A laboratory for industrial research on mass customisation in the footwear industry

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Abstract: This case study describes and analyses an Italian-based laboratory as a state-of-the-art approach to the mass customisation of shoe design and manufacturing. Based in Italy's shoemaking capital, Vigevano, the ITIA-CNR Design & Mass Customisation Laboratory (D&MC Lab) covers the entire spectrum of development and production activities of mass-customised shoes: based on a digital foot scan and an evaluation of customers' wishes, customised shoes are manufactured. The case study covers internal changes required during production, information processing and human resources management, and comments on the need to consistently manage the relationships with other external actors of the value chain for successful mass customisation.

Keywords: mass customisation; shoe industry; footwear market; experimental pilot plant.

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1 Introduction: industrial change and trends in the footwear market

In this case study, the Vigevano-based ITIA-CNR Design & Mass Customisation Laboratory (D&MC Lab), an Italian pilot factory that develops and manufactures mass-customised shoes, is described and analysed. We begin our case with a brief overview of the business environment and some important economic and social trends in the European footwear industry. Four major aspects have characterised the footwear market in Western Europe over the last few years (Euroshoe, 2002a):

1. *Increasing price competition.* This is true for almost all the market areas linked to textile and fashion: new low-cost providers from the Far East are flooding European markets with low-cost products.
2. *An increasing complexity both in the market and in corporate organisation.* Customer demands are becoming more and more heterogeneous, increasing external complexity. As a result, internal complexity also increases, as companies react to the external demand for variety with larger product programmes and exploding variants.
3. *More demanding customer requirements.* Customers are increasingly looking for integrated solutions that combine tangible products with intangible services.
4. *Globalisation and new competition.* Increasing global competition as a result of breaking trade barriers leads European manufacturers to price wars they cannot win (Almon and Grassini, 1999). In addition, new actors and brands enter the market and challenge existing footwear brands, *e.g.*, apparel brands moving into footwear.

These four different trends are interrelated and mutually influenced, as we will demonstrate in the case of Italy. Italy is the most important footwear exporter in Europe, and the D&MC Lab began its activities in this environment a few years ago. In Italy, footwear manufacturing is one of the most traditional manufacturing industries. In 2005, the market was made up of 7084 companies with 100 934 employees (ANCI, 2004; 2005), the majority of which are SMEs grouped in seven geographical districts. Around 83% of the national footwear production is exported (ANCI, 2005; ICE, 2003); Germany, France, USA, and the UK are the four main importers of Italian shoes. At the same time, however, about 70% of all footwear sold in Italy is also imported, most of it from Asia.

Consumer patterns have changed in recent years, posing new challenges to national manufacturers. In Italy, the overall demand for footwear decreased both in terms of pairs of shoes (down 10% from 2002 to 2003) and willingness-to-pay (down 6%). The same trend could be observed in regard to Italy's export markets: exports are decreasing (approximately 7% less in 2003, both in terms of volume and value). In particular, the most important foreign markets are turning away from Italian shoes (this trend is especially striking in non-EU countries, such as the USA, where Italian footwear imports decreased by 16% from 2002 to 2003). There are several reasons for these negative trends:

- Italian shoes are typically fashionable and rank at a medium-high to high level in terms of price, materials used, and manufacturing qualities. In recent years, a recessive economic trend has affected Europe, and the strong euro had a negative effect on exports to the USA.
- Low-priced shoes from the Far East (especially China and Vietnam, see Capone, 2005) are penetrating the domestic market with low-quality and very low-cost products. Although low in quality, the ratio between price and quality is competitive and appealing to many variety-seeking consumers looking for fast satisfaction and 'disposable' products (*i.e.*, inexpensive enough to be exchanged rapidly). Imports from China have grown around 50% from 2002 to 2003.

The latter threat seems to be the most dominant challenge European shoe manufacturers are facing. New competitors have to be faced with a revision of conventional competitive thinking. Low-cost salaries and wages are the main advantage of Asian shoe manufacturers. Today, European and especially Italian companies are in search of strategies and innovative approaches to uphold their businesses, and mainly act in two directions: on one hand, they press politicians and governments (both national governments and also the EU commission) to endorse a sort of protectionism with anti-dumping duties in order to defend national markets from these new market players (Nielsen and Rutkowski, 2005). On the other hand, companies look for new ways to improve their solutions and increase the quality of their offerings. Leaving 'political' issues aside, one of the most promising approaches for adding value to footwear is discussed in the following section.

