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Abstract	The aim of this document is twofold: • To provide a general overview of the European footwear characteristics in those aspects relevant for ROBOFOOT • To summarize the high level requirements of the sector for the introduction of robots in the manufacturing process.

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2 Introduction

This document is based on the analysis of some available literature and surveys and, above all, the feedback from end users, ROTTA and PIKOLINOS. This process has been carried out in parallel with the scenario definition. To this aim, both production facilities have been visited and workshops held, wherein main stakeholders have had the opportunity to exchange opinions.

The content of the document is structures as follows:

Chapter “3 Description of European Footwear sector”, provides an overview of European Footwear industry in terms of production and differences between SMEs and big companies.

Chapter “4 Shoe production classification”, is aimed at introducing different production classification criteria according to the users, assembly type and hinging mechanisms.

Chapter ”5 Process flow and production process” explains the organization of the production process in a typical footwear industry.

Chapter “6 Robots in Footwear Industry” describes some robotic applications in the sector.

Chapter “7 Requirements” summarizes high level requirements to take into account when introducing robots in production.

3 Description of European Footwear sector

3.1 Sector overview

The European footwear sector represents one of the most important and distinctive representative of the Made in Europe. The unique heritage of tradition and of craftsmanship helped building along past decades an international competitiveness and position in all market segments, which has been restricted in recent times to the **highest quality segment** of the footwear.

The shoe manufacturing industry is maybe the first example of mass customization, as old as 2000 years, when the performance needs of the Roman armies required the production of a standard walking shoe in different sizes. The Caligae was a strong sandal fitted with leather strips and a thick leather bottom, reinforced with iron nails for added grip. It was a standard element in the equipment of legionaries, who received three pairs a year.

Fig. 1 Roman Caligae

Until the second half of the XX century, the manufacturing of shoes has been a craft-made work and only the wealthy could afford to wear shoes. The industrial production, with a varied and graded supply of industrial shoes, has allowed since then a growing number of people to wear shoes for most of their day time.

The EU is the primary source for footwear design in the world and home to some of the world's largest and most prestigious footwear brands. They have created a worldwide reputation for quality and creativity. However, European industry is experiencing a severe crisis as a result of the steady increase of imports of footwear products from countries with low labour costs that compete EU production on the basis of a better price/quality ratio.

According to the latest structural data available [EUS01]:

- The European footwear sector consists of more than 26,600 enterprises, many of them SMEs, which generate 65% of the added value. The sector is characterized by a high level of competition among **micro companies and SMEs** with a low level of concentration. Under the pressure of international competition, large companies are tending to disappear, while small and flexible production units organized in clusters are better able to maintain their competitive position. The number of enterprises in the sector has gradually decreased, by more than 20% over the last ten years. More than 45% of the value added is produced by micro and small enterprises (i.e. employing less than 50 people) and more than 25% produced by medium sized enterprises (i.e. employing between 100 and 250 people). This can be compared with 30% in manufacturing industry as a whole. In the case of Italy, close to 60% of value added is created by enterprises with less than 20 employees. In the case of Spain, Portugal, France and the UK, medium or (relatively) big companies, ranging from 50 to more than 300 employees still play an important role in the production.
- They **generate €26.2 billion in turnover and €6.9 billion in value added** (0.5% of total EU manufacturing). Between 2000 and 2005 the decline in footwear production was 8% per annum on average. In2006 and 2007, the rate of decline in the production index slowed down (to 3% on average), being the major fall of 10% in 2008. Due to the continuous losses in EU production, the production index in 2008 was 50% below the index value of 2000. In the first quarter of2 009, the decline in production has accelerated to reach -18.3% compared to the same period of the previous year.

- The sector directly **employs 388,000 people** (EU-27, 2006), although the industry has lost around 4 % of its workforce per year over the last eight years. In contrast with other manufacturing sectors, the drop in employment in the footwear industry has not been accompanied by productivity gains.
- As a result of its **labour intensive character**, its share in the total manufacturing employment is higher than that of value added, with a contribution slightly higher than 1%. As a matter of comparison with other labour intensive and SME based sectors in the fashion industry, the EU textile and clothing sector contributes 4% of to total EU manufacturing production and 7% of EU manufacturing employment
- Two thirds of the total EU footwear production is actually concentrated in **three countries**: Italy, Spain and Germany, with Italy accounting for around 40% of EU production.

Hereafter we include a summary of the analysis done in [EUS02].

The competitive advantages of EU production lies in the **high quality** of production in technical, aesthetic and fashion-related terms, and the development of highly sought after brands with a strong image. Besides that, the footwear sector has undergone a restructuring in the past decades and introduced organizational and technological changes, outsourcing low added value operations to other countries (e.g. Maghreb).

However, high costs compared with Asian countries, the lack of properly skilled human resources an ageing workforce and lack of investment capacity are weak points of the European Footwear industry.

While the absolute figures at the level of the EU may appear fairly modest, the relative figures indicate that the footwear sector is a significant contributor to industrial production and employment in a number of countries such as Portugal, Italy, Spain, and Romania where it contributes up to 3% of total industrial production and 6% of total industrial employment.

The **average productivity** of the footwear sector is around 40% below the average productivity of manufacturing as a whole. The main reason is to be found in the fact that the footwear industry's production processes are highly **labour dependant**, due to the **lack of automation**.

Footwear sector is characterized by a fragmented value chain and by the presence of numerous actors in the production phase.

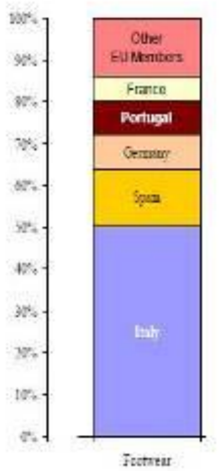


Fig. 2 Major European players, % EU27 turnover per activity (2005)

In the EU (with differences in each country) labour, material and manufacturing cost constitute 75 % of the total cost.

The preponderance of micro enterprises and SMEs in the footwear sector represents strength in the sense that companies of this size are usually more flexible and adaptable to changes in the market demand. However, the high number of SMEs in the sector is also an indicator of vulnerability as this kind of companies have in general a narrower capital base and are therefore less able to sustain external shocks and economic downturns, as currently happens.

In the footwear sector, consumers' behaviour seems to be fairly stable, the result of an increasing desire for comfort, which fosters the sales of casual shoes, and an increasing desire for brands and fashion.

In the footwear sector, liberalization took place at the same time as for textile and clothing (1st January, 2005). Quotas had only restricted trade from China and they were all lifted.

The re-installation of quotas against Chinese imports in 2005 has provoked a significant rise of the prices of China's exports to the EU. This is largely due to the fact that the quota system directly affects prices – costly quota management, speculation, etc. – and that it consequently demands firms to increase prices to compensate the reduction of production.

Liberalization resulted in a strong rise of Chinese imports and pulled import prices down by some 10% on average. The value of EU total imports of footwear went up 13% in value from 2004 and up 20% from 2003. China's market share in the EU in footwear rose to 39% in 2005 (up from 27% in 2004) in value.

To understand this situation, we present the situation of Spanish footwear industry.

	January/December (2009)			Variation % (2008/2009)			2009 % of total	
	Pairs	€	Average price €	Pairs %	Value %	Average price %	volumen	valor
China (R.Pop.)	238.574.989	617.888.368	2,59	-2,08%	0,67%	2,81%	73,21%	35,13%
Vietnam	28.208.531	248.722.515	8,82	-15,00%	-8,51%	7,64%	8,66%	14,14%
Italia	7.981.164	187.205.453	23,46	-6,55%	-13,10%	-7,01%	2,45%	10,64%
Portugal	6.466.418	100.139.973	15,49	-24,20%	-6,38%	23,51%	1,98%	5,69%
India	6.236.597	67.667.071	10,85	6,44%	14,25%	7,35%	1,91%	3,85%
Indonesia	5.352.268	79.375.075	14,83	-24,12%	-27,09%	-3,91%	1,64%	4,51%
Francia	5.027.568	71.171.682	14,16	-11,30%	-9,43%	2,10%	1,54%	4,05%
Países Bajos	4.410.708	85.653.340	19,42	8,59%	-5,91%	-13,35%	1,35%	4,87%
Bangladesh	3.775.636	21.168.757	5,61	56,68%	75,90%	12,27%	1,16%	1,20%
Brasil	3.221.701	37.688.468	11,70	-42,02%	-21,04%	36,17%	0,99%	2,14%
Marruecos	3.012.248	51.919.101	17,24	-22,38%	9,91%	41,61%	0,92%	2,95%
Hong-Kong	2.444.829	34.755.936	14,22	-1,81%	3,58%	5,50%	0,75%	1,98%
Bélgica	2.006.220	28.206.497	14,06	14,79%	2,58%	-10,64%	0,62%	1,60%
Alemania	1.813.987	20.595.352	11,35	-24,44%	-24,26%	0,24%	0,56%	1,17%
Thailandia	1.788.118	23.154.042	12,95	-31,79%	-20,78%	16,16%	0,55%	1,32%
Reino Unido	806.184	18.626.953	23,11	-14,86%	-20,50%	-6,63%	0,25%	1,06%
Turquía	548.755	2.271.753	4,14	-32,40%	-10,16%	32,91%	0,17%	0,13%
Rumanía	517.367	11.777.804	22,76	-2,75%	1,55%	4,42%	0,16%	0,67%
Túnez	413.210	10.719.578	25,94	-26,65%	49,03%	103,19%	0,13%	0,61%
Pakistán	336.001	2.910.126	8,66	-32,86%	-31,79%	1,59%	0,10%	0,17%
Camboya	332.179	3.693.457	11,12	92,87%	94,66%	0,92%	0,10%	0,21%
Malasia	329.267	1.880.738	5,71	-31,13%	-19,30%	17,18%	0,10%	0,11%
Irlanda	312.660	1.143.701	3,66	65,60%	28,73%	-22,26%	0,10%	0,07%
Taiwán	296.571	2.607.482	8,79	-39,15%	-10,79%	46,61%	0,09%	0,15%
Austria	200.018	2.353.467	11,77	-60,10%	-19,27%	102,31%	0,06%	0,13%
Dinamarca	150.480	1.170.129	7,78	-55,81%	-58,67%	-6,47%	0,05%	0,07%
Albania	106.236	1.883.890	17,73	734,47%	855,84%	14,55%	0,03%	0,11%
Otros países	1.222.321	22.736.313	18,60	-33,80%	-9,64%	36,49%	0,38%	1,29%
TOTAL	**325.892.231**	**1.759.087.021**	**5,40**	**-5,55%**	**-5,34%**	**0,22%**	**100,00%**	**100,00%**

Fuente: D.G.A : Elaboración: FICE - INESCOP

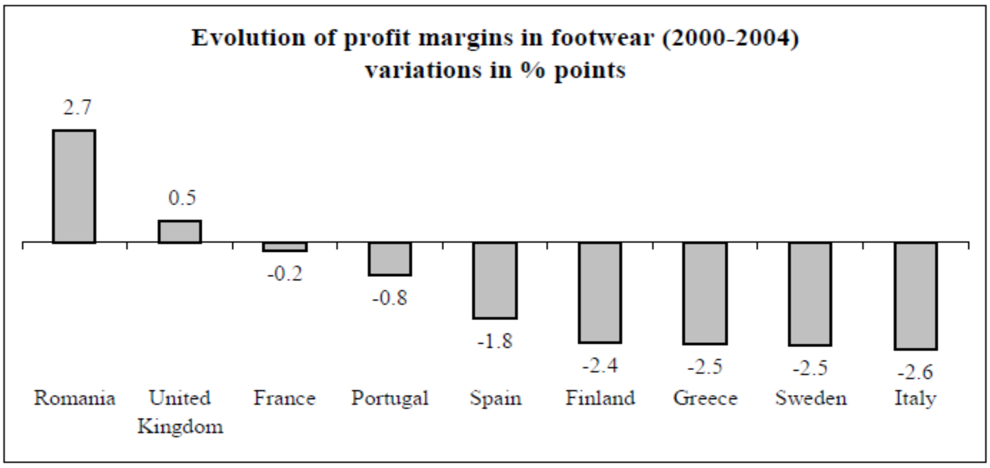
Table 1 –Spanish shoes imports

China's production increase has been detrimental for other Asian suppliers but also, to a lesser extent, for the competitive position of Mediterranean countries (-1 point in import share over the year) and non EU Central and Eastern European Countries (-2 points).

Footwear companies in most countries have recorded important falls in their profit margins between 2000 and 2004. Once again, Italy and Spain have particularly suffered, in full contrast with the British situation, because of early crisis of UK market, which determined industry shake-out.

The cash flow evolution has also been negative over the period. Italy, France and Spain suffered the largest decreases in their cash flows with respectively -21%, -11% and -8% per year on average. Nevertheless, decreases in cash flow were more limited for the UK (-2% per year) and Portugal (-1% per year)

In the footwear industry, firms have the largest profit margins in Poland (4.3%), Estonia (4%) and France (2.8%), and the lowest levels in Sweden (-0.4%), Italy (-0.6%), Spain (-1%), Portugal (-1.2%) and in the Czech Republic (-2.2%). These last figures can be at least partly explained by the fact that firms have decreased their sales of traded goods.



