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REDESIGNING SUPPLY NETWORKS TO PRODUCE SUSTAINABLE AND FASHIONABLE FOOTWEAR

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Abstract

Based on case study research, the paper compares fashion and orthopaedic footwear best practices to develop an innovative reference model that supports fashion footwear supply networks to meet the needs of specific consumers (such as elderly, obese, disabled, or diabetic persons), by producing small series of sustainable and fashionable footwear.

Keywords: Supply network; Footwear; Fashion; Sustainability.

1. Introduction

This research is part of CoReNet, a European 7th Framework Program project, whose objective is to address the needs and expectations of specific target groups – elderly, obese, disabled and diabetic people – by improving the supply network structure of the European Textile, Clothing and Footwear Industry (TCFI) to supply small series of functional and fashionable clothes and footwear paying particular attention to eco-compatibility.

The paper particularly focuses on the European Footwear Industry in order to develop innovative methods and tools to fulfil needs and expectations of the target groups.

Nowadays, the EU's population is over 500 million people and project target groups cover an important part of it since elderly persons (over 65) are 17% of the overall population, obese people 26%, diabetics 10% and disabled people 10%. Furthermore, overweight people are 50% and people with reduced mobility are more than 40% of the population (European Commission, 2007). Also considering overlapping among the target groups (e.g. many obese people are also diabetic) they still represent an important share of the population.

The combined effects of labour intensity, low entry and exit barriers, and changes in international trade regulations have made Footwear a global industry where competition is planetary and key players are no longer concentrated only in Europe and North America but located in emerging low labour cost countries (Gereffi, Humphrey, and Sturgeon 2005). Small firms have struggled to survive, often unsuccessfully, and have been progressively

weeded out (Leonidou 2004). Moreover, the overall performance of this industry is deeply affected by unpredictable and seasonal demand as well as emerging consumers' needs in terms of comfort, health and environmental attention.

This context forces companies to rethink their strategies. The production of small series of specialized and customized high value added products for the project target groups represents a key opportunity for European Footwear Small Medium Enterprises (SMEs) to foster their competitiveness entering new niche markets.

2. Literature Review

Competition within the footwear sector is nowadays among global networks and key issues are how to develop and implement innovative managerial models and methods to support collaborative practices (Dyer and Singh, 1998; Camarinha-Matos, 2010). The new paradigm of demand-driven supply networks (Childerhouse et al. 2002; De Treville et al. 2004) emerges as a collaborative scheme to better respond to consumers' direct signals and needs. Moreover, as Adler (2001) effectively discussed, the new enlarged/extended structures, characterized by high cognitive content exchanges, can no longer be coordinated by traditional hierarchy/market instruments as they require trust to share knowledge and leverage on external, updated and complementary competencies (i.e. Open Innovation model).

After a deep analysis of some of the most important supply network reference models present in literature –among others Value reference model (www.value-chain.org/value-reference-model), V - the SMART model proposed by Filos and Banhan (2001) has been selected as a starting point to develop the reference model for footwear supply networks. The SMART model allows to define practices and performance of networks according to the following three main dimensions:

1. Knowledge dimension – to map partners' competencies to be shared within the network

in terms of products and processes;

2. Information & Communication Technologies (ICTs) dimension – to support the requirements for the implementation of ICT services at different process levels along the network;

3. Organizational dimension– to provide specifications of the organizational changes for SMEs for structuring supply networks for small series production.

In order to develop the Reference Model for the Fashion Footwear European companies we update the model proposed by Filos and Banhan (2001) with another dimension, coherent with our purposes, the Sustainability dimension, to support the enterprises in the developing of a eco-compatible approach for their products and processes.

These four dimensions are then used in the following paragraphs to classify literature and analyse cases studies.

Another important concept is the fundamental dimension of the Best Fit that has been considered as a transversal one of the four main dimensions of the reference model. Best Fit has been defined by Yeung, Choi and Chiu (2010) as an intermediate level of customization where product are created specifically to address particular needs (generally modifying both structure and materials).

Fashion Footwear

Fashion sector is characterized by volatile product demand and need of quick planning and production. Footwear in particular presents a really fragmented and rigid scenario, constituted by many specialized knowledge intensive companies most of the time grouped in industrial cluster. Each phase of their production processes is deeply characterized by traditional approaches always oriented to batch quantities and local maximization (Piller et al. 2003).

Carpanzano and Ballarino (2008) support that a huge effort is necessary to drive improvement: major introduction of information technology and automation, on one side, and

integration among different actors and technologies in a network of real time collaborating enterprises, on the other, are some key factors to be achieved to respond to daily challenges, and to face the global competition.

Recently there have been published many papers discussing technological innovation in the footwear sector both in terms of automation and in terms of monitoring and real time control (Carpanzano and Cataldo, 2003; Boer and Dulio, 2007), especially with reference to mass customization.Beside technological improvements in the footwear sector, collaboration mechanisms have been studied in the recent years in order to propose paths to increase value along the supply chain (Fornasiero et al., 2009, Boer and Dulio, 2007) and to implement the mass customization paradigm (Fornasiero et al., 2010).

Orthopaedic Footwear

Most of the literature on the orthopaedic footwear is related to clinical aspects of foot pathologies, discussing different types of resolution for them. Referring to CoReNet target groups (diabetics, disables, elderly and obese persons), Pinzur et al. (2005) have dealt with diabetics' people problems with foot care and shoes. Burnes and Lees (2002) investigated elderly people on a general rehabilitation ward wearing incorrectly sized shoes and looked for the presence of complications. Jannink et al. (2006) effectively studied the use of orthopaedic shoes in patients with degenerative disorders of the foot (disable people).

Van Netten et al. (2010) also investigate the adoption of custom-made orthopaedic shoes and the association between their use and the most relevant aspects of their usability.

An important research field emerged in the last years deals with the improvement of technologies (both hardware and software) that could better address patients needs, and their functional and fitting requirements.