As mentioned before, a growing number of footwear customers are asking for 'performance' solutions and custom solutions that fit their individual physical needs, personal tastes and habits (de Buckle, 2001; Euroshoe, 2002a; Piller and Müller, 2004). These consumers belong to the middle-high and high levels of the market, but are still not willing to pay the exorbitant high prices of conventional custom footwear. This opens up vast opportunities for a mass customisation strategy in the footwear market.

2 Mass customisation in the footwear sector

The social and economical evolution of the last few decades has pushed customers towards a higher need for personalisation: marketing and sales managers started dividing the market into different (but internally homogeneous) groups of potential purchasers, and companies were asked to develop and manufacture specific solutions for each group. For this reason, large quantity production of the same object was set aside and, as a result, unit costs grew correspondingly to the increased spectrum of offered products. In response to this rise, two major approaches have emerged: mass customisation (Pine, 1993) and on-demand production (Fabris, 2003). Nowadays, the purchasing choice is no longer driven by a mere need, but much more by feelings and sensations produced by an object with an intrinsic meaning (prestige or status). Some consumers are moving away from the imitation of other people's habits and choices (simply buying goods they have already seen owned by others), displaying an increasing need for personalisation and customisation solutions (sometimes even shirking products simply because others own them). As a result, the demand on manufacturers is to put standardised needs aside and produce many different specialised versions of a single article in order to respond to such specific needs. Mass customisation can be seen as an effective answer to the external threats in the Italian footwear industry, which can benefit from the new opportunities offered by the latest information and manufacturing technologies, and respond to the rapidly evolving consumer demand for customisation. The aim of mass customisation practices is to allow highly assorted productions to keep costs and prices under control. The objective of the D&MC Lab is to fulfil exactly this requirement and provide an infrastructure and environment for mass customisation in the footwear sector.

2.1 Summary of previous research on customisation in the Italian footwear market

Before investing in the Lab, preliminary studies were conducted, which revealed several trends supporting the introduction of customised solutions in the footwear market (Euroshoe, 2002a; 2002b; 2002c). Some of these results are summarised as follows:

- The main reasons for consumer dissatisfaction with traditional shoes are perceived as discomfort due to a poor fit, problems in finding special sizes, limited availability of the desired model/brand/size in the shop, and the rapid deterioration of some parts of the product.
- Potential customers were asked to express their expectations concerning features of footwear customisation that would add the most value. In Italy, consumers are very sensitive to aesthetic aspects. The main advantages of customised shoes are seen as a solution to the problems highlighted above: good fit, availability, and high-quality raw materials.
- The targeted customer segment most likely interested in customisation includes young trend-setters interested in new stores and brands, those seeking comfort and prestige, as well as people with marginal to serious physical or biomechanical problems with their feet (Piller and Müller, 2004).
- From the manufacturers' perspective, the main incentives for the development and production of mass customised shoes in Europe are finding new means for solving efficiency and effectiveness problems in production, flexibility and closer connection to the market, powerful marketing tools, and improvements in customer services (value-adding solutions to increase loyalty and allow premium prices).
- The main barriers against mass customisation are seen in the higher costs of production, a lack of sufficient production technology, a lack of retailer cooperation, different purchasing habits, and consumer behaviour (*e.g.*, are customers willing to wait 10–15 days before they get their shoes? Are they willing to order shoes without actually trying them on?)

2.2 Dimensions of customisation in the footwear market

In the specific case of shoes, three different dimensions for customising the product can be differentiated (Jovane *et al*., 2003):

1. *Style and aesthetics aspects*. The manufacturer gives the customer the possibility to choose from a range of different colours, materials and/or finishing parts.
2. *Fit and comfort*. Size is a priority, but the shape or other dimensions of the shoes are also part of this aspect.
3. *Biomechanical parameters*. Shoes have to be suitable, conforming to and fitting the customer's feet as good as possible.

