creator company is trying to meet the customer demands for the product (Boer and Dulio, 2007). Function customization has a unique character and way to operate. Many footwear manufacturers such as Nike and Adidas are creating footwear in this very interesting way. In addition to this, various scientific studies have been conducted from different designers in order to analyze the habits of star athletes in order for example to avoid injuries. Here we can mention a potential application on a pair of swimming pool flip-flops with advanced grip on the wet surface for example. Furthermore the main purpose of every type of footwear flip-flops is to optimize the user experience and offer the customer the highest comfort and protection at an affordable price. Another well-known example of function customization is the customization for medical purposes. For example functional customized shoes and flip flops can have major results in foot orthoses and in the personal health market. Research has proven that by wearing footwear the physical condition of patients with severe rheumatoid arthritis can be improved (Shrader and Siegel, 1997). On the other hand, most practices and techniques of functional customization are the same with comfort customization. The clients can order personalized footwear from an on-line digital shop and a real retail store as well.
Customized footwear from a digital store usually has only some specific predefined choices. Choices like under pronation, normal and over pronation for the Adidas running shoe selected from the Adidas virtual shop. Limitations like this are reasonable due to the fact that the majority of the population does not have in depth knowledge about technical and function customization issues. In a physical retail store for example the customer can use a dynamic measurement device like the foot scan stage in the Adidas flagship store. With this method the user can run on the foot scanner in order to acquire results about the runners running behavior and then produce accurately a comfortable and totally personalized product (Ravindra S. Goonetilleke 2013). Here we can mention some applications in flip flops as well, applications like flip flops for foot orthoses or flip flops for the diabetic foot.

**Comfort customization**

Comfort customization in footwear is to purchase a pair of shoes or flip flops with the main purpose to make the customer feel comfortable and well fit (Boer and Dulio, 2007). There are two main type of approaches in order to measure the foot and thus make the wearer feel comfortable. The first is the measurement of the static foot shape, with lengths, widths, heights and girths of feet included (Witana et al)

The second is the dynamic shape measurement of the foot in motion. Most of the times the foot deforms during walking or running and as a result a common solution is to analyze the foot motion in the starce phase of the gait cycle (Kimura et al, 2011)

Comfort customization is following two main approaches custom fit and best match fit (Boer and Dulio, 2007). Custom fit is used to exactly and accurately tailor a last and a shoe. On the dimensions and the morphological data of the customers foot. Most of the times custom fit shoes or flip flops are made by a craftsman in order to fit the individual customer by carefully measuring the feet and manually constructing the shoes. Even though this traditional way is the most accurate very few luxury footwear producers work in this way. Most companies are adopting a middle solution of a best matched fit.

With the best match fit strategy we are choosing an “ideal” shoe last, focusing especially on comfort and functionality. This way we are avoiding to produce a very expensive tailor made product based on a high production cost fully personalized last. Alternatively we use for the production of the footwear individually adjusted lasts. With the best match fit method we achieve an equally distributed combination of comfort meeting even the higher customer demands. Comparatively to custom fit we have a lower cost in designing, selling and manufacturing procedures (Ravindra S. Goonetilleke 2013). In addition to this, the real differences between a custom fit and a best match product are very difficult to be identified. Actually the result is almost the same but with the best match fit strategy being superior in terms of cost minimization. Finally, we can see that comfort customization focuses more on the design of shoes and flip flops of high quality. The ideal customer is a person who
wants his footwear to reflect his personal identity. These types of people are willing to invest time and money to acquire a well fit product that improves their personal image. Large custom-made footwear producers like the aforementioned Finnish Left Foot Company are customizing shoes for comfort fit that are sold through real stores instead of virtual ones. In the shop sales people are using foot scanners to accurately measure the dimensions of the customers feet, save data and identify sizing problems like differences between the left and the right foot. On the other hand, in the field of flip flop custom made production we have the famous Havaianas example where the things are not working exactly in the same way. The whole procedure is conducted online on a digital platform (e-shop). The first step is to choose a category (men/women/kids) size and quantity of the desired pair of flip flops. Secondly, we choose the color of our preference among a list of twenty fancy colors. In the third step we choose the strap color of our choice among 18 color combinations while the price updating is conducted this time after the end of each step. Finally, in the last fourth step we optionally choose up to four flip flop decorating pins from a list of 30 different designs, patterns and colors. Last but not least, our creation is ready for the final checkout with three images from different angles and with the ability to enlarge. Additionally, an order summary and a final price list are available to the user before the final checkout (Us Havaianas, 2013).