Chen and Lord (1995) compared the trial shoes and the fit shoes techniques for the assessment of the fitting; while Kos and Duhovnik (2002) proposed a fitting measurement

system that firstly scans customers' feet and secondly suggests best-fit shoe models from a shoe database. Finally Luximon and Luximon (2009) present a shoe-last model based on foot shape measurement data and foot biomechanics that includes comfort and fit aspects as well as design aspect, and therefore enables design of aesthetical comfortable shoes. Since the design can be modified instantaneously, the designers could visualize design changes leading to a reduction in shoe-last design cycle.

However, there is a lack in the literature concerning the study of the processes within orthopaedic companies and the best practices applied along the orthopaedic footwear supply network. This paper starts focusing on these topics.

Table 1 summarizes the literature analysis, where research contributions are organized along the four main principal dimensions at network level (i.e. Knowledge, ICT, Organizational and Sustainability) to get Best Fit to supply small series of preventive healthy and fashionable shoes.

Then, the four principal dimensions are detailed into some sub-dimensions that can help investigation of the research goal. The blue and the green fields represent dimensions and sub-dimensions that are not covered in the published literature.

			TRASVERSAL DIMENSION		
			Best Fit		
			Context Literature	Fashion Footwear	Orthopaedic Footwear
PRINCIPAL DIMENSIONS	KNOWLEDGE	Specific Customer Requirements	x	x	x
		Production Process	x	x	x
		Innovation	x	x	x
	ICT	Design	x	x	x
		Production and Control	x	x	x
		Integrated System	x	x	
	ORGANIZATIONAL	Operational Decisions	x	x	
		Strategical Decisions	x	x	
	SUSTAINBILITY	Product	x	x	
		Process	x	x	

Table 1 – Literature Review

Interconnection between Fashion and Orthopaedic Footwear

The research of the interconnections and interfaces between fashion and orthopaedic footwear is an unexplored field. Indeed a first step to be implemented in the CoReNet project was to understand what fashion companies can learn from orthopaedic footwear industries' experience in the sector. This way footwear companies producing fashion products might shift to healthy and eco-friendly products where personalization gains a central role in order to met sector's crisis and catch a good market opportunity.

3. Research Methodology

The main objective of the research is to develop an innovative Reference Model for the Fashion Footwear SMEs that encompasses the best practices both from the Orthopaedic (the sector that actually supplied the target groups) and the Fashion Footwear sectors and helps to

transfer knowledge between Large and SMEs to supply small series of preventive healthy and fashionable shoes.

To achieve this goal, first it was analysed the existing literature on the footwear sector, underlining some gaps in the studies of orthopaedic footwear supply chains.

Then was conducted multiple case studies, as an explorative method to analyse the new research field, within fashion footwear companies and orthopaedic providers and to single out and investigate distinctive practices and processes.

The sample was selected through the adoption of the theoretical sampling (Glaser and Strauss, 1967). The approach was followed by multiple investigators in order to reduce bias and create more reliable data (Eisenhardt, 1989; Yin, 1994; Pagell, 2004). We select the sampling basing on the matrix reported below (Table 2), in which we identified different companies belonging to the two sectors (Fashion and Orthopaedic Footwear), in addition we have considered the dimension of the enterprises because of the transferring of knowledge between Large enterprises and Small and Medium Enterprises as an objective of the research.

	Fashion Footwear	**Orthopaedic Footwear**
Large Enterprises	X	X
Small Medium Enterprises	X	X

Table 2 – Sample selection

An "as is" business process analysis was conducted through focused interviews and the construction of BPMN (Business Process Modeling Notation) diagrams. This form of representation permitted to collect and formalize a rich set of data, both qualitative and quantitative. Furthermore, the requirements of each company were pointed out and analysed in detail to draw the relevant characteristics, procedures and techniques along their supply

network.

Afterwads a within-case analysis was developed where each company have been analysed singularly, followed by a cross-case analysis within each sector. It was analysed each sector basing on the three dimensions of the SMART network model (Knowledge, ICT, Organizational) together with the Sustainability dimension. Finally a cross-case analysis between the two sectors (Fashion and Orthopaedic) was conducted in order to compare and analyze the differences and the similarities between the sectors. The four main dimensions have been applied to proof whether the relationships identified in one project could fit also in the others. As suggested by Eisenhardt (1989), pairs of cases have been compared to investigate similarities and differences among our cases. Finally, existing literature and results from the field have been analysed to provide a further validation of our findings.

4. Case analysis

4.1 Fashion Footwear

Within-Case Analysis

For the analysis of the fashion footwear sector we refer to both existing literature and to direct case studies covering a producer of highly refined women shoes, a producer of special shoes components (customized insoles) and a producer of customized shoes. Indeed in this sector, the most important competitive advantage seems to lie on the design and know-how owned by the company in the footwear fashion market and by close collaboration with fashion stylists and generally with suppliers which are involved from design to production.

	company A	company B	company C
Company dimension (turnover)	43 m€	5 m€	42 m€
Company dimension (staff)	96 employees	10 employees	100 employees
Number of partners (suppliers, outsourcers)	100	20	90
Number of pair of shoes produced per year	500.000	10.000	300.000
Number of customers per year	2400/2500	-	1500
Average order dimension	5-600 pairs	On demand	500 pairs

Table 3 – Fashion footwear companies involved in the case studies

Company A is a worldwide company operating with own brand in the footwear fashion market, which main products are highly refined shoes for women. Company A exports 65-70% of its whole production; the market covered are mainly Italian and European markets (Italian and European markets 80%); the production is around 500.000 pairs of shoes for the winter and 250.000 for the summer-collection. The production greatly affected by seasons and trends.

Company B is a specialized laboratory in which the shoes are completely customizable. They perform internally all the phases of their production process starting from the designer, stylist arriving to the final product. The production process is completely automatized.