Expanding on these dimensions, three different manners of footwear customisation can be defined (Boer *et al*., 2004):

1. *Style customisation*. With a standard size of the lasts, the customer can change design details (colours, accessories) within a range of possible options.
2. *Best fit*. The customer's feet are measured with a 3D scanner or other measuring device. The computer then selects the best-fitting last, sole, and insole from an existing database. The pair of shoes is manufactured on-order and delivered after a few days. Some modifications in design are possible, albeit limited. Compared to the traditional standard sizing system, there is already a large advantage with regard to fit and comfort.
3. *Custom-made*. The customer's feet are measured (foot scan and collection of biomechanical data) and the pair of lasts is custom-made for each user's personal profile. Some aesthetic changes are possible (within some technological bounds). This type of approach makes it possible to obtain the best fit and highest possible degree of comfort, as the shoes are made according to the actual dimensions and shape of each user's feet.

In the last two cases (best fit and custom-made), a few pairs of shoes are usually displayed at the retailer shop in order to assist customers with their choice, which is particularly important when making a first-time purchase. However, there is no large inventory of ready-made goods; all products are produced on-demand (made-to-order). This allows a reduction of the size and costs of the stock, the unsold products, and as a result, also serves as a better environmental safeguard: manufacturers produce only the shoes that have already been actually purchased, *i.e.*, products that have been ordered by consumers.

Another *variation of the best fit solution* is based purely on a 'matching' approach. Customers' feet are still scanned in the shop, but then the best match from all available shoes in the shop's inventory is determined with the help of specific computer program, and the shoes are immediately sold to the customer from in-house stock. In this case, no changes in the life cycle of the product are required and the shoes are still manufactured in the same traditional mass production manner. This variation is becoming rather popular, and the demand for an easy-to-use, accurate 3D scanner has considerably increased in the last two years. However, because the shoes are not made-to-order, we do not consider this variation of best fit as a form of mass customisation.

For each level of customisation, different impacts on the shoe's life cycle are evident. The impact can be measured in terms of investment in technology, manpower, organisation, promotion, retail, *etc*. In the *best fit* case, the design and manufacturing departments have to increase their flexibility: more models and a larger number of lasts must be produced. In addition, sales activities are becoming more complex: a scanner for foot measurements has to be installed in each shop and data must be collected and stored in a proper database. On the *custom-made* level, the impact on the life cycle process is particularly strong. The implementation of scanning instruments requires a re-design and re-definition of the sales process, and well-trained sales personnel. The design activities call for intense customer involvement. In manufacturing, machines have to be more flexible in order to produce a virtually 'infinite' range of different lasts, and handling systems have to be flexible so as to allow direct connections between each machine in the production system.

The approach followed by the D&MC Lab is an efficient custom-made solution. This distinguishes the D&MC Lab from other initiatives in mass customisation footwear (see the case studies on Adidas and left® foot in this volume, both of which are based on a best-fit solution).

2.3 Prerequisites for converting to mass customised footwear

From a generic point of view, a custom-made mass customisation system for footwear requires three basic capabilities:

1. *Design of shoe lasts.* A virtual 'father' object is created, from which different 'children', *i.e.*, variants related to the original last, are derived (based on the individual scans of each end consumer). Such a concept implies the creation of strict relations in data infrastructures in order to properly manage the inheritance of geometrical properties of the father shoe last in the derived objects. Furthermore, the shoe last's scalability to different fits has to be taken into account because customers might possibly have different needs in regard to the length and the width of the last. All the aforementioned elements, which might be so typical of the shoe sector, are pushed to the extreme when it comes to custom-made shoes. Customised footwear is made by automatically adapting the father last to the specific shape of the customer's foot; in this context, customisation deals with an individual foot, which results in a pair of two different items as no one's feet are physically identical.
2. *Adaptability of aesthetic design.* Shoe model styles are designed in a 3D CAD environment on a base size last, where every single component of the shoe is modelled. Such an approach results in a tree of objects consisting of the sole, insole, or upper components. All items are characterised in terms of their geometrics, material, and position in the shoe. One innovative feature of this type of modelling is the possibility of dynamically linking the tree to different lasts so that specific customer needs can be fulfilled. Furthermore, such an operation has to be performed in a virtual mode on non-standardised, custom-made lasts.
3. *Manufacturing and information management.* A core requirement of any mass customisation production system is the integration of customer information in the manufacturing process. Automatic information management and its customisation is the starting point for this process. From a technological point of view, customisation

demands the conception of new solutions throughout all production steps, *e.g.*, new machines in the cutting phase, new organisation of the stitching phase, new machines and production lines in the assembly phase, as well as the introduction of configuration systems in the sales process. Also, agile logistic processes are needed in regard to heterogeneous objects and shortened set-up times.