Source IFM : Amadeus

Fig. 3 Profit margins in footwear (2000-2004)

In the footwear industry manufacturers are increasingly interested in new markets and business models, particularly the safety shoe market and orthopaedics where the high level of quality and service required enables suppliers to charge their clients for a quite high value added or the mass customization concept.

Another important phenomenon in the sector is the increasing role played by clothing retailers, all over Europe. For example Zara, with more than 20 million pairs sold each year, has become one of the largest shoe retailers in Europe.

In **Germany** there are very few truly independent retailers. Nearly 90% of them work with central buying offices. However, the overall number of outlets is diminishing, due to consumers' extreme sensitivity to prices on the German market. As independents are losing market shares, the market chain stores go on expanding at steady rates. They only represented 23% of consumption in 2004 (35% in 1995).

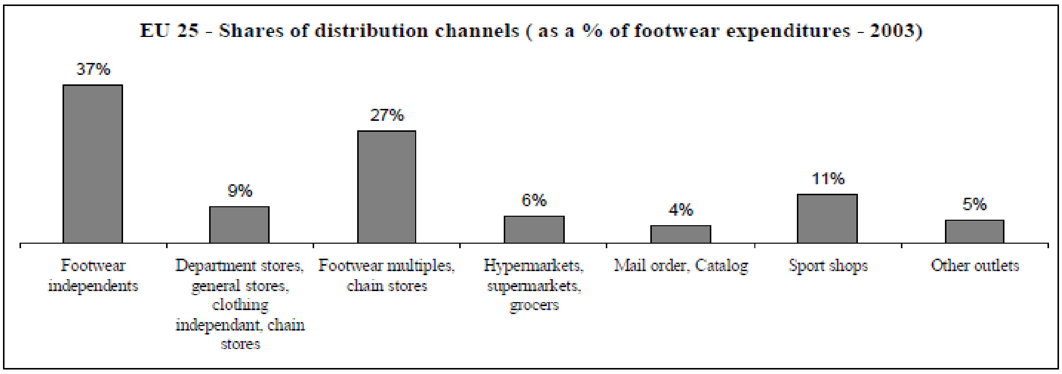
The **Spanish** shoe market has been developing quite fast over the last ten years. The vast majority of sales (80%) are done through the independent retail network.

Specialty shoe (custom made shoes, security shoes, technical shoes,...) trade occupies an important place in the French shoe market. Independent retailers have seen their market share fall between 1995 and 2004 from 26 to20%. They now seem to have stabilised their position. Chain stores have changed little overall during the period studied. The market shares won by hypermarkets on the outskirts of towns have been counterbalanced by the ground lost by inner-city chain stores. The most striking change concerns sport stores whose market shares have gone from 10% in 1995 to more than23% in 2004. [EUS02].

The **Italian** market is the largest in Europe. The market share represented by independent retail is still quite large in comparison to other countries, though it is constantly shrinking. In1995, independent shoe retailers represented 72% of the Italian market in value. In 2001, this share dropped to 67%, then to 65% in 2003.

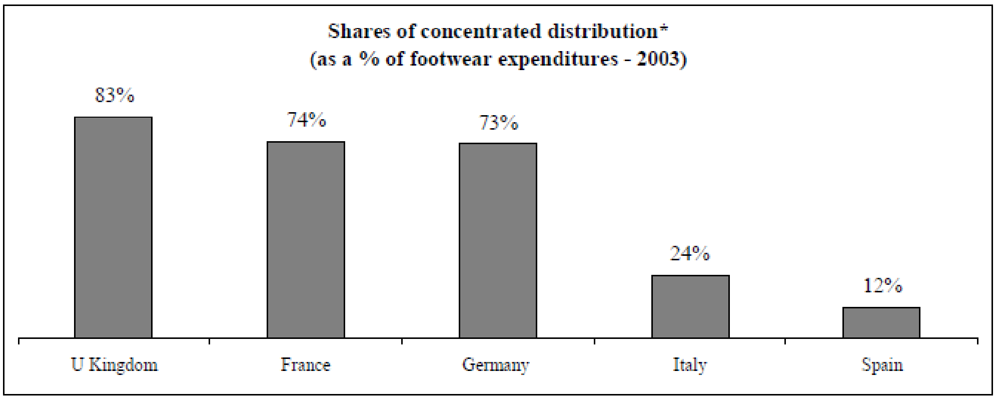
With 10% of the **UK market** against 14% in 1995, independent retailers have stabilised their position by continually being on the lookout for new brands, amidst the highly standardised offer of organised business. The mid-market range is stagnating, while low price and very up market stores are gaining ground. In recent years chain stores have been concentrating their business increasingly and more new stores have been created.

In the **United States**, local or regional discount brand-name shoe chain stores are cropping up increasingly. They began to appear on the market two or three years ago and the competition they represent to department stores and specialty stores is now considerable. These large box stores are often located on the outskirts of big cities; they sell American or European brands of shoes in all categories (women, men and children) at prices that are 20 to 60% lower.



Source IFM according to Sepic/FFC - Fédération Française de la Chaussure's data

Fig. 4 Distribution channels



*Concentrated distribution = department stores, general stores, mail order, footwear multiples, chain stores, hypermarkets, supermarkets, grocers, clothing chain stores, part of sport shops
Source : IFM estimate according to Sepic/FFC - Fédération Française de la Chaussure's data

Fig. 5 Shares of concentrated distribution

Consolidating the different strategic analyses above allows building the following “maps” indicating where European firms can today competitively and sustainably produce their manufactured products, be it for the internal markets or for exporting outside of the EU.

EU high costs

In this geographical area firms can competitively produce goods with higher added value for consumers. The key aspects are fashion, creativity, flexibility, raw material availability. The production is characterised by:

- High - mid price, reactive fashion
- Very fine materials, leather and others
- Diversified series
- Sport, protective, orthopaedic high quality footwear

EU medium costs

Labour cost is an important feature besides fashion, flexibility, raw material availability. The production is characterised by:

- Medium to low price, small quantities, based on fine materials, including leather
- Lower priced goods based on local leather
- Not reactive orders
- Medium price technical shoes with medium to large batches

Euromed non-EU

Cost is even more important in this zone, although flexibility and raw material availability have to be considered as well. The production is characterised by:

- Medium to low price, small quantities, for local markets and exports
- Items based on fine materials, including leather
- Lower price goods based on local leather

Turkey

The value added which is generated by Turkish manufacturing is based on several factors: cost, fashion, flexibility, availability of quality materials. The production is characterised by:

- Medium to low price, fairly reactive fashion
- Items based on fine materials, including leather
- Lower priced goods based on local leather
- Components for technical items

Asia

Price is the first criterion for outsourcing production but some other factors play an important role also, especially for very specific type of products for which local base material and know-how are globally renowned.

Footwear: in particular high volume capacity, sport segments know how

- Large quantities per production runs
- Rather permanent collections than fast fashion items
- All quality ranges in sport shoes and almost same for leather shoes
- High volume standardized technical footwear

3.2 Production data

In table 1 data on EU footwear production, exports, imports, apparent consumption and the EU market share are shown since 1998 until 2005.

Some key figures can be extrapolated:

- 2001 was the second year in which the production decreased below 1 billion pairs, and also the first year in which imports in the EU exceeded EU production;
- Since 1998, production dropped by 534 Mio of pairs;
- In the same period, imports have been doubled.

	1998	1999	2000	2001	2002	2003	2004	2005
Production	1.147.271	1.030.320	996.857	970.013	883.187	782.280	693.047	613.011
Exports (world)	240.922	228.491	236.879	227.767	214.348	181.276	170.142	163.262
Imports (world)	761.681	984.729	1.033.941	1.160.782	1.232.914	1.455.084	1.717.530	1.956.654
Apparent consumption (1)	1.668.030	1.786.558	1.793.919	1.903.028	1.901.752	2.056.088	2.240.435	2.406.423
EU produces market share (%)	54	45	42	39	35	29	23	19

(1)Apparent consumption=production + imports–exports

Source: Eurostat, National Federations

Table 2- Production (thousands of pairs)

Euro (€)

	2000	2001	2002	2003	2004	2005
Eur25 Production	70	69	67	54	53	47
TotalImports	30	31	33	46	47	53

Source: Eurostat, National Federations

Table 3- Market share in the EUR25 in %

Recent data show a slight trend inversion, testifying data stabilization and a certain degree of recovery. Hereunder some data for European production are presented:

EU-27 Structural data

	2004	2005	2006	2007
Number of firms	28 941	27 125	26 624	26 100
Turnover (€m)	26 389	25 922	26 233	30 296
Production value (€m)	25 072	24 854	24 583	28 927
Value added at factor cost (€m)	7 214	6 793	6 944	7 631
Direct employment	443 900	404 500	388 100	368 600

Products covered / Nace Rev. 2 code DC 19.3

Source: Eurostat

EU-27 Production, consumption and external trade

1000 pairs	2005	2006	2007	2008	% growth 2005-2008
Production	706.704	684 639	642 386	605.824	-14,3
Exports	161.914	168.495	175.201	177.509	9,6
Imports	1.932.645	2.102.748	2.512.129	2.429.626	25,7
Apparent consumption	2 477 435	2 618 892	2 976 066	2.857.941	15,4

Apparent consumption: production + imports - exports

Source : Eurostat + estimates by DG Enterprise & Industry

Table 4- Structural data, production and consumption trends

3.3 SME production characteristics

Two important factors characterize this sector: fragmentation and the financial weakness of many companies.

The fragmentation issue is complex as on the one hand it is the result of a complex segmented home market that leads to fragmentation of supply. It is also the consequence of intrinsic fragmentation of processes, consumption and fashion cycles. The fragmentation is also the result of history and profile of local entrepreneurs. Fragmentation remains high and there is no significant trend of overall consolidation, although large companies dominate processing activities as well as global brands, the overwhelming pattern of the industries is **SME-based**. As such special attention should be given to how the tools and programmes available can better reach and help them.

Fragmentation brings considerable weaknesses:

- a vulnerable financial and/or commercial base
- a limited range of skills available in the company and sometimes
- a narrow regional focus with a lack of global perspective. It significantly limits controlled delocalisation of production and thus implies that firms are at a higher risk of rapidly ceasing activities altogether.

The fragmentation of the industries is also a severe obstacle when it comes to implementation of complex changes in export strategies or participation in research.

A particular source of concern for SMEs in the footwear sector under review is their vulnerable financial position. More acutely than larger firms they suffer from a structural decline with intensified global competition in a period (2001-2005) of cyclical downturn. Only few firms reach healthy financial levels that would allow them to finance redeployment, adapt to EU norms and regulations, and diversify from commodity to specialty products (requiring specific investments) or better focus on markets with higher barriers to entry. Redeployment may then only occur through internal restructuring of assets especially by transforming fixed assets (buildings) in current assets, thus delocalising production in order to regain profits and relying on subcontracting instead of directly controlled production. This is however only possible when there are no legacy costs, property is attractive and the restructuring itself does not involve closure costs that severely limit resources for investment in new activities.

However fragmentation provides flexibility, creativity and intensive incremental innovation. It means also specialisation in markets and technologies and provides opportunities for entrepreneurship.

They should receive specific attention in the implementation of policies, particularly at the EU and national levels. They should also be stimulated to mutualise efforts and assistance through modern service oriented industry associations, chambers of commerce and industries.

INESCOP is an example of this last idea: it is a service organisation that develops a series of scientific and technical activities of great interest to the Spanish footwear industries. These activities cannot normally be undertaken individually by companies due to their small size but, however, such activities are of a great interest for the maintenance and strengthening of the footwear sector in Spain.

ROTTA's data below can give an idea of main production characteristics in SMEs:

- Number of models per season: more than 200
- Number of seasons: 2
- Number of pairs produced: min 75.000; max 90.000. It means an average of 400 pairs per day.

- Average size of a production batch per model/number: it depends on product and season and can vary from a min of 50 up to a max of 3.500
- Number of different models produced simultaneously in the production line: 14 models
- Lead time (from design to production of a sample): 8 hours
- Number of models that are finally produced for each season: 140
- Number of different lasts per season: 26
- Number of shoe models per last : 3
- Number of sizes per last: 9
- Number of lasts in the factory (number of models): 50
- Number of identical lasts (same model, same size): max. 3. This is one of the reasons there are so many different models in the manovia at the same time.
- Time employed per pair (average): 2 minutes (2200 working hours per year).
- Time needed to introduce a new model in the production line: 2 month
- How long does it last a production order in the production line: it depends on availability of raw materials and can vary from 3 days up to 2 months
- The lasts usually used within the production process are 98% lampo hinged. The rest 2 % are cuneo hinged and mainly used for boots' production.