Company C is similar to company A, with a different position in the supply chain topology, since it belong to a big Japanese group that distribute shoes all over the world.

Cross-Case Analysis within the Fashion Footwear

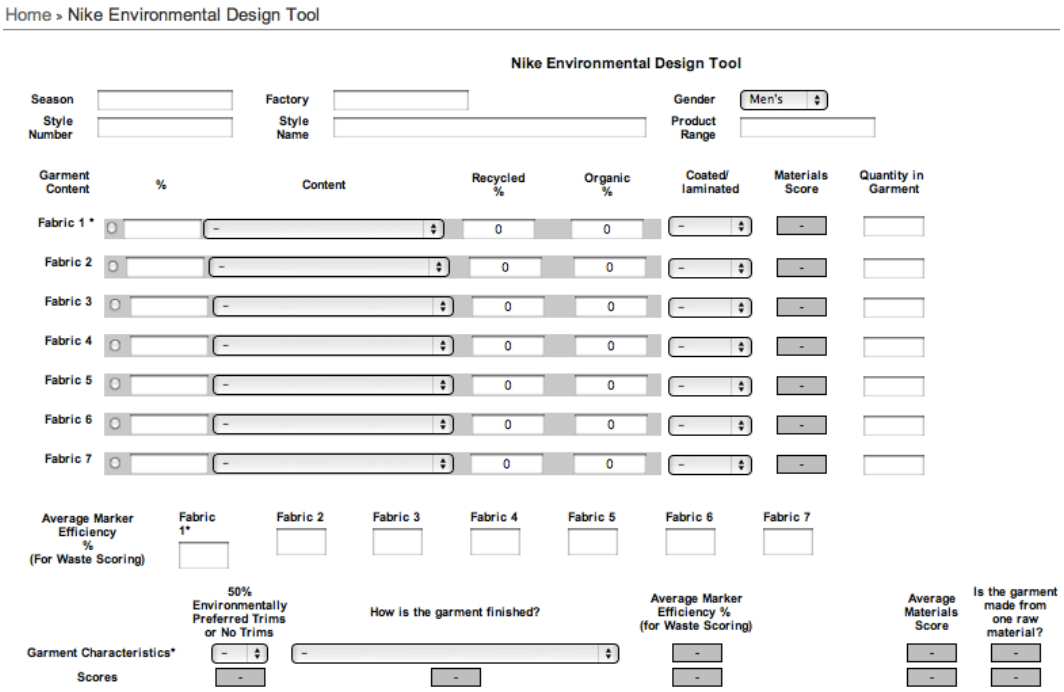
Knowledge: innovation is strongly customer driven, and especially in the latest years companies started to work smaller lots with a higher level of customization (both based on aesthetic and functional features) to face competitively the market. Evolving customer needs influence production with requests of personalization and customization of components

and/or the materials, but not the structure of the products according to the best fit approach. Design capabilities and know-how on production owned by companies represent an important competitive advantage for them.

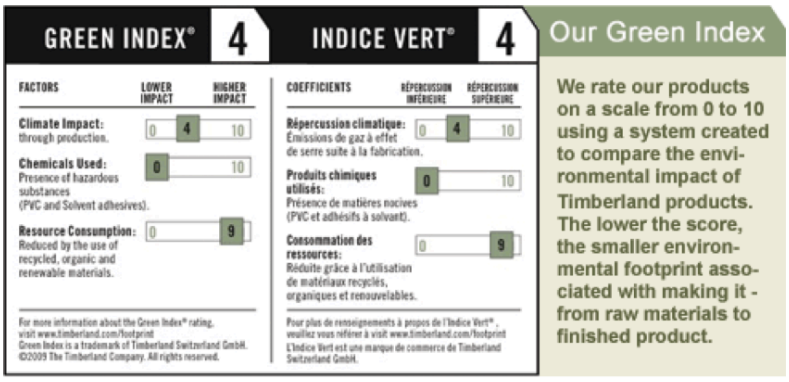
ICTs: manufacturing processes of fashion footwear companies are more and more supported by CAD based design starting from the 2D drafts to 3D development of models and size. Through identification of landmarks, CAD translates drawing into operations that machinery has to carry out. Other production activities are also supported by IC technologies, for example the laser cutting and leather marking. However, several other phases, particular within the smallest companies, are still characterized by traditional approaches a huge effort is necessary to drive improvement towards automation and real-time monitoring along networks (Carpanzano and Ballarino, 2008).

Organizational: Long-term relationships are established and suppliers are involved in the design phase and during industrialization, since each of them has to develop its own component according to information received from the shoe producer. Suppliers provide both standard components and exclusive products (i.e. soles and heels can be patented). Several phases of the production processes are commonly outsourced: cutting, stitching and often final assembly. Companies develop a strong relationship with their outsourcers as well to guarantee the highest quality to their customers, and benefit from their availability and flexibility along the season, according to collected orders variation.

Sustainability: the large enterprises are trying to implement sustainable practices moving to eco-products and eco-processes. Nike for example developed an environmental apparel design tool to design eco friendly products (see picture 1); Adidas implement a test to check the sustainability of raw materials and Timberland develop a Green Index in which they rate their products in a scale form 0 to 10 using a system create to compare the environmental impact of Timberland products.



Picture 1 – Nike environmental design tool



Picture 2 – Timberland Green Index

The table below, proposed by Hagenhoff (2004), describe the supply chain topology for the fashion footwear sector.