3 The ITIA-CNR Design & Mass Customisation Laboratory

The ITIA-CNR Design & Mass Customisation Laboratory (D&MC Lab) analysed in this case study is a laboratory and pilot plant. Operated as a pilot factory and development centre by ITIA-CNR, (the Italian Research Council), the D&MC Lab is one of the first plants to adopt a true *custom-made* approach to mass customisation in the footwear industry. Previous *industrial* implementations of mass customised footwear have all followed the best-fit approach (*e.g.*, miadidas, selve.net, left® foot). While production volumes of the Lab are rather low, experiences gained at this facility are useful for two different reasons: the Lab serves as a test field for future (high-volume) production and allows experimentation with new technologies and organisational procedures without any risk of disturbing the workflow at an existing factory. This is in line with the strategy Kotha (1995) recommended for implementing mass customisation in an existing industrial structure. More importantly, however, the Lab is a powerful means to motivate footwear companies interested in this kind of business. Given that most of the manufacturers are SME, a real-life demonstration of the feasibility of customisation in the footwear industry is much more important than extensive research publications. The main purpose of the Lab is to allow both customers and footwear manufacturers to experience this innovative approach to shoe production and assess its results.

Table 1 Overview of company data

Name	D&MC Lab ITIA-CNR, Vigevano, Italy
Address	Via Pisani 1, Vigevano (PV), Italy
URL	www.itia.cnr.it (Vigevano laboratory)
Year of foundation	2001 (EUROShoE project start)
	2004 (production start)
Number of employees	15
Industry	Pilot plant for customised shoes
Products	Footwear
Markets	Italy

3.1 Capabilities and processes

Shoe design and manufacture is still an ancient process – one that has been nearly unchanged by the industrial revolution or modern technologies – which is the reason why most labour has been moved to low-cost countries. This generic manufacturing process can be divided into four phases that also correspond to the Lab's main areas (see Figure 1).

1 *Making the last*. After taking the customer's foot measurements and choosing the desired style of shoes in the store, the first manufacturing step is the production of the custom last. In this phase, adapted copies of the feet are cast in plastic using a turning mill (an exact copy of the feet would be of no use because of the required adaptation to the shoe style). For better order tracking, an RFID chip is positioned on each last. The set of lasts is made just once for each customer and for each shoe style. For repeat orders, the lasts are kept stored at the factory.

2 *Cutting and stitching of the upper; construction of outsole*. Based on the individual measurements, the leather components of the upper are cut using a flexible laser cutting system. The components are then fixed to the last using water vapour so they adhere better to the smooth surface. Because of the irregularity of leather on different surfaces, the machine used to cut the different pieces detects if and where the material is too thick or if any defects are present, and determines how to proceed with cutting. After this procedure, all components are placed in a box with the last (including the microchip) ready to be recalled by the operator for the next phase. Parallel to the preparation of the upper, the sole is cut and arranged with one of two main procedures depending on the material of the sole. Leather soles are worked at the D&MC Lab; a laser machine traces the line where the upper is to be sewn. Up to now, injected rubber soles have been bought from an external supplier. Finally, the different components of the upper are sewn and stitched together.

3 *Attaching the upper and lower (sole) parts*. Next, the upper edge is roughened to make the surface easier to be glued to, and once adhered, the shoe is cooled to fix the glue. Finally, the upper is ready to be attached to the sole, the insole is inserted, and the shoelaces or other details are added. The last step includes brushing off the shoe and giving it a leather treatment.

4 *Finishing process*. The shoe is then finished, cleaned, shined, and controlled for quality. These steps do not differ from those of conventional shoemaking.