3.4 Big companies' production characteristics

Production has been organized according to new world global situation. Their product map configuration allows them to manufacture shoes in different countries based on costs and quality criteria. No fashion shoe lines can be sent to external countries for developing and production manufacturing. A previous work must be done on selecting partners taking care of quality standards. Most of brands can take different options in order to guarantee quality issues:

1. Onsite self trained persons.
2. To train native persons for quality supervision
3. Quality supervision outsourced

On the other hand, fashion shoe lines must be manufactured in local areas due to delivery issues. This kind of product is manufactured at the last moment in order to absorb new trends. Outsourcing of production is really complicated for this kind of products.

PIKOLINOS' data below can give an idea of main production characteristics in big companies:

- Number of models developed per season: Average: 600 models (both brands), of which only 300 models are finally launched to market.
- These 300 new models per season means 120 new lasts.
- Number of seasons: winter and summer. Some reprise collections are done to fulfil required market trends.
- Number of sizes produced for each model: Men: 39-46, Women: 35-42
- Average size of a production batch per model/number

  60 pairs model/colour (Main PIKOLINOS factory in Spain, Vabene)

- Number of different models produced simultaneously in the production line: 15
- Lead time (from design to production).

  Development: 23 labour days (design approval, fitting approval, sample size mould, cutting dies)

  Sample manufacturing: 21 days
- They use Lampo mechanism (99%) and occasionally without hinging mechanism (1%).
- Production: 1.600.000-2.000.000 pairs/year

In Vabene, the production company belonging to PIKOLINOS group, there are 15 operators working simultaneously in each production via (two vias in peak season), plus another 8 persons in the packaging/inspection area. In this production facility the staff changes during the different seasons, from 30 to 70 operators as an average.
Most of the PIKOLINOS staff (around 200) works in Spain and only 7 inspectors work in those countries wherein most of the production is outsourced (China, India and Morocco). In fact, the distribution of production is as follows:

- Spain: 20-30%
- China, India, Morocco: 80-70%

The production scheduling in a complete season is presented in the next picture:

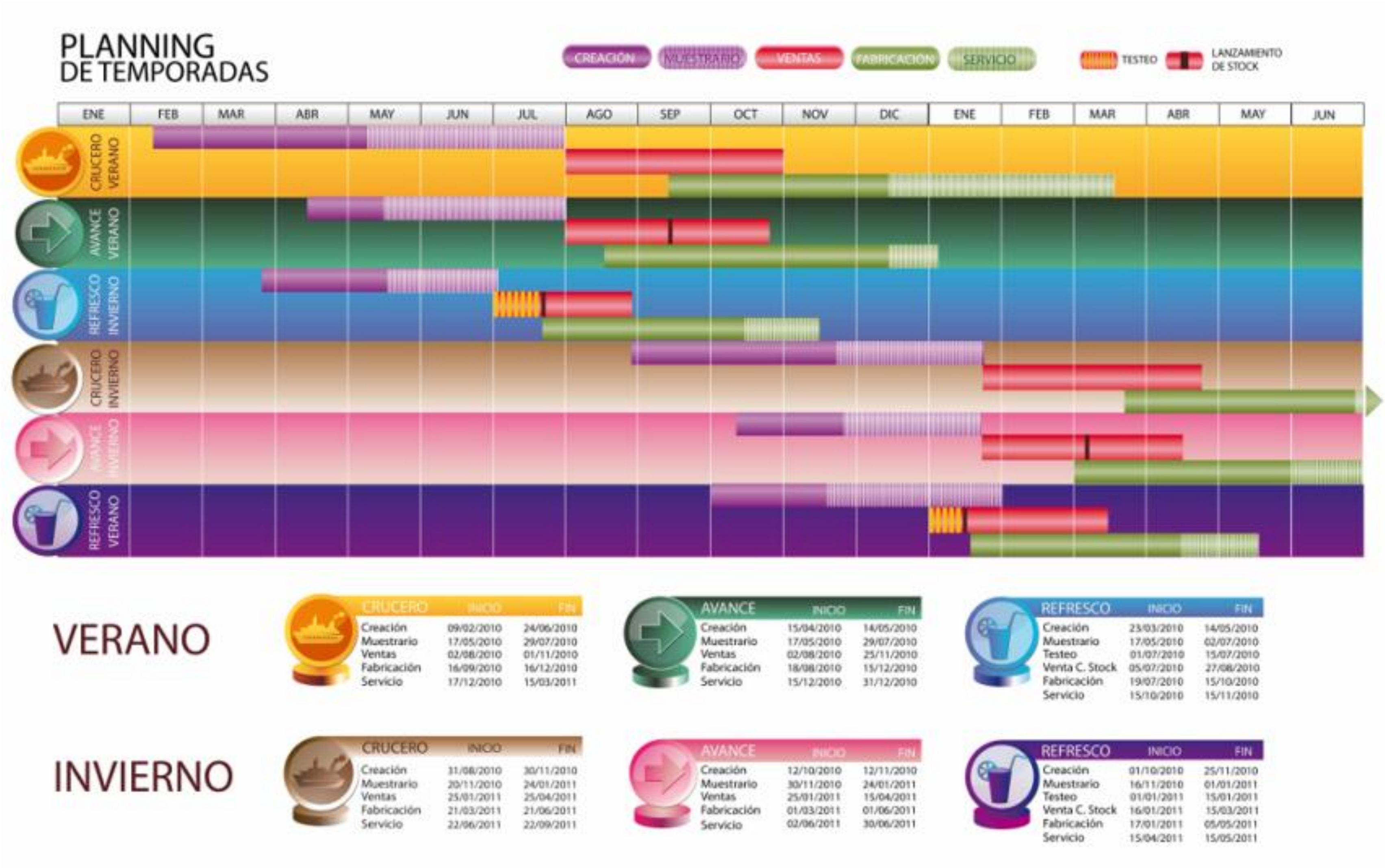


Fig. 6 Season production planning at PIKOLINOS

- Number of models that are finally produced for each season

  Average: 420 models (both brands)

  Produced in Spain: 140 (both brands)

  Main PIKOLINOS factory (Vabene): 85
- Number of different lasts per season

  Average: 120 lines (both brands)

  Produced in Spain: 25-30 (both brands)

  Main PIKOLINOS factory (Vabene): 15-20
- Number of models per last

  Average number of models per line is 6,3
- Number of lasts in the factory (number of similar lasts)

  Average number of Lines manufactured in Vabene is 15-20
- Production rate: 1.41 pairs per minute

The high level production organization at PIKOLINOS is shown in the diagram below. Basically there are 15 operations related to manufacturing and 5 operation related to supervising and packaging.

There are some operations identified as bottleneck, wherein 2 workers are assigned (instead of one). In periods with low production, workers are reassigned and are in charge of several operations.

Line capacity is 85 pairs/hour, i.e. 1.41 pairs per minute.

OEE (Availability*efficiency*quality)=0.92*1*0.97=0.8924= 89%, where:

Availability: **(TO / TPO) =0.92**

TPO= Total operation time (12h)–planned breakdowns(2,20h)=9,80h

TO= TPO (9,80h)–breakdowns (0,75h)=9.05h

Operation time planned=9.80h/day

Breakdown time (average)=0.75h/day

Efficiency: ideal cycle time/(operation time/production units)=0.0097/(9.05/1003)

ideal cycle time=35s (0,0097h)

TO=9.05h

production units (average)=1003/day (41,79/h)

Quality= Units OK/total units=0.97

Units NOK (average)= 33/day

Main breakdown sources are:

1. Upper No OK to be lasted. Upper with problems to be mounted. Too much leather for example.

2. Toe lasting machine
3. Sole pressing machine

Maintenance= 8h/month (out of operation time).

Fig. 7 Production organization at PIKOLINOS

4 Shoe production classification

In order to better clarify the problems to be faced and make clear which the background of the project is, some additional information is hereafter given about material, terms and definitions, available technology and processes.

Footwear varies widely in style, construction technique complexity and related costs.

The materials commonly used depend on a number of factors such as:

- ✓ Prevalent use (user target types)
- ✓ Construction technique (type of assembly)
- ✓ Class of cost
- ✓ Fashion Requirements

A shoe can be divided into two major parts: upper (in Italian “tomaia” coming from the latin “*tomarion”* which means “scrap of leather” and “corte” in Spanish) and outsole.

Leather is the material most commonly used for the upper as well as plastic and textile.

The leather, rubber and plastic are the materials widely used for the outsole.

The shoe manufacturer, in the production of shoes is using a dummy foot in graded sizes, around which the shoe is shaped. This dummy is called **last** and the assembly process of the various parts of the shoe is called **lasting**.

Fig. 8 A last: the shoe is shaped on it

Lasts are graded in sizes roughly representing the shape of feet of different dimension and following standard rules defining the differences in length, width and height from one size to the next. Many such rules coexist today, contributing to further increase the problems for the customer seeking his perfect shoe. Unfortunately, the individual foot is seldom matching the Last, since every person has his own peculiar foot shape and even left and right of the same individual may differ by as much as 2 standard sizes (13 mm). The only choice a customer is left with is to look for a Last shape that is similar to his foot in the varied offer of the market and stick to it, till the model is substituted by new ones and the search starts all over again.

A preliminary nomenclature of major part composing a shoe is hereunder introduced in order to set a common language for articulating shoe production classification.

4.1 Shoe components

PART 1 - SOLE

The bottom of a shoe is called the sole, and can further be articulated into the following sub-parts.

Part 1.1 - Insole

The insole is the interior bottom of a shoe, which sits directly beneath the foot under the footbed (also known as sock liner). The purpose of insole is to attach to the lasting margin of the upper, which is wrapped around the last during the closing of the shoe during the lasting operation. Insoles are usually made of cellulosic paper board or synthetic non woven insole board. Many shoes have removable and replaceable footbeds. Extra cushioning is often added for comfort (to control the shape, moisture, or smell of the shoe) or health reasons (to help deal with defects in the natural shape of the foot or positioning of the foot during standing or walking). Basically, this is a main part of shoes which can absorb foot sweat. Footbeds should typically use foam cushioning sheets like latex and eva, which provide good wearing comfort of the shoe.

Part 1.2 - Outsole

The outsole is the layer in direct contact with the ground. Dress shoes often have leather or resin rubber outsoles; casual or work-oriented shoes have outsoles made of natural rubber or a synthetic material like Polyurethane. The outsole may comprise a single piece, or may be an assembly of separate pieces of different materials. Often the heel of the sole has a rubber plate for durability and traction, while the front is leather for style. Specialized shoes have modifications on this design often: athletic or so called created shoes like soccer, rugby, baseball and golf shoes have spikes embedded in the outsole to grip the ground.

Part 1.3 - Midsole

It is the layer in between the outsole and the insole that is typically there for shock absorption. Some types of shoes, like running shoes, have another material for shock absorption, usually beneath the heel of the foot, where one puts the most pressure down. Different companies use different materials for the midsoles of their shoes. Some shoes may not have a midsole at all.

Part 1.4 - Heel

The bottom rear part of a shoe is the heel. Its function is to support the heel of the foot. They are often made of the same material as the sole of the shoe. This part can be high for fashion or to make the person look taller, or flat for a more practical and comfortable use.

PART 2 -VAMP/UPPER

Every shoe has an upper part that helps holding the shoe onto the foot. In the simplest cases, such as sandals or flip-flops, this may be nothing more than a few straps for holding the sole in place. Closed footwear, such as boots, trainers and most men's shoes, has a more complex upper. This part is often decorated or is made in a certain style to look attractive.

See pictures Fig. 9 and Fig. 10 for more details:

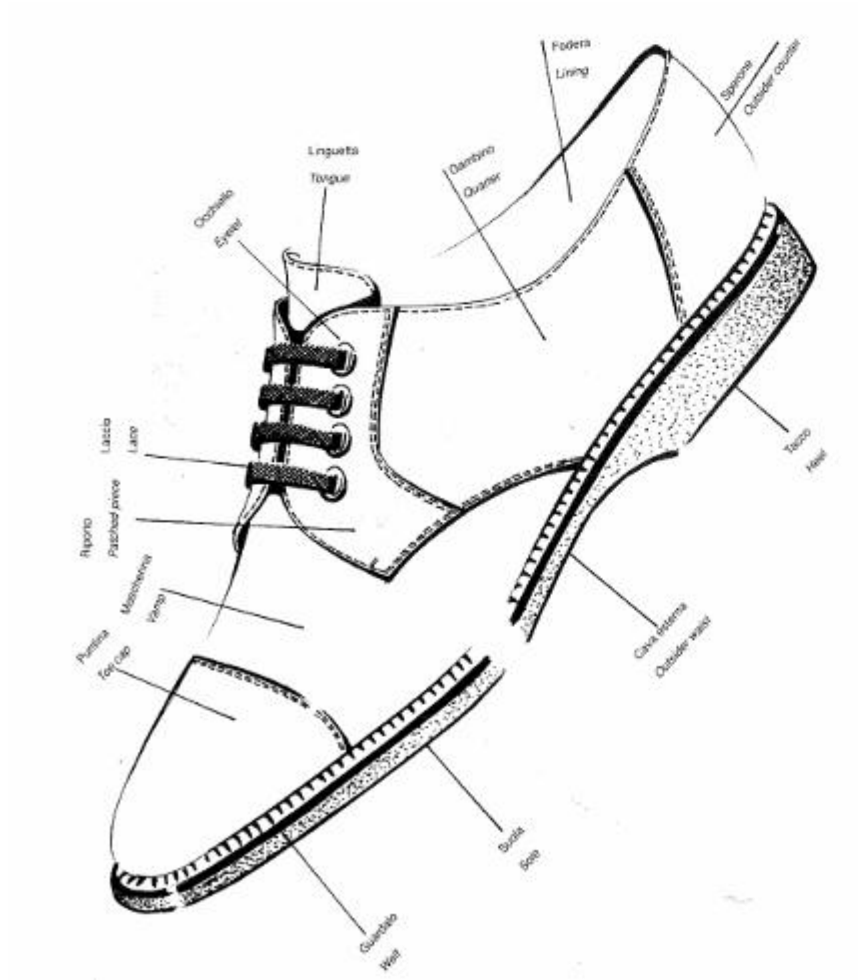


Fig. 9 Man shoe components

Fig. 10 Woman shoe components

In the following sections we will present a classification of shoes according to two different criteria:

- Criteria 1 - User target types: women, men, casual, fashion, safety, sports...
- Criteria 2 - Type of assembly

4.2 Criteria 1 - User target types

DRESS AND CASUAL

Dress shoes are characterized by smooth and supple leather uppers, leather soles, and narrow sleek figure. Casual shoes are characterized by sturdy leather uppers, non-leather outsoles, and wide profile.