Characteristic	Instance					
Direction	Horizontal		vertical		diagonal	
Time horizont	long term		mid term		short term	
Intensity	exchange of experiences	coordination of tasks and functions	mutual specialisation	kombination of core competencies		
Business Area	logistics	warehousing	Procurement	production	production planning	quality assurance
Limitation of resources	not limited		limited			
Size of partner	Heterogeneous		homogeneous			
Partner structur	Polyzentric		pyramidal			
Partner location	local	Regional	national	international		
Amount of partners	2		3-10		> 10	
Planning interval	< 1/2 year (short term)		1/2-2 years (mid term)		> 2 years (long term)	
Commitment	contracts		rules		oral agreement	

Table 4 – Hagenhoff (2004) for the fashion footwear sector

4.2 Orthopaedic Footwear

Whitin-Case Analysis

The orthopaedic footwear market in Europe is normed by the National Nomenclature. The Nomenclature gives the guidelines for the regulatory of the orthopaedic footwear market; it defines the typologies of shoes distributed and reimbursed to the patient that can benefit of a medical prescription:

1. Standard orthopaedic shoes
2. Customized orthopaedic shoes

The normative also defines the lead-times for the supply of the orthopaedic shoes (maximum 40 days), the warranty and the renewal of the medical prescription for each patient (1 year for customized shoes and 6 months for standard ones).

Referring to the CoReNet target groups (diabetics, disables, obese and elderly people), as emerged from our case studies only diabetics and disables persons with motor disability can benefit from the National Health Service distribution of shoes, under a medical prescription.

Historically, the production of customized orthopaedic shoes is handmade, and the craftsmanship is an important value-added for an orthopaedic footwear producers to obtain the best quality for the shoes and the best results from the patients. Nowadays, in the analysed companies roughly 30% of these shoes are produced using milling machine for last production. Technologies could be involved in different stages of the process: the measurement can be taken using 3D scanners, instead of the traditional foam used; the plaster cast technique is anyway used for the most serious case. Information from 3D scanners can be sent directly to the milling machine for the production of the last. Thanks to innovative technologies, efficiency increased, lead-time for last creation decreased and precision of the production process improved.

	company D	**company E**	**company F**	**company G**
Company dimension (turnover)	4,6 m€	1,5 m€	1,7 m€	1,8 M€
Company dimension (staff)	45 employees (10 for shoes)	22 employees (12 for shoes)	18 employees (6 for shoes)	1000 employees (50 for shoes)
Number of partners (suppliers, outsourcers)	From 15 to 20	From 15 to 20	From 15 to 20	From 15 to 20
Number of shoes produced per year	20000 (1200)	1500	300	From 80 to 100
Number of customers per year	1500	2000	400	1500
Average order dimension	1	1	1	1

Table 5 – Orthopaedic Footewar companies analysed

Company D is an Italian company that produces internally both healthy and orthopaedic shoes, they work with specialized technicians that starting from the measurement with the patient and arrive at the production of the shoes. Company D is also an outsourcer that produce orthopaedic shoes for third-party.

Companies E and F are orthopaedic laboratories that produce orthopaedic shoes for their customers and patients; the companies externalize to company similar to A some phases of the production process.

Company G is part of a research institute and his core products are the customized insoles, they also produce orthopaedic shoes as an alternative business.

Cross-Case Analysis within the orthopaedic footwear sector

Knowledge: knowledge is focused especially on the acquisition and fulfilment of the functional requirements to answer effectively to patients' needs. Shoes are customized according to customer's measurement, while standard shoes are "best fit" configured, both for structure and materials, according to the pathology requirements, basing on the data collected from past customers and detailed studies of the pathologies to obtain the best corrective effects. Customers can usually chose their favourite model and the materials from a limited list of products. The orthopaedic technician collects other qualitative observations from the patient, such as specific pains and injuries. Then, merging patient's measures and requirements with medical indication, the orthopaedic technician designs the specific shoes for the customer, according to the chosen model.

ICTs: traditionally the production of customized orthopaedic shoes is handmade, and craftsmanship is an important value-added to obtain the best quality for the shoes and the best results for the patient. In the analysed companies, roughly 30% of the shoes are produced using personalized last. ICTs could be implemented in different stages of the process: foot measures can be taken using 3D scanners, instead of the traditional foam; the plaster cast technique is still used for the most serious cases. Information from 3D scanners can be sent directly to the milling machine for the production of the last. Thanks to innovative technologies, efficiency increases, lead-time for last creation decreases and precision of the production process improves.

Organizational: supply networks of orthopaedic producers and providers are organized to compress response lead times and improve quality of the products, considering that patients have specific and complex needs due to their particular conditions. Costs/price are not a critical issue, because of the fixed reimbursement defined by national healthcare systems. Because of the monopolistic advantage that orthopaedic providers can benefit in their territory, organization and improvements on the downstream/market side are minor or neglected. Indeed customers can get full or partial reimbursements by the National Health Service (NHS) only for shoes bought at the specific orthopaedic shops registered at the ministry. Vice versa orthopaedic producers tend to establish strong partnerships with technologies suppliers to improve and innovate their production processes and products in terms of lead-time compression and better quality. Generally orthopaedic providers do not outsource production but it happens that they buy the final product from other suppliers according to available standard models.

Sustainability: the orthopaedic providers are usually small and medium enterprises that try to implement sustainable practices only for the products. In particular regarding the glue used to assemble the shoes they started to use water based glue.

The supply chain topology for the orthopaedic footwear sector is described in the table below.

Characteristic	Instance					
Direction	Horizontal		vertical		diagonal	
Time horizont	long term		mid term		short term	
Intensity	exchange of experiences	coordination of tasks and functions		mutual specialisation		kombination of core competencies
Business Area	logistics	warehousing	Procurement	production	production planning	quality assurance
Limitation of resources	not limited			limited		
Size of partner	Heterogeneous			homogeneous		
Partner structur	Polyzentric			pyramidal		
Partner location	local	Regional		national	international	
Amount of partners	2		3-10		> 10	
Planning interval	< 1/2 year (short term)		1/2-2 years (mid term)		> 2 years (long term)	
Commitment	contracts		rules		oral agreement	

Table 6 – Hagenhoff (2004) for the orthopaedic footwear sector

4.3 Cross-case analysis between the fashion and the orthopaedic footwear sectors

In this section it is compared the fashion and the orthopaedic footwear supply chains to identify the interchangeable best practices.