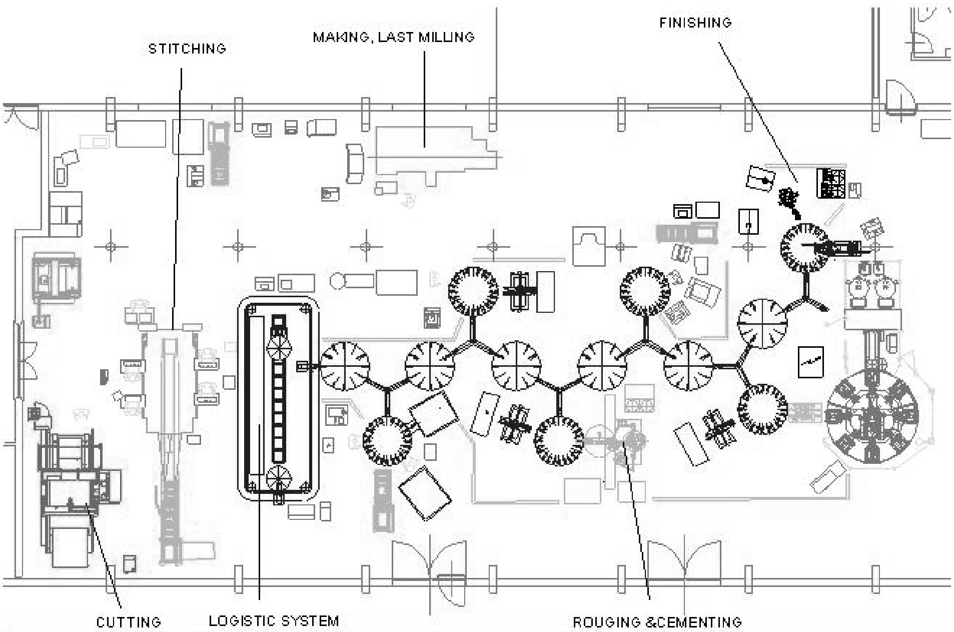
In the case of handmade shoes, a cobbler is in charge of carrying out all these steps. At the D&MC Lab in contrast, almost all of these steps are automatically performed with the objective of creating a scalable industrial system. Thus, employees are no longer responsible for manual labour, but have to make sure that the system is synchronised, machines are working, and, through the logistic system, that all shoe components are in the right places. Yet this system also differs from a traditional mass production system. Here, batches of identical products are usually placed in one line to reduce the impact of set-up costs on a single pair of shoes. Flexible machines go a step beyond: they are able to manufacture different kinds of shoes, but with higher investment costs and longer throughput times.

The approach pursued by the D&MC Lab tries to couple flexibility (one-of-a-kind batches) with low costs (for set-up, internal logistics, *etc*.). To achieve this goal, the following infrastructure features have been implemented at the Lab:

- The *internal transportation* of components and WIP is one of the most distinct features of the D&MC Lab production system. This logistic system links all the different machines of the plant. Through this system, all shoe components can be localised and moved precisely at any time and in any place thanks to the electronic chip incorporated in the last.

- *Flexible machinery* applied at the Lab (because of space restrictions, we are not able to elaborate on these technologies in greater detail here; see Boer *et al*., 2004), such as a turning milling lathe to produce ready-to-use hinged lasts, a 'super flexible' toe lasting machine, a robot-based roughing/cementing cell (an industrial robot with incorporated force control for roughing operations, which is fully integrated in the shop floor data network and programmed from CAD), and a robot-based finishing cell (an industrial robot to perform spraying, creaming, and brushing operations).
- A *complete ERP environment* for the mass customisation of footwear has been installed to manage the corporate database and order/production processing. Orders originating from the sale points (virtual shops, see below) are differentiated by shoe models and level of required customisation, and sorted and prepared for subsequent scheduling. Sales orders are processed to generate production orders, initially at the level of master production schedules and then on a more refined level. Material requirement planning is also performed at this stage. Next, production lot processing generates the correct sequence of production lots based on the customers' orders, taking constraints and requirements of shop floor logistics into account. The system is also integrated with a supply chain management application and a finite capacity scheduler.