Some designs of dress shoes can be worn by either gender. The majority of dress shoes have an upper covering, commonly made of leather, enclosing most of the lower foot, but not covering the ankles. This upper part of the shoe is often made without apertures or openings, but may also be made with openings or even itself consist of a series of straps, e.g. an open toe featured in women's shoes. Shoes with uppers made high to cover the ankles are also available; a shoe with the upper rising above the ankle is usually considered a boot but certain styles may be referred to as high-topped shoes or high-tops. Usually, a high-topped shoe is secured by laces or zippers; although some styles have elastic inserts to ease slipping the shoe on.

Men's shoes

They can be categorized by how they are closed:

- **Oxfords** (also referred as "Balmorals"): the vamp has a V-shaped slit to which the laces are attached; also known as "closed lacing". The word "Oxford" is sometimes used by American clothing companies to market shoes that are not Balmorals, such as Blüchers.

- **Blüchers** (American), **Derbys** (British): the laces are tied to two pieces of leather independently attached to the vamp; also known as "open lacing".

- **Monk-straps**: a buckle and strap instead of lacing

- **Slip-ons**: There are no lacings or fastenings. The popular loafers are part of this category, as well as less popular styles, such as elastic-sided shoes.

Men's shoes can also be decorated in various ways:

- Plain-toes: have a sleek appearance and no extra decorations on the vamp.
- Cap-toes: has an extra layer of leather that "caps" the toe. This is possibly the most popular decoration.
- Brogues (American: wing-tips): The toe of the shoe is covered with a perforated panel, the wing-tip, which extends down either side of the shoe. Brogues can be found in both balmoral and blucher styles.

Women's shoes

There is a large variety of shoes available for women, in addition to most of the men's styles being more accepted as unisex. Some broad categories are:

- **High-heeled footwear** raises the heels, typically 2 inches (5 cm) or more above the toes, commonly worn by women for formal occasions or social outings. Variants include **kitten heels** (typically 1½-2 inches high) and **stiletto heels** (with a very narrow heel post) and **wedge heels** (with a wedge-shaped sole rather than a heel post).

- **Sneaker boot** or sneaker pump: a shoe that looks like an athletic shoe, but is equipped with a heel, making it a kind of novelty dress shoe.

- **Mules** are shoes or slippers with no fitting around the heel (i.e. they are backless)

- **Slingbacks** are shoes which are secured by a strap behind the heel, rather than over the top of the foot.

- **Ballet flats**, known as **ballerinas**, **ballet pumps** or **skimmers**, are shoes with a very low heel and a relatively short vamp, exposing much of the instep. They are popular for warm-weather wear, and may be seen as more comfortable than shoes with a higher heel.

- **Court shoes**, known in the US as **pumps**, are typically high-heeled, slip-on dress shoes.

- **Platform shoe**: shoe with very thick soles and heels

UNISEX

- **Clog**

- **Moccasin**: originated by Native Americans, a soft shoe without a heel and usually made of leather.

- **Sandals**: open shoes consisting of a sole and various straps, leaving much of the foot exposed to air. They are thus popular for warm-weather wear, because they let the foot be cooler than a closed-toed shoe would.

- **Espadrilles** are casual flat warm-weather shoes of a style which originated in the Pyrenees. They usually have cotton or canvas upper and a flexible sole of rope or rubber. There are high-heeled versions for women.

- **Saddle shoe**: leather shoe with a contrasting saddle-shaped band over the instep, typically white uppers with black "saddle".

- **Slip-on shoe**: a dress or casual shoe without laces; often with tassels, buckles, or coin-holders (penny loafers).
- **Boat shoes**, also known as "deck shoes": similar to a loafer, but more casual. Laces are usually simple leather with no frills. Typically made of leather and featuring a soft white sole to avoid marring or scratching a boat deck. The first boat shoe was invented in 1935 by Paul Sperry.

- **Boots**: Long shoes (covering the ankle) frequently made of leather. Some are designed to be used in times of bad weather, or simply as an alternate style of casual or dress wear. Styles include rubber boots and snow boots, as well as work boots and hiking boots.

- **Sneakers or Canvas shoes**

ATHLETIC

Men's and women's athletic shoes and special function shoes often have less difference between the sexes than in dress shoes. In many cases these shoes can be worn by either sex. Emphasis tends to be more on function than style.

- **Running shoes**: very similar to above, with additional emphasis on cushioning.

- **Track spikes**: lightweight; often with plastic or metal cleats

- **Cleat (shoe)**: a type of shoe featuring moulded or removable studs. Usually worn to play sports such as rugby, football, American football, or baseball.

- **Golf shoes**: with "spikes" for better grip in grass and wet ground. Originally the spikes or "cleats" were made of metal but replaceable "soft spikes" made of synthetic plastic-like materials with prongs distributed radially around the edge of each spike are much more common today (and are required on many golf courses since they cause less damage to the greens).
- **Bowling shoes**: intermediate style between ordinary dress shoes and athletic shoes. They have harder rubber soles/heels so as not to damage bowling alley floors. They are often rented or loaned at bowling alleys.
- **Climbing shoes**: a shoe designed for rock climbing. They typically have a close fit, little if any padding, and a smooth sticky rubber sole with an extended rubber rand.

- **Hiking shoes or boots**: usually have a high somewhat stiff upper with many lace eyelets, to provide ankle support on uneven terrain, with extra large traction on the sole.
- **Walking shoes**: have a more flexible sole than the running shoe, lighter in weight than the hiking boot, may have air holes, may not be water proof.
- **Skating shoes**: typically called *skates*. They have various attachments for skating on the bottom of the shoe portion.

- **Ski boot**: a large, thick plastic boot specially designed for attachment to the ski.

- **Skate shoes**: specifically designed for use in Skateboarding, the shoes are manufactured with flat soles as to allow a skateboarder to have better grip when riding a skateboard. They are very wide and have extra layers of padding to protect the skateboarders feet.
- **Cycling shoes** are equipped with a metal or plastic cleat to interface with clipless pedals, as well as a stiff sole to maximize power transfer and support the foot.

- **Snowshoes** are special shoes for walking in thick snow. In temperate climates, snowshoes are used for mostly recreational purposes in winter.

ORTHOPAEDIC

Orthopaedic or "comfort" shoes are made with pedorthic and anatomically-correct comfort qualities, such as padded removable footbeds, wide toe boxes and arch support are made especially for those with problematic feet.

DANCE

- **Pointe shoes** are designed for ballet dancing. These have a toe box that is stiffened with glue and a hardened sole so the dancer can stand on the tips of their toes. They are secured by elastic straps and ribbons that are tied to the dancer's ankles.

- **Ballet shoes** are soft, highly pliable shoes made of canvas or leather, with either continuous or two-part sole (also called *split-sole*). The sole is typically made of leather, with thicker material under the ball and heel of the foot, and thinner and thus more flexible material under the arch so that the foot can be pointed to its utmost. Ballet slippers are usually secured by elastics that cross over the top of the foot. They are most commonly pink, white, black, or pale tan, although they may be made in specialty colours such as red or blue.

- **Jazz shoes** typically have a two-part, rubberized sole (also called *split-sole*) to provide both flexibility and traction, and a low (one inch or shorter) heel. They are secured to the foot by laces or elastic inserts.

- **Tango** and Flamenco shoes are used for dancing the tango or flamenco.
- **Ballroom shoes** fall into two categories: Ballroom and Latin American. Both are characterised by suede soles. Men's ballroom shoes are typically lace-ups with one-inch heels and patent leather uppers. Ladies' ballroom shoes are typically court shoes with two-inch heels, made of fabric that can be colored to match the dancer's dress. In contrast to the low Ballroom heel, which evenly distributes weight across the foot, Latin American shoes have higher heels designed to shift weight onto the toes. Latin shoes are also more flexible than ballroom shoes. Men's Latin shoes typically have 1.5- to 2-inch high, shaped heels, while Ladies' Latin shoes have 2,5-inch to 3-inch heels. Ladies shoes are typically open-toed and strapped.

- **Dance sneakers.** Also known as dansneakers, these are a combination of a sneaker and a dance shoe, with a reinforced rubber toe.
- **Character shoes** have a one to three inch heel, which is usually made of leather, and often have one or more straps across the instep to secure it to the foot. They may come in soft-soled (suede) or hard-soled varieties. They may be converted to tap shoes by attaching taps.
- **Foot thongs** are known by various names depending on the manufacturer, including dance paws, foot undies, and foot paws. They are slip-on, partial foot covers that protect the ball of a dancer's foot from skin abrasions while executing turns. From a distance, flesh colored foot thongs give a dancer the appearance of having bare feet.
- **Tap shoes** have metal plates mounted to the bottoms of the toe and heel. The metal plates, which are known as *taps*, make a loud sound when struck against a hard performance surface. Tap shoes, which are used in tap dancing, may be made from any style of shoe to which taps can be attached.

WORK/SAFETY

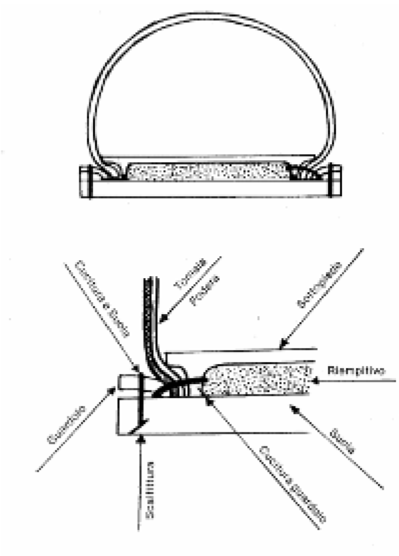
Work shoes are designed to stand heavy wear, to protect the wearer, and provide high traction. They are generally made from sturdy leather uppers and non-leather outsoles. Sometimes they are used for uniforms or comfort by nurses, waitresses, police, military personnel, etc. They are commonly used for protection in industrial settings, construction, mining, and other workplaces. Protective features may include steel-tipped toes or plastic protective toe caps and soles or ankle guards. Safety Shoes in particular shall conform to EN 20345 norms, in order to satisfy strict protective requirements.

4.3 Criteria 2 - Type of assembly

There are several construction techniques available in shoe making process, some of which are typical of certain shoe typology (e.g. Strobel construction for injected safety shoes).

Following paragraphs focus on specific construction techniques by detailing sectioned shoe in terms of sewing and component assembly.

<table>
<tr><th colspan="2">“Goodyear” welt construction</th></tr>
<tr><td>Such construction consists of:
• Sewing between insole and upper+ welt
• Sewing between welt and sole

Resource used in assembly: dedicated stitching/sewing machines and operators</td><td>
Fig. 11“Goodyear” welt construction</td></tr>
</table>

“Blake” construction

Such construction consists of:

- In-out sewing: to sew the sole, last shall be removed before such operation, and then re-inserted for finishing. Such sewing is visible from insole.

Indicated for flexible and light footwear

Resource used in assembly: dedicated stitching/sewing machines and operators

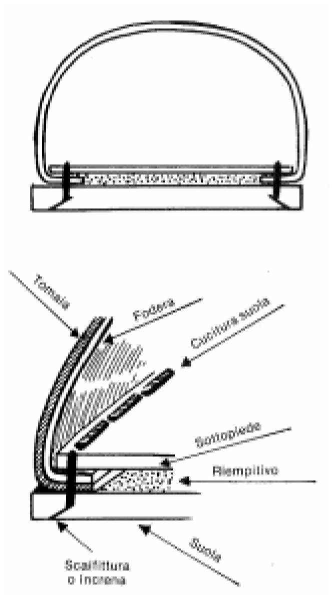


Fig. 12“Blake” construction

“Mixed” construction

Such construction is similar to Goodyear and differs from the nailed welt (instead of stitched).