According to the information collected, the comparison shows differences and similarities between fashion and orthopaedic companies according to the four dimensions of the model:

Knowledge: in the footwear industry (especially referring to project target groups) knowledge is particularly focused on defining the requirements of products and developing the capabilities to better fulfil customer needs.

The following customization options were identified in order to map the different types of shoes production (Yeung, Choi and Chiu, 2010):

- Pure customization – customized shoes, completely based on direct measurement (with 3D scanners or manual measurement), fully personalized on the specific needs, functional

requirements and aesthetic preferences of the customer. Last production is personalized too, and nowadays this kind of process is largely applied by orthopaedic companies and still very limited in fashion ones.

- Best fit shoes are created specifically for best addressing specific functional requirements (generally modifying structure and materials); customer's foot is measured but last is chosen among models already available, according to the parameters that better match foot measures. This process can be applied to both standard orthopaedic and fashion shoes, matching standard lasts and foot measurements.
- Configuration – in this case only aesthetic features are personalized based on a product platform, chosen by the customer among those available. The platform is pre-defined and all interchangeable shoe modules are then settled. This is a case getting popular in the fashion sector (NikeID and MiAdidas).

ICTs: differences between sectors consist predominantly in the level of automation and industrialization implemented in the process. As for the orthopaedic footwear, the two production processes to obtain customized and standard shoes diverge significantly. The former leverages on craftsmanship to best address customers' functional requirements, needs and expectations, the latter is closer to the fashion footwear production process, mainly because the higher level of industrialization. However, lately, a great effort has been spared to increase the level of automation in the orthopaedic sector: the development of foot-scanning tools (such as 3D scanners) and milling machines for last production are important steps in this direction..

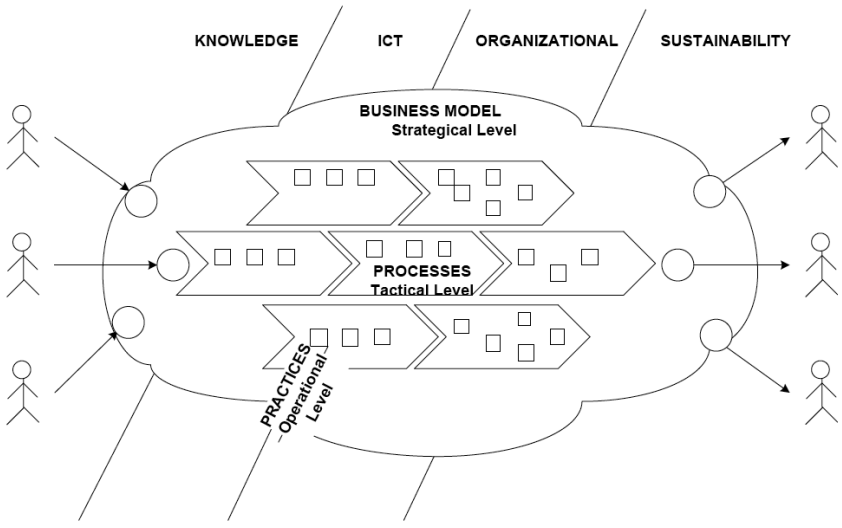
Organizational: several actors overlapped in the two supply networks both for fashion and orthopaedic companies. In particular for the upstream partners raw material (leather, synthetic materials) and components suppliers are the same. Outsourcing is relevant only in the fashion footwear, where cutting, stitching and also assembly are generally externalized.

For orthopaedic providers, the production process is either fully vertically integrated or fully externalized (i.e. they buy standard final products). Concerning downstream supply chain, the orthopaedic shoe distribution is strongly dependent on National Healthcare System and retailers and consumers' behaviours and relationships are deeply shaped by this circumstance. In any case also for preventive shoes, where medical prescription is not necessary, the relationship with customer is much stronger than what is usually established in the fashion sales since it is very much important to know the specific requirements of each customer in order to provide the best shoes.

Sustainability: regarding the sustainability dimension it is important to transfer knowledge form the large fashion footwear enterprises to the small and medium enterprises in order to develop eco-compatible product and processes.

Findings

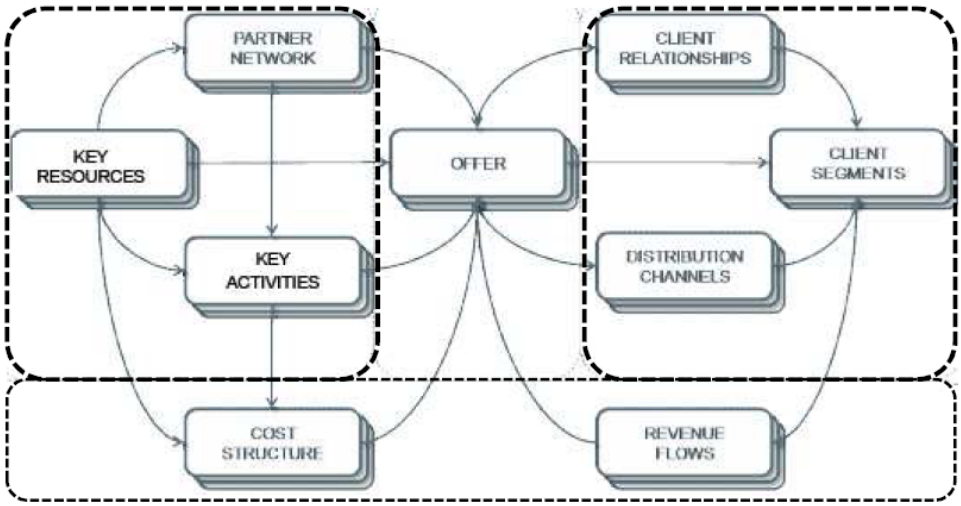
The Reference Model resulting from the case-analysis is based on mapping footwear processes at three levels: strategic, tactic and operative according to our four main dimensions (Knowledge, ICT, Organizational and Sustainability).