Figure 1 D&MC plant layout

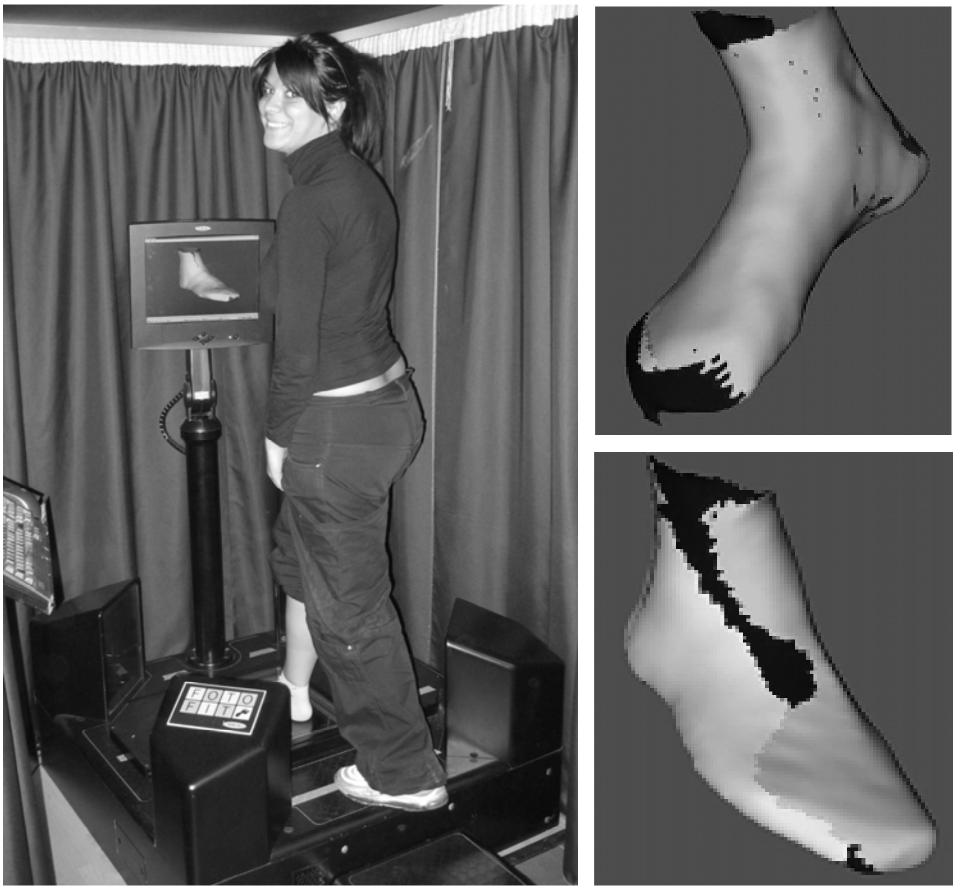


3.2 The interaction and configuration process from the customers' perspective

Mass customisation, however, is more than just a flexible manufacturing set-up. Its most dominant design feature is the connection with each individual consumer. In this regard, mass customisation refers to a customer co-design process of products and services that meets the needs of each individual customer with regard to certain product features

(Piller, 2005). To fulfil this objective, part of the Lab's infrastructure is also a *virtual shop*, *i.e.*, the main interface between the manufacturing area of the Lab and the consumer. Here, the customers' feet are scanned (Figure 2) and the selection of the shoe is assisted by an interactive configuration system that takes the customer's needs, habits, and biomechanical aspects of the feet into consideration. All of this data is transferred to the ERP system and placed with the order to the production area.

Figure 2 Foot scanning device and resulting 3D scan images



To provide some more insights into consumer acceptance of the Lab's products and procedures, the results of a market test and evaluation campaign are briefly described as follows: For the test, a mock-up store was created at the Lab. The test involved about 500 volunteers who were asked to visit the Lab and have their feet scanned. For each of the subjects, a pair of customised shoes was manufactured. Test customers were surveyed about their shopping experience and the shoes' fit. The first analysis of 270 consumers (153 women and 115 men) revealed that the level of satisfaction with the product was high: 241 pair of shoes were evaluated as 'good' and 'fitting', while only 29 consumers were discontent with the fit. Of the latter 29 pairs of shoes, nine were re-made, seven of which were ultimately rated 'ok' by the customers. However, test customers received their shoes for free and were therefore not in a real purchasing situation. Also, they had no possibility to compare the experience of this mass customisation environment with similar set-ups, as it was their first-ever contact with this type of product solution.