Resulting footwear is more rigid, and is based on last with metal plate.

Resource used in assembly: dedicated stitching/sewing machines and operators

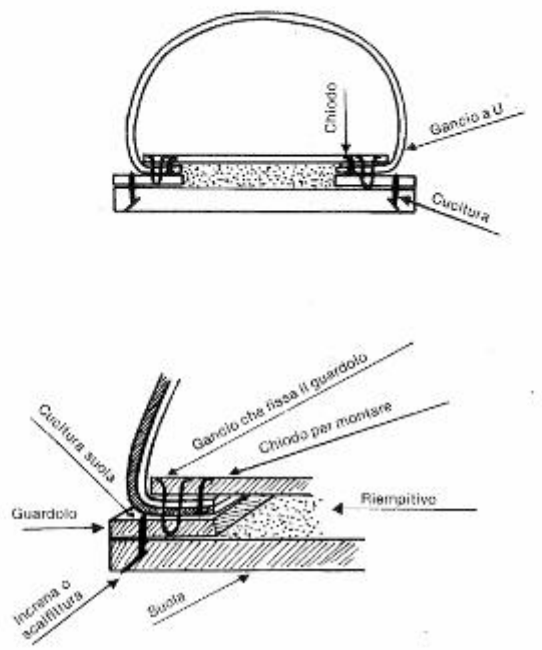


Fig. 13“Mixed” construction

“Reversed” construction

Upper is reverse stitched on sole.

Then stitching is reversed, leading to a right/left swapping.

Last is then inserted and shoe goes to finishing.

Indicated for light and flexible footwear.

Resource used in assembly: dedicated stitching/sewing machines and operators

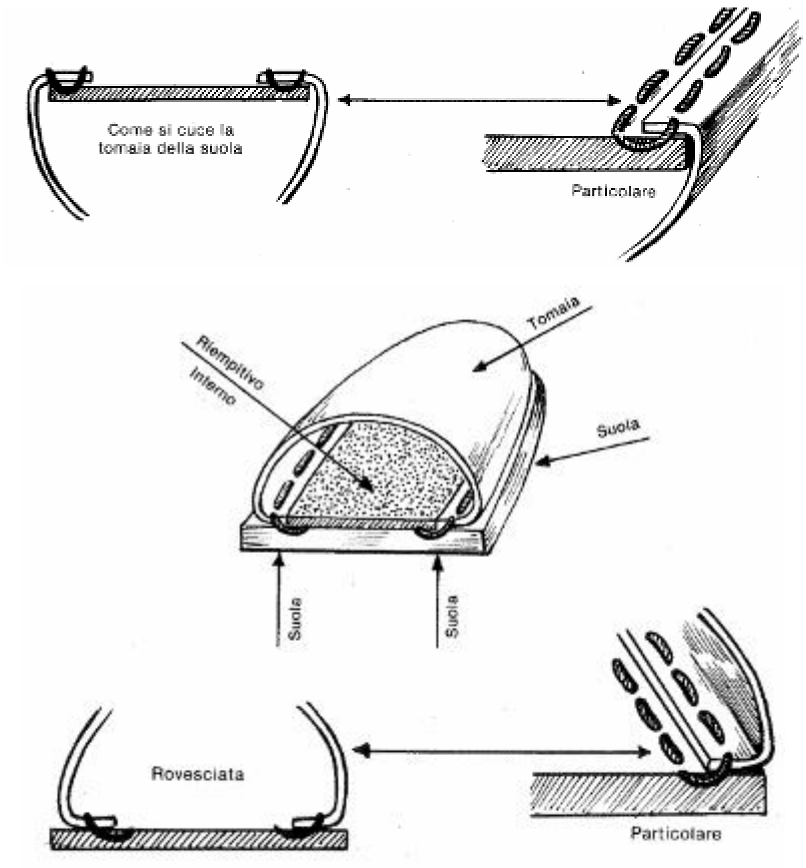


Fig. 14“Reversed” construction

“Ideal/St.Crispin” construction

Particularly indicated for summer shoes such as sandals, as it produces light and flexible footwear.

Some variants can be applied so as to enable use in winter shoes (with rubber sole)

Resource used in assembly: dedicated stitching/sewing machines and operators

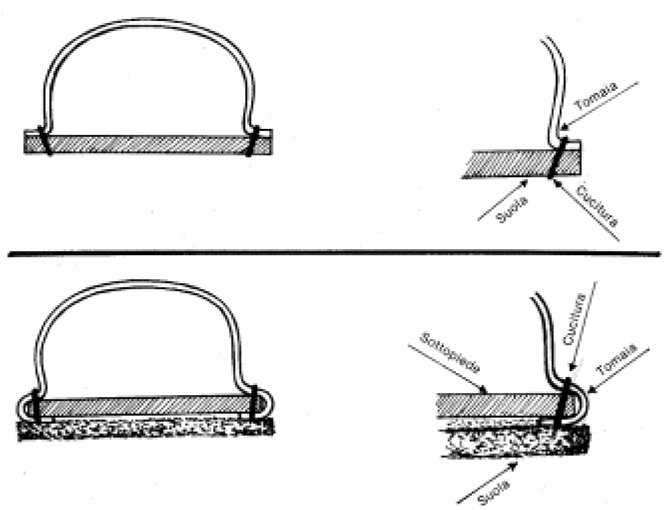


Fig. 15“Ideal/St.Crispin” construction

“Sole applied” construction

For medium quality footwear with reduced costs. Upper and sole are assembled through:

- Roughing
- Cementing
- Pressing

Upper is prelasted with glue and/or nails

Glue for sole application can be thermoplastic/neoprene/water based adhesive.

Resource used in assembly:

- Roughing (manual/automatic)
- Cementing
- Sole pressing

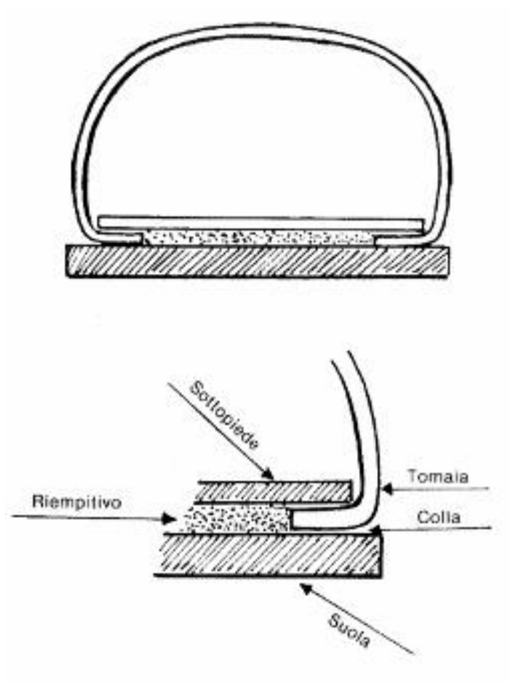


Fig. 16“Sole applied” construction

“Sol-California” construction

Upper is stitched to insole together with band covering wedge heel.

Resource used in assembly: dedicated stitching/sewing machines and operators

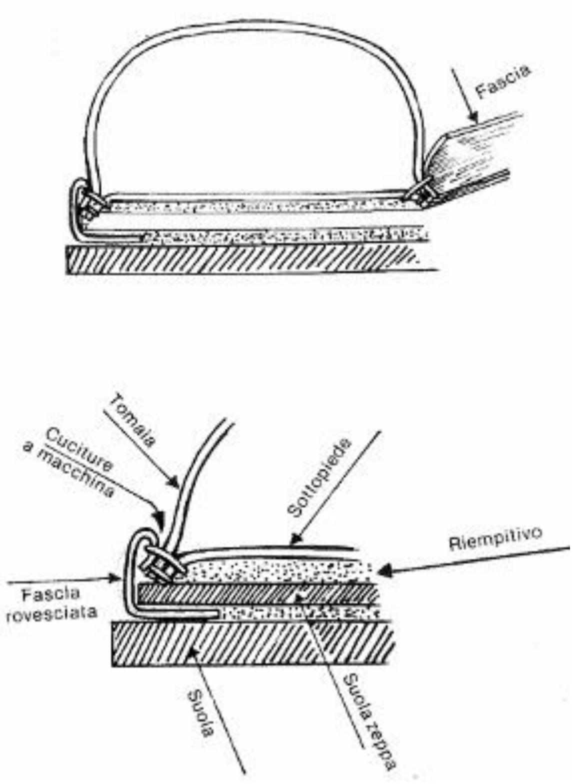


Fig. 17“Sol-California” construction

“Vulcanized” construction

Upper shall be mounted on metal last, and inserted in mould, previously filled in with rubber in granules. Both last and mould are heated, while pressed to couple.

Quantity of rubber to be “vulcanized” in the mould shall be calculated properly with reference to various sizes. Upper to be used for such type of construction shall be worked out properly, so as to resist to thermal stress.

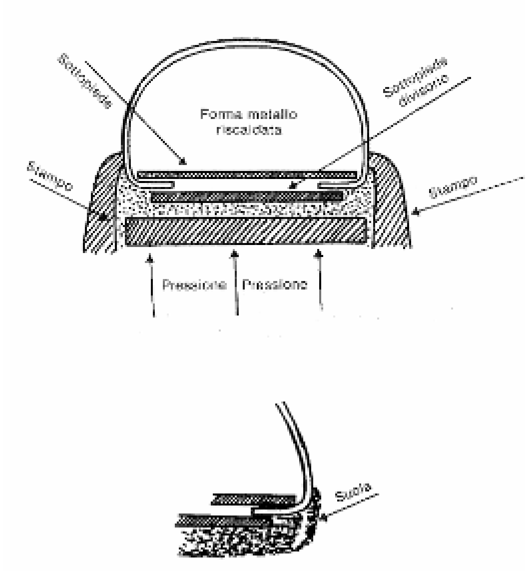


Fig. 18“Sol-California” construction

“Injected” construction

Similar to Vulcanized, it differs on the following steps:

- Pre- melting of rubber;
- Direct injection within mould, under pressure.

Uppers can be constructed:

- By gluing insole to vamp
- Like a socket;

Resource used in assembly: dedicated injection carousels

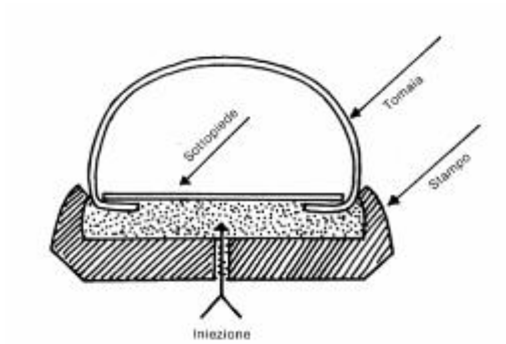


Fig. 19“Injected” construction

4.4 Hinging mechanism

Nowadays the production process of a last consists of several operations, the majority of which are aimed to obtain the needed volume and qualify of the surface, typically through copying machines and/or milling centres, both performing the roughing and finishing of the last surface.

Nevertheless, a last obtained as a unique block is difficult to be used in production, due to the fact that the shoe, once mounted on it, is hardly removable without creating wrinkles and/or scratches over the upper. Quality of final shoe obtained would be low, resulting in a product not suitable for selling.

Fig. 20 Solid (Man-Lady) Last

In order to solve such a problem, there is the need to “articulate” the last so that the shoe can be easily removed from it. Last articulation is nowadays performed by a hinging mechanism, i.e. a mechanism which allows opening the last in the shoe. Opening the hinge reduces its length and the last can be easily taken out of the shoe.

4.4.1 Hinge typologies

Hinge typologies can be distinguished based on several criteria:

- Application: traditional vs injection based constructions;
- Cost: depending on hinge reliability and repeatability over time;
- Product typology: some particular products, e.g. high heel lady shoes or shoes made of very delicate material (e.g. veil of nubuk) require the use of some hinging mechanism (e..g wedge hinge), in order not to mark the upper.

Mostly used hinge types are:

Hinges for traditional footwear

4.4.1.1 Lampo hinge

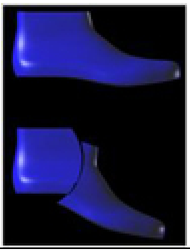
	Last is cut into 2 parts, according to a C cut. Through the use of a system of bolts, frame and spring, the front part of the last has two stable positions: • Closed: spring and frame kept front part in position and aligned with back part • Open: front part bends downwards

Fig. 21 Lampo hinged last

A variant of this is the so called “America hinged last”, with unblocking mechanism leverage on top.