Picture 1 – Reference Model Context Diagram

Regarding the strategical level, we consider a set of building blocks (see picture 2) in order to develop a business model for the fashion footwear companies to guarantee them to provide small batches of comfortable and healthy shoes.

The inputs that we have to consider in order to build up our business model are the footwear sector (as for "client segment"), small lots and the target groups of interest (as for "offer"); the partner that are involved in this network are suppliers (both technological and material suppliers), outsourcers and customers (as for "partner network").



Picture 2 – Building Block for the strategical level (Osterwald, 2010)

For what concern the tactical level, a set of critical areas (business requirements) are emerged at the network level.

IM1 – direct acquisition of footwear products with dedicated features for consumer groups with the possibility of product configuration and full visualization of products characteristics;

IM2 – Online customer acquisition of catalogue product with special features configuration and full visualization of products characteristics;

CD1 - Through knowledge management and data mining approaches, consumer-oriented market segments, needs and expectations are recognized. Subsequent data analysis through

knowledge management tools support designers and stylists (with the assistance of KMT managers) in the identification of market needs and consumer preferences for new products and functionalities in the footwear sector;

CD2 – Definition of New Collection of products for specific target groups: this implies to have a collaborative environment where different type of users (internal and external) with different roles (and IT skills) can contribute to define a collection of suitable products for the target consumers. External Actors: stylist, retailer, distributor, etc.;

CD3 – This activity is carried out by the designer and produces the CAD technical model of the product. Also selection of materials and components is a fundamental step in this phase both in footwear. For this reason in this process, the availability and the ability of suppliers to support a specific product concept is a very important factor;

CD4 – Process planning is carried out in two phases: the first one performed by the product designer is responsible to identify the internal and external components in order to establish the generic production process; the second phase is done by the production engineer and is responsible to the detailed process plan identifying the resources, process sequence, durations and line balancing. Taking into account cost considerations and the partner selection this activity is responsible to select which specific supplier partners will participate in the process and in which process step they will be involved. For this reason in this process, the availability and the ability of suppliers to support a specific production is a very important factor;

CP1 – This process starts once the company receives (from process IM1 and IM2) customer order for a specified item (including configuration, customization features, delivery conditions as well as standard input as quantity, size, due date, etc.). Before generating the related Production Orders it is necessary to manage a workflow that includes a specific set of administrative and pre-production steps (also the definitive assignment of external activities

to Partners); workflows can be based on communications steps, exchange of documents, status monitoring, etc.;

CP2 – Once the Customer Order for a specified item has been confirmed the related Production Orders can be generated. This process is based on fixed product and process data (i.e.: inherited from the product model); other data are "customer order" specific (in general, no changes at Design Level and new Materials are allowed) and must be provided in order to allow internal and external manufacturing activities. This process also implies the definitive assignment of external activities to Partners;

CP3 – Once the Production Orders related to a Customer Order have been completed (all data for product manufacturing have been provided) they need to be scheduled and launched for the actual production. Due dates and any other synchronization step for the Production Orders assigned to external partners must be agreed and formalized (negotiation). Info/documents and materials/components needed for the PO execution can be exchanged to this purpose;

CP4 - This process is devoted to collect from suppliers and outsourcers information about the sustainability of their manufacturing processes. From the manufacturer point of view the following aspects can be characterised: 1) monitoring for quality assurance of products and processes; 2) monitoring sustainability of suppliers (both from the production process point of view and the eco-compatibility of materials) and outsourcers activities; 3) monitoring sustainability of internal factors. Information on processes sustainability shall be collected periodically from suppliers and outsourcers and shall be used as a parameter to evaluate their performance and to choose the best partner for the network.

We have validated these business requirements during our business process analyses with the fashion companies; then we have mapped them along the four main dimensions of the SMART network model:

BUSINESS REQUIREMENTS	KNOWLEDGE	ICT	ORGANIZATIONAL	SUSTAINABILITY
SALES/CONFIGURATION PROCESS				
IM1 Traditional shopping support for specific customer groups	Customer involvement. Customer requirements management. Clinical aspect and functional requirements.	Hardware side: availability of machines like scanners, cameras, virtual mirrors, etc.. able to get images, 3D rendering of feet\bodies for product design. Software side: integration of hardware outputs directly into PDM\CAD environments. It is necessary also to have shop workstations for configuration and virtual representation\rendering of shoes directly to end users. There must be tools able to read the scanner results and evaluate them from a medical point of view without the need of specialized personnel.	In a customer driven supply chain, end-user demand drives all activities among trading partners according to a culture that puts the customer first. Companies which put this approach at the heart of their supply chain strategy in fact design and align their processes in order to achieve the objective of winning the customer at the point of use or at the point of sale. The upstream supply chain is then designed backwards to deliver this. This have to be realized creating a supply chain that meets the needs of consumers and customers, integrating commercial and supply chain teams to work collaboratively across the internal and external supply chain.	Commitment with the customer to give information on sustainability.
IM2 Online visualization, configuration and acquisition of leather/footwear	Formalized knowledge of information needed for the customer to assess the performance of the product.	It is necessary to create a clear and single access point that customers can recognize as online shop. Portal tools are good solutions to integrate both end-users and producers facilities. The two roles must be clearly defined and distinguished in the portal. The part related to end user must be very simple and easy to use. Tools should be clearly understandable and the user must never feel lost or have doubts about how to proceed.	Some of the steps realized by downstream supply chain actors (distributors, retailers, ..) can be reduced compared to direct sales. The purchasing approach of online shopping has specific peculiarities and customers shall be familiar with online shopping and product configuration. In case of final customer belonging to the target group addressed by the project, as elderly people, it is important to promote and implement very simple tools for product configuration with few easy steps to reach to the final configuration of the product.	Formalized knowledge of information needed for the customer to assess the sustainability of the products.
DESIGN PROCESS				
CD1 Co-design with Knowledge Management Tools support	The knowledge representing the behaviour and preferences of the customers is obtained from companies transactional systems (including retailers and sales departments databases) but also from social networks (Facebook, MouthShut, Twitter, etc.) and online communities of	• Data analysis based on semantic web (ontology) tools for structured and unstructured data; • Customer profiling, trend analysis features; • Usage of OLAP, Data Mining and Business Intelligence tools; • Integration with PDM for product characterization; • Collaboration Portals where	Manufacturers and especially stylists and designers need to identify specific consumer groups in order to design and develop the appropriated products and accessories for these market niches and not address the market as one. A fundamental step of this	Connection with the social networks to know which are the requirements in terms of sustainability. Market trends, Customer needs.