In addition to this, many companies are offering another type of mass customization in flip-flops namely custom sand imprint flip flops. Custom sand imprint flip flops are created in the same way that ordinary non-customized are created but they have a “mirror” engraved logo, motto, quote, name or date on the bottom of the flip flop. This way the user can express himself with creativity by printing on the sand different logos, mottos, quotes, names or dates. The same method has been used by various companies such as HSBC, Nokia, or Foster’s for promotional reasons. The product in reality advertises the company by sand printing the logo on every footprint. This way we have invented a unique creative advertising method for every company or brand.

Furthermore, there are online companies providing this type of custom sand imprint flip-flops such as the website company www.flipsidez.com. In this website any type of sand imprint flip flop customization can be achieved. We can create promotional flip flops for other companies, we can create anniversary and wedding flip-flops for couples, and of course anything else that the user imagines can also be imprinted on the flip flop. The website user interface is simple to use and clear to understand on first sight. Three main steps and a fourth final one make up the whole procedure. While additional predefined solutions from previous choices are proposed as featured designs, designs like wedding name & date, famous quotes or anniversary dates. Furthermore, another predefined list of best sellers is provided to the user for an easier and faster choice.

On the other hand, if we follow the path of a totally customized solution, the procedure will begin with the first step which is to choose the size and the color of
the desired pair of flip-flops. Here we can see two basic choices for the material of the product firstly, a premium multilayer sandal choice and secondly, a single layer rubber flip flop choice. The first choice has a retail price of 24.95 US dollars while the second has a price of 19.95. Furthermore, 10 different colors are available to the user in order to select the color of preference. In the next step after the selection of style and color we select the size. Various choices are available for every gender as well as an international size chart. In the third step there is a feature in order to add the desired text or logo on the flip flop, customized logos or designs are also a potential choice. Finally at the last fourth step we can add some popular symbols or send our own customized one. The flipsidez example is one of the examples of style customization for personal or promotional reasons. Many other companies are offering similar solutions and of course many other crazy and creative ideas can be added in order to enhance and enrich style customization of flip flops (Flipsidez, 2012).

In addition to this, mass customization has other various extensions in many scientific fields such as marketing and consumer psychology. Martin Schreier from the University of Bocconi quotes on the “pride-of-authorship” effect. When consumers are being active co-creators of a product, their involvement in the procedure creates added value to the product due to the fact that their contribution in the procedure raises feelings of enthusiasm, uniqueness, creativity and joyfulness. As a result, the participation of the customer in the co-design process can be considered as a creative problem-solving activity and this way can become a motivation to order a tailor made product. Furthermore, studies in marketing have proven that the flow which is essential during the customer’s participation in the co-design process increases satisfaction and joy. Thus the “ideal” user experience can be achieved when the customers participating in the process feel an inner balance between their skills and their contribution to the co-design toolkit. As a result the usability of the toolkit is highly interconnected with the customer’s satisfaction during the process. All in all it is clearly proven by different scientific fields that mass customization can be considered as a major competitive advantage for most companies and firms. Thus the strategy of mass-customization can be a subpart of a larger competitive advantage strategy and of course one of the main axis of the company’s sustainability.

Somewhere here it is very important to mention one of the most common mistakes of mass customization strategies. A mass customization strategy in many cases is not mass customized in order to suit the needs of each specific company. As a result we have a vague and general strategy applied without identifying and improving the specific weak points of each company. As a result there is no one correct path for mass customization, every company customizes its own mass customization strategy (Walcher and Piller, 2012).
Now in order to apply these mass customization strategies we mainly use three strategic capabilities namely solution space development, robust process design, and choice navigation.

In solution space development the first priority and the most important factor is the ability of the company to research, analyze, and deeply understand the hidden idiosyncrating needs of the customers. A fact that contradicts with the strategy of the mass-production for fulfilling vague and general periodically changing social needs and trends. Furthermore for a successful mass customization, solution space development strategy product features and characteristics should be closely interconnected and interdependent with the customer needs. As a result the company can deeply understand what the end user actually needs and create the product accordingly. This way the “solution space” can be clearly defined for what is going to be produced and what not.

On the other hand, the second mass-customization strategy is robust process design. In this strategy it is crucial to secure that the vague, personalized and hidden indiosyncrating needs of the user do not affect the interrelated average performance of the supply chain. As a result, it is obvious that the large variety of different user needs and the user centered mass-customization strategy must not affect the crucial firms operations or the supply chain. Thus a robust supply chain design approach is totally necessary in order to reuse and recombine the already acquired organizational and supply chain resources in order to meet the various individualistic user needs. Thus robust design process offers mass-customized solutions that can nearly meet mass-production precisely and accurately.