Further qualitative interviews were conducted with 25 women and 25 men (Redaelli *et al*., 2005). Test customers felt deeply involved in the shoe production process. All subjects trusted the proposed technology and viewed it as a possible solution for shoe-fit problems. An interesting aspect revealed in the interviews was that the vast majority of the subjects showed interest in an active involvement in the product design, providing suggestions, and strong interaction with the product development team. Here once again, mass customisation meets user innovation (Piller, 2005).

4 Case assessment

4.1 The Lab as an intermediary between research and application

Today's Western manufacturers face major threats from low-wage economies. Focusing on knowledge-based, worthwhile activities seems to be the best answer to this challenge: in many manufacturing (and also non-manufacturing) sectors, developing value-adding integrated solutions coupling tangible and intangible goods that meet customers' increasingly demanding requirements has become a crucial paradigm. Referring to a modern representation of value chains, actors involved in 'pure' research activities (*e.g.*, research centres, universities) need to be supported by intermediaries who should be able to make discoveries and innovations (both at the technological and at the managerial level) for the 'real world' (Pedrazzoli and Boer, 2004).

The D&MC Lab can be seen as one of these intermediaries (Dulio and Boer, 2004). Its objective is to *exploit radical innovations* from research for valuable applications and tools for the manufacturing industry. The resistance of traditional footwear manufacturers to apply innovation on their own has shown that this type of intermediary is also needed for traditional sectors, and not only high-tech growth sectors. At the Lab, research and innovation provided by the Euroshoe and similar projects are transferred to practicable, workable solutions and methodologies. The Lab, however, is much more than a traditional technology transfer centre, as it simultaneously provides a place for piloting, exploration, and improvement. Beyond this *role of piloting and exploitation of innovation*, the second role of the Lab is to *create further awareness and dissemination* of the developed knowledge and the business models behind these new technologies. Oftentimes, radical innovations are not easily accepted by the different stakeholders of an industry; they have to be convinced of the benefits stemming from such innovation and, furthermore, must be actively involved in the development process of suggesting adaptations and explaining requirements. The role of the D&MC Lab is to foster collaboration between actors for a future footwear value chain: research centres, machine builders, software providers, manufacturers, component suppliers, retailers, and potential final consumers. Table 2 presents four scenarios representing these business options for the Lab as described before.

Table 2 Different scenarios of the further development of the Lab

Scenario	*Description*
Scenario A	Very first step towards mass customisation. Minimum investment in order to produce 'best-fit' shoes. Main investments and costs expected: • scanning tool (including matching software and configuration system) • database for handling customer data • shop equipment (including maintenance, training, *etc*.) • marketing
Scenario B	Next step: lasts for custom-made shoes are internally manufactured. Main investments and costs expected (in addition to those mentioned for Scenario A): • machinery for last production, production of custom-made shoes (for standard and best-fit shoes, lasts' production is outsourced) • purchasing of CAD and CAM systems (to integrate the shoe design process and the part programme definition with the production of the last) • employee training in new software
Scenario C	Further step towards mass customisation. In this scenario, the company adopts ERP, MES, PDM, and SCM systems in order to manage and optimise the information flow concerning products, customers, and suppliers. The production of standard and customised shoes is run in parallel in two different lines. Investments and costs (in addition to those of Scenario B): • ERP, MES, PDM, and SCM systems • new automated production line, devoted to the customised shoes (best fit and custom-made) • additional employees for the cutting, stitching (which become internal activities), and assembling process • licences for software updates • maintenance costs for new machinery
Scenario D	In this scenario, the company adds an innovative logistics system to manage the distribution of materials and components along the different machines and phases of the new production line. Investments and costs (in addition to those of Scenario C): • logistics system • pallets and other appliances in the system • maintenance of the system • operators' training • costs for external logistics for delivering customised shoes