	consumer target groups. This means the need of data sharing agreements between retailers, manufacturers and designers but also the involvement of consumers through specific online communities of consumer target groups.	different type of user roles can be identified: internal user (different depts.); partners; consumer communities; retailers, etc.	process aims at the collection and formalization of important information that are the basis for the conception of a new collection and related product models. This is realized through the analysis of fashion trends, results of market research, trend books realized by creative and data collected in fashion forums. Moreover a framework related to eco-sustainability aspects, as specific law regulations or thresholds, supporting the definition of product/collection characteristics for this issue should be defined. For all the above mentioned reasons, also the number of stakeholders to be managed is enlarged.	
CD2 Definition of Collection Support	Knowledge on the specific functional requirements of the customers.	• PDM system with enhanced data management ICT allowing to easily include any kind of extended product features as could be required for "functionalities" related to specific consumer targets; • Standard based technology for data management and integration are also required for an effective exchange of product related data concerning LCA and KMT issues • PDM/CAD integration providing fast sketching and modeling functionalities allowing to start from existing 2D images 'Blue print, 2D Sketch, Photos and similar inputs for quick 3D viewing of the products and enabling faster and cheaper cost of prototype; virtual prototyping approach.	Shoes collections are designed and launched in the market according to seasonality. Usually there are from two to four collections per year and they are also linked to important sector fairs and exhibitions. The creation of the new collection starts from all the information collected and formalized in the KMT (CD1). The process involves the collaboration of stylists, external designers, internal designers and of the commercial department. Eco-compatibility issues have also to be taken in account from the beginning, defining the characteristics that the collection should have in terms of impact of materials, components and accessories (during their realization and after product dismissal) and on the productive process side (eg. polluting processes of tanneries and laundries) in order to integrate them into the collection defined.	Critical aspect for specific target groups. Platform mapping sustainable product and materials available in the market.

CD3 Product Design with CAD modelling support	Modularity, Postponement, Product innovation, Open innovation.	Automatic tools and IT support for product models deployments (technology aspect also related to IM1/2 for product virtual representation), taking into account the aesthetic and functional requirements provided by the internal and external customers. 3D/2D models need to be developed: these models are devoted to characterize the product components to be processed and assembled (including variants, grading, prototyping, etc..). Since also in these technical phase of the process different actors and competencies are required, collaboration technologies and environments for concurrent processes can play a relevant role.	In footwear last, components and materials selected impose constraints to manufacturing which must be dealt with during design and engineering. Height of the heel and materials (leather or fabric) for the upper strongly influence the design or selection of the last and have to be fixed at the beginning of each collection development. So after the definition of the collection in the CD2, in CD3 it has to be decided which kind of last, heel (heel high and its material) and sole are more suitable in order to realize the new shoe according to the style idea proposed. The choice of materials have to be made also according to the Eco-compatibility characteristics fixed in the collection definition phase, for what concerns the impact of materials and accessories used. For all these reasons is important to involve suppliers in the choice of materials and components during the product design phase.	Green product innovation. Application of ECD, LCA, DFD, DFE, DFR. Competencies on eco-materials, competencies on functional aspects related to each material. Eco-design practices.
CD4 Process planning support	The use and re-use of previous models and past experience of the production engineer streamlines the implementation of new solutions in terms of new process plans, as well as reduces the time needed to reach satisfactory solutions.	IT support is required both by the designer and production engineer in first: the definition of the generic process plan and subsequently for the construction, simulation and finally the definition of the detailed process plan. Specific process planning and simulation tools are required in order to estimate durations, resource usage, specific and overall performance. A Web tool to create shared plan (GANTT views) and BPMN processes is suggested.	The cost considerations, resource capacities and supplier specific data are crucial elements in the definition of the most efficient process plan for new product supply chain. But in case of fashionable goods, there is also the need to consider the agility and responsiveness of the different suppliers. For all these reasons is important to involve suppliers in the process planning in the design phase of the supply chain. Their collaborative contribution is fundamental in order to the production engineer accomplish efficient, balanced and resilient solutions.	Eco-friendly raw material, TQEM, Green manufacturing and re-manufacturing, Reverse logistic, Environmental awards, ISO certification.
PRODUCTION PLANNING PROCESS				
CP1 Customer order processing support	(a) the analysis and translation of the product configuration information into the production article	Product Data and Customer data must be handled once the configuration is completed and the order is confirmed.	During this phase the selection of partners is done at operative level (CM1): given the partners	Cooperation with customer in order to implement pollution preventive technologies.