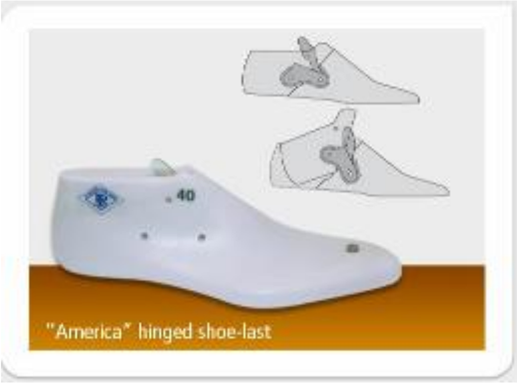


Fig. 22 “America” hinged last

4.4.1.2 V hinge

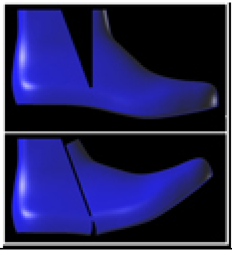
	Last is characterised by an empty “V” shaped volume. Through the use of a system of bolts, frame and spring, the front part of the last has two stable positions: • Closed: spring and frame kept front part in position and aligned with back part • Open: front part bends upwards

Fig. 23 V hinged last

4.4.1.3 Wedge hinge

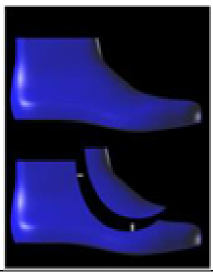
	The last is divided into two parts, with a curve cut following the neck of the foot. Through the use of a system of bolts (one of which inserted into a seat with a spring behind, and therefore pushable down), the front removable part of last can be detached.

Fig. 24 Wedge hinged last

Hinges for injected footwear

Main feature and difference of such lasts is the necessity to be more firm and stable, due to the use in high pressure injection carousel, likely to deform normal lasts.

Therefore main solutions for hinging opt either for the application of a metal plate to guarantee the perfect alignment of the two parts of the lasts, or on particularly articulated geometries.

4.4.1.4 Lampo hinge for injection

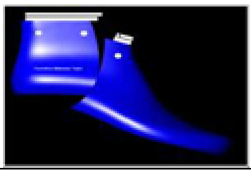
	Based on the aforementioned functioning principle, and characterised by superimposed metal plate to guarantee alignment.

Fig. 25 Lampo hinged last for injection

4.4.1.5 ART hinge for injection

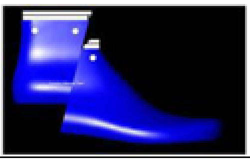
	A variant of lampo hinge based on linear cut, based on the aforementioned functioning principle, and characterised by superimposed metal plate to guarantee alignment.

Fig. 26 ART hinged last

4.4.1.6 Reverse hinge for injection

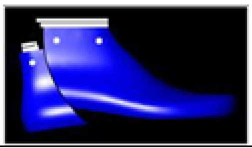
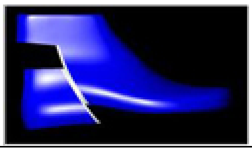
	A variant of lampo hinge based on reverse C cut and the bending of the rear region of the last, holding the metal plate

Fig. 27 Reverse hinged last

4.4.1.7 Slide hinge for injection

	A variant of reverse hinge based on "partial" reverse C cut, stopped at the level of the Achilles tendon insertion.

5 Process flow and production process

This section details the process flow and production process for some paradigmatic construction typologies among aforementioned ones.

5.1 Process flow

In particular, the figure below shows the first level of the functional view for the process. This is the most global level.

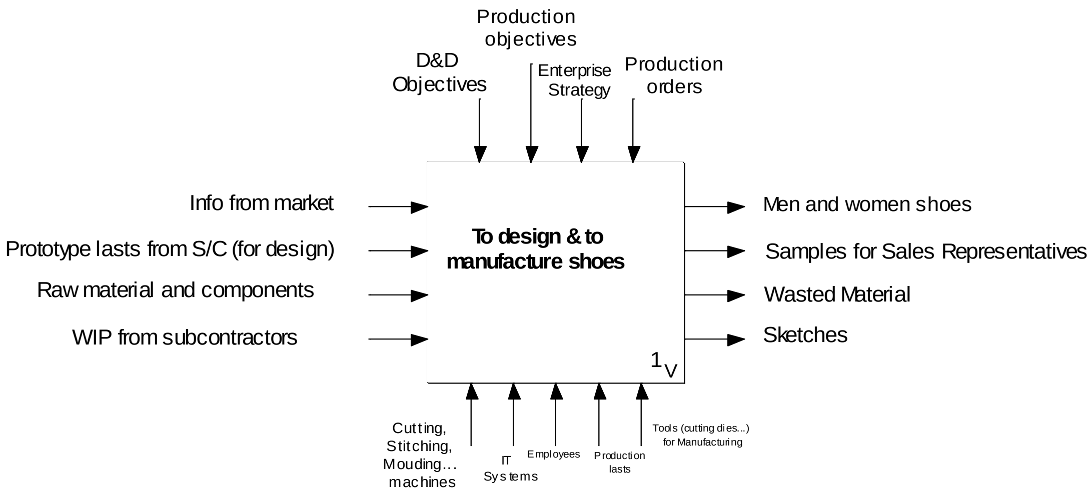


Fig. 28 The Typical global activity of manufacturing and design

Each box describes the transformation performed by the typical activity.

On the left of the box are represented the typical inputs of the system. These inputs are information or parts (including raw material) which are transformed by the physical activity.

On the right are represented the outputs of the typical global activity. These are the results of the transformation.

On the top of the box are represented the controls and constraints of the activity. This information is used to perform the activity but not transformed by this activity.

Under the box, they are represented the mechanisms. These are the physical and human resources required to perform the activity.

The model of next figure shows the two main activities which are the decomposition of the previous global one.

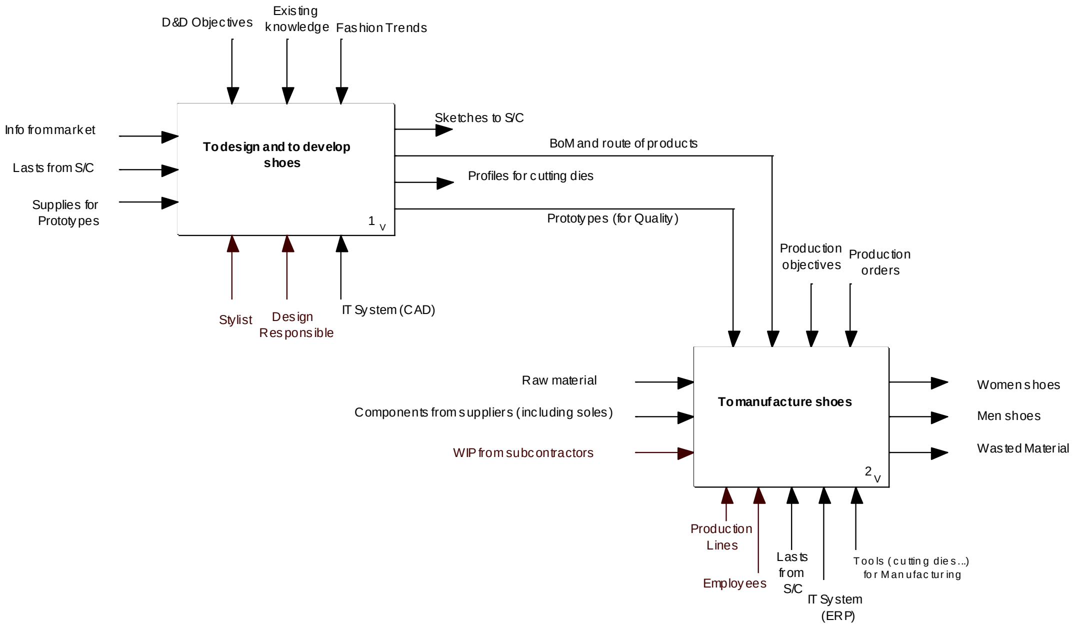


Fig. 29 The two main phases of Design and Manufacturing

This model also shows the links between the design and the manufacturing activities in a typical shoe enterprise. In particular, the Bill of Material (BoM) and the route of products are two of the results of the design and development activity and are required but not transformed by the manufacturing activity.

Figure below shows the business process of the manufacturing activities.

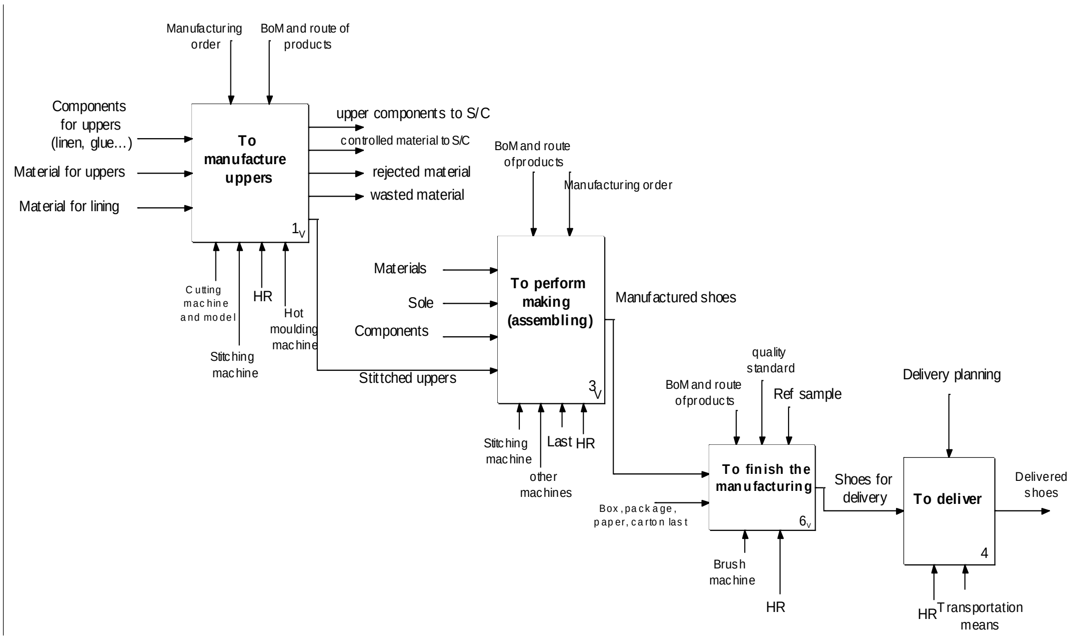


Fig. 30 Evidence of the 4 main phases of the Manufacturing process

There are four main activities involved in the shoe manufacturing :

- The manufacturing of uppers
- The making (assembling)
- The finishing
- The delivery.

The first main phase of the process is "manufacturing of uppers". After a quality control aimed at verifying possible defects of the materials, all the pieces required for subsequent assembly are cut.

The next step is the preparation of each cut piece for the subsequent stitching phase, through various specific operations (skiving, splitting, ...) that depends on the design requirements.

Finally the pieces are stitched together to obtain a pair of 'upper', namely the upper part of the shoe.

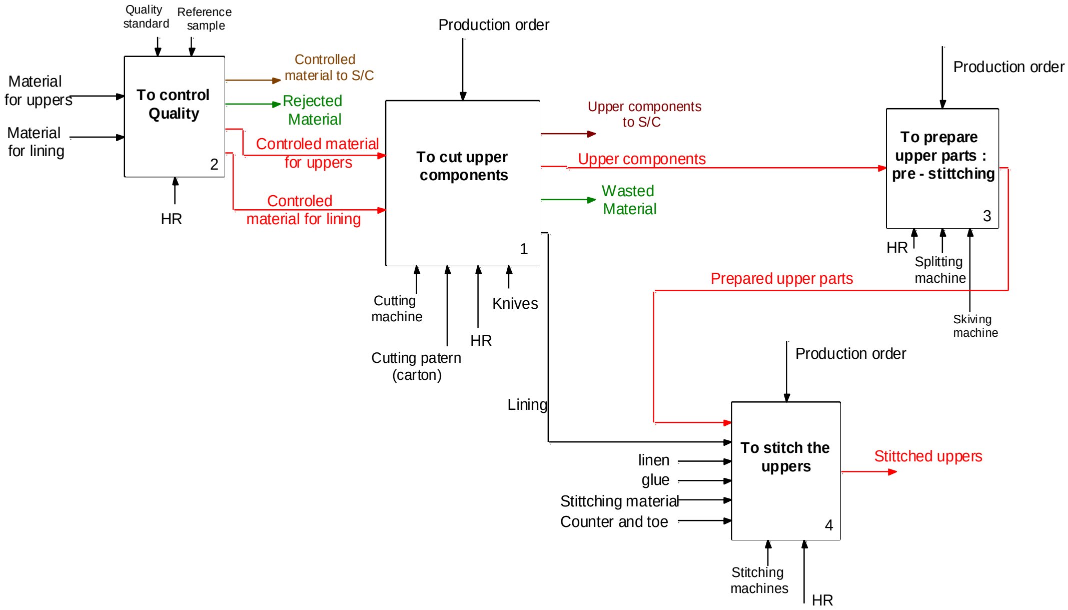


Fig. 31 Description of the 'upper manufacturing' phase

Next main phase is "making" of the shoe. First step is pre-assembling, where the 'uppers' are prepared for next steps. The set of operations in 'Lasting' are aimed at modelling the upper and the insole around the 'last'. Then the shoe is processed mainly in order to prepare the leather for the subsequent main group of operations, to apply the sole and possibly the heel. Next operation is last removal, where the last is separated from the shoe and send back to the beginning of the process for its reuse in a subsequent production batch.