Finally the last mass-customization strategy is choice navigation. With choice navigation the company motivates the users to identify their own problems and create their custom made solutions within a simple and functional virtual environment. If the company does otherwise and exposes the customer to a large variety of choices the cognitive cost of the evaluation can be hugely increased and of course the customers can be more easily confused. If we work this way and offer a huge variety of products and subsolutions then it is more likely that the users will postpone or suspend their buying decisions. As a result it is absolutely necessary to create a simple and functional product selection process (Piller et al. 2012).
Chapter 7

Proposal: “Tailor made 3D printed flip-flops”

After extensive research during the composition of this dissertation on foot, 3D foot scanning techniques, mass customization on style, comfort, function and of course 3D printing, we proceed to formulate a proposal for tailor made 3D printed flip-flops. The whole process is inspired by the existing footwear mass-customization systems on style, comfort and function applied of course uniquely to the flip-flop area.

To begin with the first step of the process is the well-known 3D foot scanning method. In this phase a customer has to visit the real actual store in order to have his foot 3D scanned and acquire his own unique digital footprint. After acquiring his footprint, the customer can be informed from the store about size differences between the two feet, specific common foot problems like flat feet or more medical conditions like the diabetic foot. In the next step, the client can actually see the “negative” of his digital footprint on the PC screen and thus let the store know about any modifications or changes. This way the user co-creates the upper part of the flip flop in an anatomic way. If we are dealing with flat feet we can give additional height on the middle part of the sole and likewise for any foot problem or disorder. After the final “negative” of the flip flop is created, the user can decide on the thickness of the sole. If it is for women for example that sometimes want to look taller, it can be higher, if it is for a heavy body of a tall man it can be shorter and more flexible. After the upper part, the sole and the lower part are ready in terms of form and dimensions, the user can choose the required material. A wide range of materials can be offered with only one limitation- the compatibility with a 3D printer. This way the user can choose up to three different materials for the lower part of the flip flop. A natural material like cork for example for the upper that comes in contact with the foot, a synthetic material with low price for the middle body of the sole in order to keep the production cost low, and a high quality and durable material like rubber for the lower part that comes in contact with the ground. In addition to this, another style customization this time can be applied easily. In order to make our flip flops totally personal, unique and reminiscent of a specific time period in our lives we can add the sand print feature. With the sand print feature letters, numbers or patterns and logos can be mirror engraved on the lower part of the flip flop. This way the flip flops are leaving a name, quote, date or stamp on the sand with every step resulting in an extremely funny and creative phenomenon. Furthermore, various colors are available for every part of the flip flop sole. The whole designing and mass-customizing process is conducted online through a central online system connected directly with the production and thus the 3D printing system. In order to get to the final product, the digital model should be created first. As a result, after the creation of the sole and the selection of the desired colors and materials, we pass to the design process. The user can choose one of the predefined designs according to his foot dimensions, his gender, and personal taste, or create his own at a real retail
store with the help of the staff. After choosing the desired design for the sole, the same procedure also starts for the strap. Selection or creation of the strap design, color, material etc. On the strap additional different designs can be added on designs like diamond cubes, skulls, hearts, stars and other predefined symbols that express the user’s feelings and personal needs. In addition to this, after the selection of colors design and materials for the strap and the sole is conducted, we can have a style personalization.

Style personalization is acquired through the selection of different patterns and color combinations as well as through sand imprint customization. Different color combinations on the flip flop can easily express the user’s feelings and personal taste. Furthermore, flag colors or any other symbol that represent the user can be added in order to have a user representative fully customized product. Finally, with the sand imprint feature, the tailor made product can go one step further where famous quotes, symbols or even important dates can be added in order to make the pair of flip flops totally reminiscent of places, people and important life stages. This way a simple pair of flip flops can become an extraordinary gift or a collector’s item for specific important events in people’s lives.

Finally, the last part of the process consists of the 3D printing procedure. After the final design is finished digitally the digital file is transmitted to the 3D printer. The required material is loaded on the 3D printer, the procedure begins and the flip-flops begin to be created layer by layer. After the creation of both parts of flip-flops the final assembly of the product is conducted manually. The additional accessories are positioned on the strap of the flip flop and the product is ready to be packaged. A smooth woven shoe bag is the first packaging step with the client name printed on it. Last but not least, the final step before the delivery of the product is the natural recyclable exterior packaging with the production number printed on the package as well as on the flops flops. Thus the flip-flops are ready to be delivered to the user totally customized and with an anniversary character as well.
Step 1

The process begins with a high quality 3D scanning of the customer’s foot at the retail store from an experienced shop assistant.
Step 2