	data in terms of materials and production processes (for lot size 1, and for small series). (b) Aggregation of orders: If available in an appropriate kind (e.g. rules) the aggregation of orders can be processed automatically. (c) Partner selection: Standard (technical) selection criteria, which can be processed automatically. But at least of same importance are quality, flexibility and reliability of this collaborating partner.	Product data (measures and configuration options) is required for the process planning finalization where the product model and working instructions/tools can be finalized. For Product data the integration with a PDM system is recommended Integration with legacy systems is needed for customer order management (administrative): Accounting (Bills, Invoices, etc.); Delivery-Logistics, CRM and any other application based on customer data. This is based on the synchronization procedures of master data for product and customer.	selected at strategic level it will be possible to define which one should be "activated" for the specific production order according to their availability to produce according to the time constraints. Production orders are generated taking into consideration different customer orders arrived in the period of time used for decision taking. In small series orders, production orders are the results of the aggregation of different customer orders. For example in the case of footwear it may be that personalized products have some components which do not change. For this reason production orders of these components are aggregated and sent to the partners for production of those specific components.	
CP2 Support for collaborative process planning	Information that have to be properly handled in this process are related to different aspects. The first are the ones already stored in the PDM system and related to generic BOM and working cycles for product models. Order specific information that will integrate these will have to be coherently structured according to a common framework. Information on framework agreements are also important in this step and have to be recalled here in order to support and frame the negotiation with partners on their availability and collaboration conditions.	CAD/CAM systems dedicated to fashion products: special designs and modifications set by end users in the shop. Collaboration tools to communicate with selected partners and send them the so created PO. Integration with PDM\ERP to register the order on partners side.	The creation of the PO is realized integrating basic information already defined and stored, as the generic working cycle and BOM, for the product models required in the customer order and information order specific information as the ones related to personalization options (esthetical). On the basis of this additional data basic working cycles and BOM are completed. One of the most relevant information added in this phase is related to the assignment of the external productive operations to the partner (outsourcer) more appropriate in terms of capability and skills. This can happen at different level according to specific conditions. In most cases partners have been already identified and operation assigned during the Design Process Plan phase (CD4).	Acquisition of supplier availability.

CP3 Support for collaborative production planning and control	Impact of the right or wrong production on the pathologies.	At this level it is necessary to have a collaborative process tools supporting the Production Planning of external activities and a workflow control for the whole customer/production orders. • Setting up and management of activities • Production order logbook (including rating functionalities) • Provide a graphical representation (Gantt) and filtering tools • Exchange documents • Scheduling and optimizing planning of activities Workflow Management tools: Product specific workflows can be used to control the overall process for Customer Order management.	Collaborative planning means that partners accept to share their planning to coordinate them. Collaborative planning includes aspects that enable partners to recognize how individual companies plans should be adapted, according to which criteria the planning can be optimized, and which restrictions in the common planning must be accepted. In short, collaborative planning describes how individuals are able to orient their plans towards each other to reach a joint optimization of the planning across company boundaries. In case of small series, demand forecasting is very difficult and production is based on high flexibility not only of the manufacturing systems but also of collaborative schemes.	Collaboration/integration with partner and suppliers in order to implement pollution preventive technologies.
CP4 Partner monitoring and trace support	An important aspect implied in this phase is related to the ability to include in the definition of KPIs proper inputs from final customers requirements and needs, especially the ones belonging to the target groups addressed by the project as, for example in terms of anallergic and no toxic materials. This information can be retrieved from market analysis made for the definition of the seasonal collection including also indications from medical centers and experts. Another issue concerning knowledge is related to the proper storing of data obtained from KPI calculation, their use and the access provided to actors involved.	It must be defined and released a set of KPIs (ontology, vocabulary, etc…) that define different aspects related to quality and sustainability. Web services must be written to check such KPIs and confront them with the producers' processes and raw material origin to elaborate a final judgment on the product. Such web services must be integrated with producers' PDM to elaborate directly and automatically on relevant data. Track and trace tools must be available to check raw material origins and to check the status of completion of orders.	First of all a set of proper KPIs referred to Eco and Quality aspects have to be defined. This is done by the production department and can be based on inputs from customer groups targeted by the project and referred to their specific requirements and needs. Eco and quality monitoring run in parallel during the realization on each production order, collecting data and information useful to calculate the KPIs previously defined. For what concerns quality check, a first step is realized when materials and components are purchased from suppliers. When the realization of outsourced phases for a PO are realized, related materials are sent to the outsourcers premises and the production process is monitored collecting data on the eco-compatibility of the process that will be used also for the LCA calculation. A similar monitoring is realized on the internal productive phases. A second quality check is done on the outsourced WIP when delivered and on the	Long-term relationship with partners, Environmental Performance Indicators.

			internal WIP in order to avoid defects. Then a final quality check on the product is made. All these quality checks need to be planned within the network according to the availability of the quality control staff and according to the production plans.	

Table 7 – Business Requirements mapped on the four main dimensions

Further researches will focus on the development of the operational level of the Reference model in order to highlight which are the best practices for the footwear companies that want to implement in practice the Reference Model.

Conclusions

Case analysis has clearly revealed how fashion footwear companies can address the needs of the target groups enlarging their production of fashion shoes to "preventive shoes" which represents an interesting opportunity to capture new market shares providing healthy and fashionable products. Moreover, case studies showed how, particularly for the production of standard orthopaedic shoes, the production in parallel of fashion and orthopaedic shoes make easier the sharing of the upstream supply network and some similar equipment within the production process (i.e. cutting machines for the upper or stitching activities) could offer greater efficiency and larger economies of scale.

The research proposes a reference model to implement an innovative consumer-cooperative environment to enable European Footwear companies to produce and deliver small series of specialized and customized high value added products. The industrial and empirical nature of the RM guarantees full feasibility of its guidelines.

In particular, the RM highlights sustainable methods and tools for product design, planning, production and distribution activities, rapid manufacturing technologies and processes for

small series industrial production. The RM faces trade-offs between costs and lead-times, flexibility and service quality along the supply networks and throughout the product's life cycle.

Finally RM facilitates Footwear supply networks in obtaining and managing consumers' data to know their needs, involve consumers in product design and configuration, exchange consumers' data through adequate data models and secure systems, collaborate with suppliers, implement innovative manufacturing machines, monitor quality and sustainability of products.

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