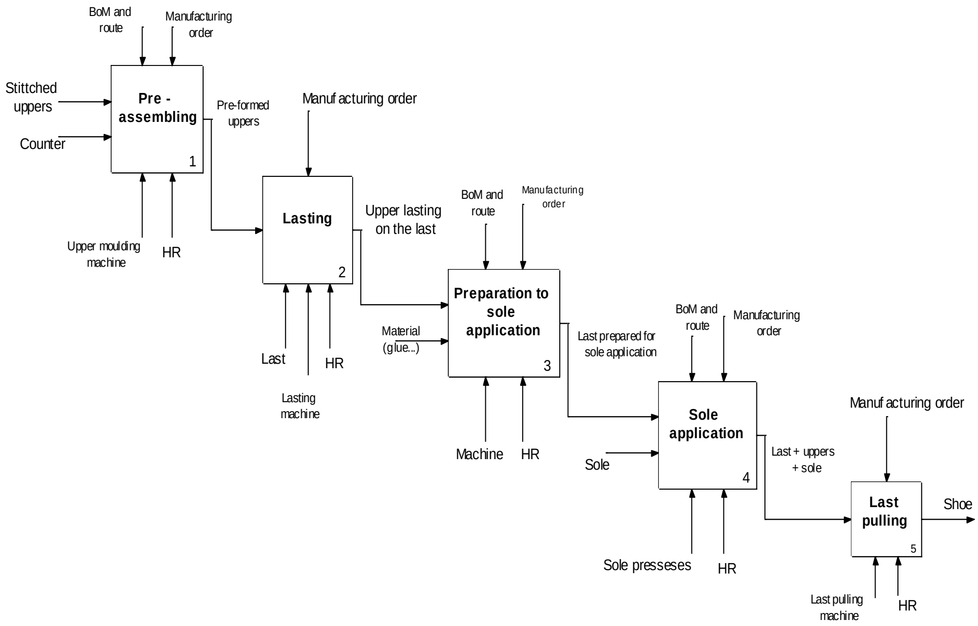


Fig. 32Description of the 'making' phase

The last main phase of production regards polishing of the shoes, addition of various accessories, laces and insocks, final check for possible inaccuracies and preparation of the box for delivery or stock in warehouse.

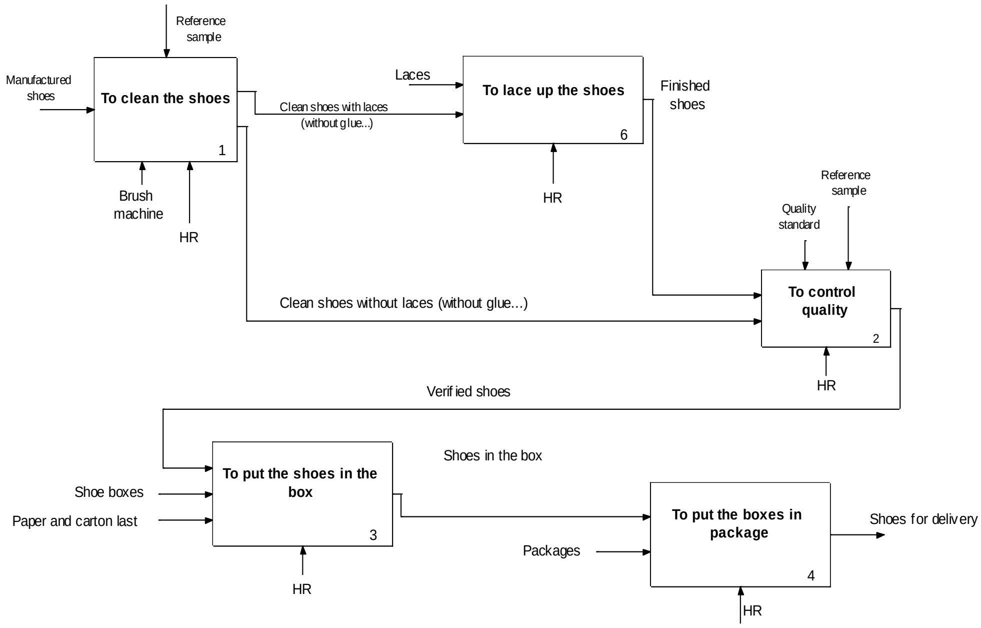


Fig. 33 Description of the 'finishing' phase

5.2 Production Process(es)

Within aforementioned process flow, some changes occur at production process level, depending on specific necessities related to particular shoe construction technique.

In this section we present some examples of production system setup (focused on shoe assembly phase) in a comparative mode for different shoe models.

Please refer to the legend hereunder as for classification:

Colour	***Explanation***
	Human operated machines
	Partially Automated operations
	Automated robotised operations

It should be noticed that among machines currently used to perform operations we have included some robots. However they correspond to applications with a different approach to that foreseen in ROBOFOOT (see explanation in Deliverable D1.2).

MAKING CYCLES								
Model			**Man classic with applied sole**		**Woman classic high heel with sole applied**		**Man leisure lasted PU sole**	
Type of manufacture			Goodyear construction		lasted with unit sole		lasted - Saint Crispin construction	
Department	*Station*	*Unit*	*Operations*	*Machines*	*Operations*	*Machines*	*Operations*	*Machines*
Preparation			outside counter preforming	moulds			sole washing	
Lasting	**Pos 1**	**Automatic warehouse**	last upload	1.1-warehouse	last upload	1.1-warehouse	last upload	1.1-warehouse
	Pos 2	**Manual**	insole application shoe lacing last dressing	2.1-nailing mc.	insole application last dressing	2.1-nailing mc.	insole application last dressing shoe lacing	2.1-nailing mc.
	Pos 3	**Humidificator and Toe lasting**	upper humidification toe lasting	3.1-umidifier 3.2-toe lasting mc.	upper humidification toe lasting	3.1-umidifier 3.2-toe lasting mc.	upper humidification toe lasting ("loose lasting")	3.1-umidifier 3.2-toe lasting mc.
	Pos 4	**Heel and side lasting**	heel and side lasting	4.1-heel/side lasting mc.	heel and side lasting	4.1-heel/side lasting mc.	heel and side lasting ("loose lasting")	4.1-heel/side lasting mc.
	Pos 5	**Thermal conditioning unit**	thermal conditioning	5.1-heeter	thermal conditioning	5.1-heeter	thermal conditioning	5.1-heeter
	Pos 6	**Manual**	Goodyear stitching and trimming bottom filling	6.3-"Goodyear" stitching mc.	bottom pounding heel setting	6.1- punding mc. 6.2- seeting mc.	insole and upper stitching (Saint Crispin)	6.4- "Saint Crispin" stitching mc.
	Pos 7	**Roughing and cementing robot**			bottom pre-ruoghing bottom roughing bottom cementing	7.1- rough./cement. robot 7.1- rough./cement. robot 7.1- rough./cement. robot	bottom pre-ruoghing bottom roughing bottom cementing	7.1- rough./cement. robot 7.1- rough./cement. robot 7.1- rough./cement. robot
	Pos 8	**Dryer**			solvent drying	8.1-dryer	solvent drying	8.1-dryer
	Pos 9	**Manual**	mid-sole pre-fixing with glue "Rapid" stitching outsole and heel block application bottom trimming	9.3-"Rapid" stitching mc. 9.2-sole pressing mc. 9.4-Trimming mc.	sole cementing glue reactivation sole coupling and application by pressing	9.1-reactivator 9.2-sole pressing mc.	sole cementing glue reactivation sole coupling and application by pressing	9.1-reactivator 9.2-sole pressing mc.
	Pos 10	**Direct injection carousel**						
	Pos 11	**Freezer**	cooling	11.1-freezer	cooling	11.1-freezer	cooling	11.1-freezer
	Pos 12	**Finishing robot**	polishing	12.1-finishing robot	polishing	12.1-finishing robot	polishing	12.1-finishing robot
	Pos 13	**Last slipping machine**	last slipping	13.1-last slippimg mc.	last slipping	13.1-last slippimg mc.	last slipping	13.1-last slippimg mc.
Finishing								

MAKING CYCLES								
Model			**Man classic with applied sole**		**Man classic with applied sole**		**Man casual with applied sole**	
Type of manufacture			lasted		lasted		lasted	
Department	*Station*	*Unit*	*Operations*	*Machines*	*Operations*	*Machines*	*Operations*	*Machines*
Preparation							sole washing sole roughing outside counter preforming	
Lasting	**Pos 1**	**Automatic warehouse**	last upload	1.1-warehouse	last upload	1.1-warehouse	last upload	1.1-warehouse
	Pos 2	**Manual**	insole application last dressing	2.1-nailing mc.	insole application last dressing	2.1-nailing mc.	insole application last dressing	2.1-nailing mc.
	Pos 3	**Humidificator and Toe lasting**	upper humidification toe lasting	3.1-umidifier 3.2-toe lasting mc.	upper humidification toe lasting	3.1-umidifier 3.2-toe lasting mc.	upper humidification toe lasting	3.1-umidifier 3.2-toe lasting mc.
	Pos 4	**Heel and side lasting**	heel and side lasting	4.1-heel/side lasting mc.	heel and side lasting	4.1-heel/side lasting mc.	heel and side lasting	4.1-heel/side lasting mc.
	Pos 5	**Thermal conditioning unit**	thermal conditioning	5.1-heeter	thermal conditioning	5.1-heeter	thermal conditioning	5.1-heeter
	Pos 6	**Manual**	bottom pounding		bottom pounding	6.1- punding mc.	bottom pounding	6.1- punding mc.
	Pos 7	**Roughing and cementing robot**	bottom pre-roughing bottom roughing bottom cementing	7.1- rough./cement. robot 7.1- rough./cement. robot 7.1- rough./cement. robot	bottom pre-roughing bottom roughing bottom cementing	7.1- rough./cement. robot 7.1- rough./cement. robot 7.1- rough./cement. robot	bottom pre-roughing bottom and side roughing (only bottom on 4345) bottom cementing (two times)	7.1- rough./cement. robot 7.1- rough./cement. robot 7.1- rough./cement. robot
	Pos 8	**Dryer**	solvent drying	8.1-dryer	solvent drying	8.1-dryer	solvent drying (two times)	8.1-dryer
	Pos 9	**Manual**	sole cementing glue reactivation sole coupling and application by pressing	9.1-reactivator 9.2-sole pressing mc.	sole cementing glue reactivation sole coupling and application by pressing	9.1-reactivator 9.2-sole pressing mc.	sole cementing glue reactivation sole coupling and application by pressing	9.1-reactivator 9.2-sole pressing mc.
	Pos 10	**Direct injection carousel**						
	Pos 11	**Freezer**	cooling	11.1-freezer	cooling	11.1-freezer	cooling	11.1-freezer
	Pos 12	**Finishing robot**	polishing	12.1-finishing robot	polishing	12.1-finishing robot	polishing	12.1-finishing robot
	Pos 13	**Last slipping machine**	last slipping	13.1-last slippimg mc.	last slipping	13.1-last slippimg mc.	last slipping	13.1-last slippimg mc.
Finishing								

MAKING CYCLES						
Model			**Man leisure + PU sole**		**Man leisure + EVA sole**	
Type of manufacture			lasted - Strobel construction		California construction with opanka stitching	
Department	*Station*	*Unit*	*Operations*	*Machines*	*Operations*	*Machines*
Preparation			sole washing			
Lasting	**Pos 1**	**Automatic warehouse**	last upload	1.1-warehouse	last upload	1.1-warehouse
	Pos 2	**Manual**	last dressing shank application with glue		last dressing	
	Pos 3	**Humidificator and Toe lasting**				
	Pos 4	**Heel and side lasting**				
	Pos 5	**Thermal conditioning unit**	thermal conditioning	5.1-heeter		
	Pos 6	**Manual**				
	Pos 7	**Roughing and cementing robot**	side roughing and cementing bottom cementing	7.1- rough./cement. robot 7.1- rough./cement. robot	side roughing bottom cementing	7.1- rough./cement. robot 7.1- rough./cement. robot
	Pos 8	**Dryer**	solvent drying	8.1-dryer		
	Pos 9	**Manual**	sole cementing glue reactivation sole coupling and application by pressing	9.1-reactivator 9.2-sole pressing mc.	sole cementing glue reactivation sole coupling and application by pressing	9.1-reactivator 9.2-sole pressing mc.
	Pos 10	**Direct injection carousel**				
	Pos 11	**Freezer**	cooling	11.1-freezer		
	Pos 12	**Finishing robot**	polishing	12.1-finishing robot	polishing	12.1-finishing robot
	Pos 13	**Last slipping machine**	last slipping	13.1-last slippimg mc.	last slipping	13.1-last slippimg mc.
Finishing					Opanka stitching	opanka stitching mc.