Looking at the different scenarios, it becomes evident that different degrees of innovation imply different capabilities to answer the market's demand. If the level of innovation is low (Scenarios A and B), the producer manufactures customised shoes (best fit) using the traditional production line. If the level of innovation is high (Scenarios C and D), there is no reason to reduce the production of standard shoes, because customised (both best fit and custom-made) footwear is produced on the new production line with an overall increase in the total amount of produced shoes. Concerning the estimation of the price of the customised shoes, other preliminary studies estimate a possible premium of 20%–30% on the price of conventional shoes. According to the collected data and their correlation, each scenario offers the possibility of increasing the Net Present Value (NPV) with different impacts according to the variability of the demand and correlated variables (variable costs, price, *etc*.). The NPV of such investments for a traditional shoe producer is always above zero, and comparing the four scenarios, it becomes clear that the value of NPV continually grows correspondingly to the increase in the demand level, which in turn can be satisfied thanks to the introduction of new technologies that can compensate for the increase at the cost level.

Beyond these scenarios, data collection from real-life experiences at the D&MC Lab made it possible to create a generic economic modelling tool. This tool is to be used by traditional shoe manufacturers to investigate various alternative approaches to mass customisation, and select the most fitting and profitable model. A mass customised solution can be seen as an integrated solution consisting of tangible components (*i.e.*, the shoes) and intangible components (*e.g.*, the service during the purchasing and co-design process). Costs and earnings deriving from the development of the entire solution are considered, and provide a cost and profit calculation tool for manufacturers considering mass customisation.

4.2 SWOT analysis and outlook

When analysing the strengths, weaknesses, opportunities, and risks of the D&MC Lab, it should be emphasised that the Lab is a non-profit institution. It was created in order to test the feasibility and practicability of an innovative technology for switching footwear production from mass production to mass customisation. Given that most of the manufacturers are SME, a real-life demonstration of the feasibility of customisation in the footwear industry is much more important than extensive research publications. The main purpose of the Lab is to allow both customers and footwear manufacturers to experience this innovative approach to shoe production and, moreover, to appreciate the results. Still, the Lab should be self-sustaining. Acting as a mini-factory for mass customised shoes for different brands, the Lab has a breakeven point of around 50 to 70 pairs of customised shoes per day, depending on the shoe type.

The SWOT analysis provided in Table 3 attempts to take into account both the Lab's point of view (particularly in regard to technical and organisational aspects) and some of the worthwhile lessons learned for entrepreneurs interested in starting up their own mass customisation production line or company. Small companies interested in following up the Lab experience face the typical challenge of entering a new, non-mature market in which consumers and retail partners have no experience with the offered solution. Yet at the same time, one of the major strengths also lies here: the innovativeness of the adopted technology and the offering of an integrated product-service solution that meets precisely the needs of demanding consumers in Western markets. The possibility of customising and personalising shoes could appeal to an increasingly wide spectrum of customers seeking best-fitting solutions for their individual needs. Thus, finding a wide range of potential customers (and cooperating shoe manufacturers) is one of the foremost objectives of the D&MC Lab initiative.

Table 3 SWOT analysis

Strengths	*Weaknesses*
Innovativeness of solutions and technologies First in the market (advantages originating from the learning curve) Organisation flexibility, production efficiency, and a good attitude towards innovation Being a non-profit institution, research activities are not driven by mere market considerations and, moreover, the dissemination of findings and results is one of the main goals	Lack of experience New technologies to be refined The Lab is not expected to be lucrative: this could also inhibit business-oriented developments Continuous funding as a non-profit entity: the Lab's persistence in the mid-long term is strongly dependent on (especially public) funding
Opportunities	*Threats*
New customer needs. The range of new customer requirements and the innovativeness of the adopted technology assure a short-medium term sustainability of the Lab EU-funded project has given the opportunity to create the Lab and, moreover, a network of contacts and relationships with a wide range of entities Technological evolvements can be applied and tested within the Lab	Funding shortage/stop. The interest of public funding in this specific area could decrease Problems in disseminating results: different approaches and lack of a real business orientation could invalidate the dissemination of results to the industrial world Persistence of results passing from prototyping to large-scale production

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