The customer can view his personal digital footprint on the pc screen and with the help of an experienced shop assistant create and modify a digital model.
Step 3

The customer can choose the desired material for his fully tailor made flip flops with the only limitation for the material to be compatible with the 3D printer.
Step 4

At this step the customer can add sand imprint personalization in order to have a name, quote or date printed on the sand while he walks additionally he can also choose color.
Step 5

The design and the pattern printed on the flip-flop can be chosen by the customer at this step.
Step 6

The personal style of the customer can be expressed also here with style customization in color combinations and additional accessories.
Step 7

The 3D printing process begins with the customer watching his tailor made pair of flip-flops be created layer by layer.
A natural fully recyclable high quality limited edition package with the name of the user and the production date on it is the final step of the process before the product reaches the user.
Final conclusion

As we have seen, the recent technological innovation in the 3D foot scanning and measurement techniques have brought radical changes to the footwear production industry. Changes that are not only limited to an experimental scientific stage but also expanded to every day cutting edge innovations that have altered and recreated the form, the function, the design, the production methods, and the marketing techniques for an innovative and successful product.

Namely, starting with a more technical aspect, the rapid technological evolution in the 3D foot scanning and printing process, as well as the innovative foot plantar measurement and foot bed and insole design systems provide the advanced technological equipment for the production of high quality flip-flops. Continuing with the more theoretical, for example, the up to date scientific methods for the customer needs analysis were presented. Methods like (QFD) Quality Function Deployment, Conjoint Analysis and (VOC) Voice of the Customer focus more on the marketing aspect of the product development process. Furthermore, more engineering based methods like the famous Japanese Kansei engineering method contribute to the product development process from the product design point of view based on user emotion.

According to the research presented, equally important results came to the surface from the scientific evaluation of the mass customization process. It has been proved that mass customization is a mix of art and science combined to provide user centered tailor made solutions for products in general and flip flops in particular. The results have shown that mass customization has two major goals. Firstly, to provide products of high quality that satisfy customer needs and secondly, to keep the product cost at the closest possible amount to mass production. It is my belief that in this way the user acquires a major role in the product design process and as has been mentioned by various scientists, the customer thus becomes a co-designer. Finally, to sum up, a proposal for a tailor made 3D printed pair of flip flops is provided. The results have shown that the markets nowadays are full of every type of product at almost any quality and price. Thus, a fully tailor made product, in our case a pair of flip flops at an affordable price, can have huge market success.

Based on the previous results, I propose a combination of both physical and virtual retail stores. We have seen that a customer can visit the physical stores to 3D scan his foot and afterwards digitally modify the produced model to anatomically match with his personal footprint needs.
However, in the virtual e-shop the customer can continue the mass customization process with style customization and modifications. After the product is virtually style customized and the materials have been chosen, the 3D printing process begins with the user expecting a fully tailor made product of high quality.

In conclusion, the main reason I have chosen this proposal is because I wanted to combine the quality and comfort of anatomic flip-flops with the style, attractiveness and trend of the most fancy and colorful flip-flops worn by celebrities. As a result, a fully customized solution is provided even for the most demanding customer for both anatomy, comfort as well as attractiveness, aesthetics and style. The choice is yours.


Creative industries research institute, product brief development tools AUT University, Quality function deployment n.d.

Gaskin, Griffin, Hauser et al VOC Encyclopedia 2011 [pdf]


Mi adidas Customizable shoes, Apparel & Accessories adidas.com, 2013 [online] Available at :<http://www.adidas.com/us/custom/_/N-1z12gjj>


Okamoto, R. H. (2007); Comparison between statistical and lower / upper approximations Rough Sets models for beer can design and prototype evaluation. The 10th International Conference on Quality Management and Operation Development (QMOD '07), Sweden: Linköping University Electronic Press, ISSN 1650-3740.


Reilly, Norman B, The Team based product development guidebook, ASQ Quality Press, Milwaukee Wisconsin, 1999

Rosenthal, Stephen R, Effective product design and development, How to cut lead time and increase customer satisfaction, Business One Irwin, Homewood, Illinois 60430, 1992


Appendix

Traditional Zori from rice straw

Natural palm leather flip flops
In-shoe foot plantar pressure measurement system

Mat foot plantar pressure measurement system
Custom made insoles

Custom made footbed
3D foot scanning system (Digital)

3d foot scanning (actual)
Kansei engineering methodology

Source: Schütte (2005)

Kansei Engineering System (KES)

Psychological Feeling (Kansei)

Source: Nagamachi (1989)
Custom sand imprint flip flops

Havaianas make your own