MAKING CYCLES						
Model			**Woman classic low heel**		**Man Safety/Sport/classicwith injected sole**	
Type of manufacture			lasted with unit sole		California construction with injected sole	
Department	*Station*	*Unit*	*Operations*	*Machines*	*Operations*	*Machines*
Preparation					outside counter and toe-end preforming (toe-end only for City)	
Lasting	**Pos 1**	**Automatic warehouse**	last upload	1.1-warehouse	last upload	1.1-warehouse
	Pos 2	**Manual**	insole application last dressing	2.1-nailing mc.	last dressing	
	Pos 3	**Humidificator and Toe lasting**	upper humidification toe lasting	3.1-umidifier 3.2-toe lasting mc.		
	Pos 4	**Heel and side lasting**	heel and side lasting	4.1-heel/side lasting mc.		
	Pos 5	**Thermal conditioning unit**	thermal conditioning	5.1-heeter		
	Pos 6	**Manual**	bottom pounding heel setting	6.1- punding mc. 6.2- seeting mc.		
	Pos 7	**Roughing and cementing robot**	bottom pre-roughing bottom roughing bottom cementing	7.1- rough./cement. robot 7.1- rough./cement. robot 7.1- rough./cement. robot	side roughing (only Golf Classic)	7.1- rough./cement. robot
	Pos 8	**Dryer**	solvent drying	8.1-dryer		
	Pos 9	**Manual**	sole cementing glue reactivation sole coupling and application by pressing	9.1-reactivator 9.2-sole pressing mc.		
	Pos 10	**Direct injection carousel**			direct injection on upper	10.1-direct injection mc.
	Pos 11	**Freezer**	cooling	11.1-freezer		
	Pos 12	**Finishing robot**	polishing	12.1-finishing robot		
	Pos 13	**Last slipping machine**	last slipping	13.1-last slippimg mc.	last slipping	13.1-last slippimg mc.
Finishing						

6 Robots in Footwear Industry

Present section is articulated into two parts, dealing respectively with robotised applications for footwear manufacturing deriving from R&D projects and from industrial practice.

6.1 Robots in footwear R&D funded projects

Hereunder some important initiatives are reported, documenting results from funded research projects.

Italian "Sistemi di produzione Integrati" - SPI6 project (1996-1998)

A first generation of automatized production lines for footwear manufacturing was developed – within a national funding scheme by Italian Ministry of University and Research – aiming at fully automated production of man and lady shoes. Within such a context, a first robotised cell was developed by "Scienzia Machinale" (www.smrobotica.it), a system integrator specialised also in robotics. Such an application was devoted to roughing and cementing, and it was integrated with an innovative transport line – different from traditional "manovia".

The robot had a 6 DoF, and was carrying the last by means of a grasping device. To be worked last was moved along dedicated trajectories for roughing and cementing, being the former performed on a motorised roughing belt and the latter on a gluing unit. Both devices were mounted in vertical on a tower machine. The robot was "modulating" its action only by means of a passive compensation, based on a spring mounted on the robot end effector: trajectories were fixed a priori. Final solution was therefore capable of replacing the operator only on "nominal tasks", being endowed with no intelligence of adaptation mechanisms.

European 5th Framework programme – Development of the processes and implementation of the management tools for the extended user oriented shoe enterprise - EUROShoE (2001-2004)

Aim of EUROShoE project was to develop methodologies, tools and production solutions for the fully automated production of customised footwear. Customisation was both aesthetic and geometrical, being based on specific scanning of (left and right) feet of the customer. The whole production process was consequently adapted to such needs and requirements: a specific set of 2 lasts was developed started from base ones and milled. CAD and CAM parameters were morphed and adapted on final requested geometries, and machine part programs were consequently generated.

Overall project result was the Integrated Pilot Plant in Vigevano (PV-Italy), being managed by CNR-ITIA.

Within such a context, two specific developments were addressed in the robotic field for footwear manufacturing, namely a roughing and cementing cell and a finishing cell.

The first cell was developed by CNR-ITIA (www.itia.cnr.it) targeting both bottom and side roughing and cementing operations: chosen approach consisted of keeping the last in position (by means of specific pincers) and of a 6 DoF robot manipulating two dedicated units: a 2 discs rotary roughing head, based on active compensation, and a gluing head. Trajectory was varying dependently on specific size and geometry. Such solution was capable of replacing the operator in nominal and not nominal tasks, being the latter confined to adaptation to irregularities due to different quantity on thermoplastic glue, leather surplus accumulated in particular points.

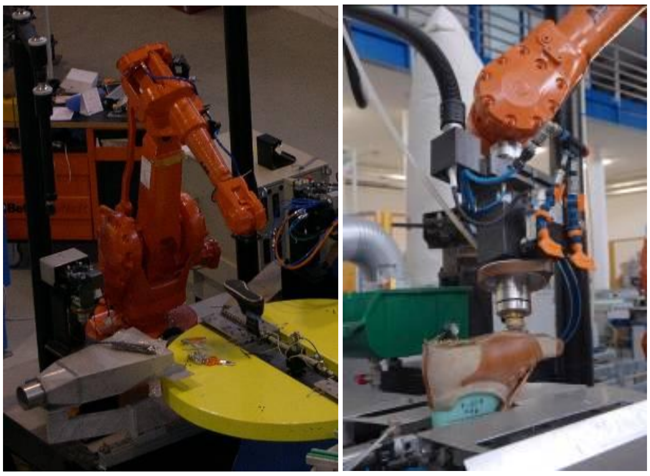


Fig. 34 EUROShoE roughing and cementing cell

The second cell was developed by Josef Stefan Institute (www.jsi.si) and was aimed at creaming/ wax spraying, polishing and brushing operations. Such tasks were performed by a 6 DoF robot with a specific gripper endowed with a finger to pick up and hold the last. Shoe was then moved along different work-posts (cream brush, box for spraying, brushing and final finishing), and oriented according to ad hoc generated trajectories. Contact between shoe and tools (brushes) was not particularly critical to be handled. Nevertheless contact area was not well defined, therefore specific portions of the shoe could be hardly isolated and excluded from polishing areas. No specific application was developed for other important finishing operations like inking.

Fig. 35 EUROShoE finishing cell

European 6th Framework programme – Custom Environmental and Comfort made Shoe – CEC made shoe (2004-2008)

CEC made shoe was one the biggest 6th FP project and moved the focus on advanced features for products. Specific product concepts as bio, active and snap shoe were realized, focussing on environment (bio shoe with biodegradable materials) comfort and functionalities (active shoe with shape memory materials and devices) and new agile production concepts (snap shoe with new solution for manufacturing).

Robotics was used to develop specific production processes for the snap shoe. Particularly, CEI, a company from Portugal (www.zipor.pt) conceived and patented a specific robot based application for laser engraving and laser roughing.

The aim of such an application was to:

- enable major creativity on aesthetics of the shoe by 3D engraving, i.e. engraving on final lasted shoe;
- roughing (especially on the bottom) faster, with higher precision, and above all according very complex geometries, difficult to be followed by humans and or robots, both holding roughing devices operating for material take away.

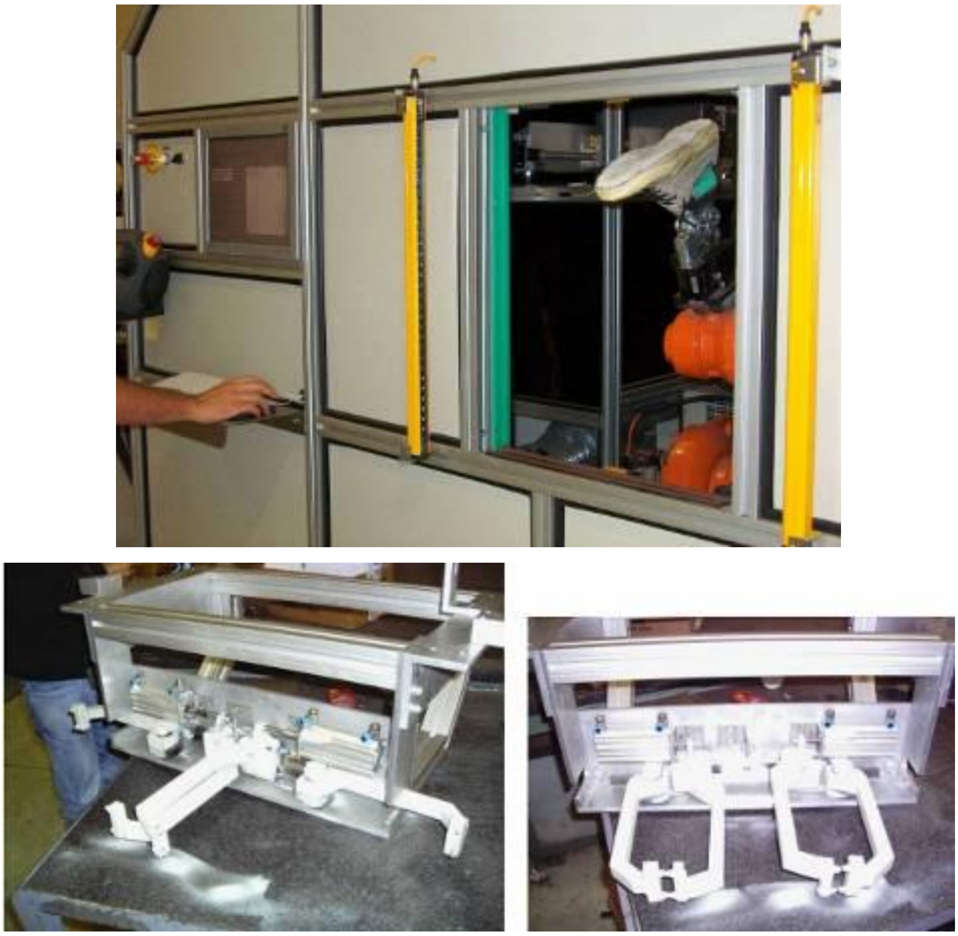


Fig. 36 EUROShoE laser robotised cell

Running European 7th Framework programme – Special Shoe Movement – SSHOES (2009-2012), Innovative design and manufacturing systems for small series production for European footwear companies - IDEA-Foot (2010-2011)

Within 7 FP, some ongoing project are targeting robotics applications, particularly on last milling (SSHOES) and on heel lasting, roughing and cementing (IDEA-Foot). Results from such research lines are still under development.

6.2 Robots in footwear industrial applications

Considering industrial practice and applications currently in use in the footwear manufacturing process, the major player to be considered is KLÖCKNER DESMA SCHUHMASCHINEN GMBH (www.desma.de), although several other minor actors are present on the market (e.g. Autec Automation, http://www.autecautomation.com, for various footwear operations, Techno Pu.Ma. http://www.technopuma.com, specific to sole injection and pouring).

Founded in 1946, DESMA quickly became a leading manufacturer of machinery for footwear, in particular focusing on devices for injection molding machines. Keeping the focus on progress of automation in the manufacturing sector, DESMA, has developed considerable expertise in the development of robotic stations for most of the operations on injected shoe, either in polyurethane (PU) or in thermoplastic (TP) or rubber.

Fig. 37 – DESMA automation line

Hereunder some robotised applications are described, testifying the state of the art currently available for the footwear sector (although mostly applied for injected shoe models)

6.2.1 Multifunctional robotised cell

By means of specific clamping and vision, such robot is capable of picking up a (not endowed with grasping device) last and to carry out some operations on it, namely bottom pre-roughing, bottom fine roughing, side roughing, parts cleaning, glue spraying and glue brushing.

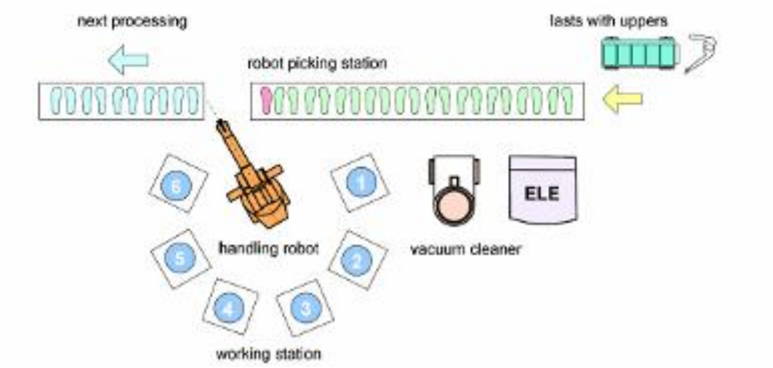


Fig. 38 – DESMA Multifunctional robotised cell

6.2.2 Laser roughing and engraving robotised cell

By combining dexterity of robot manipulating the last and laser control, both fast roughing and engraving are obtained

Fig. 39 – DESMA laser robotised cell

6.2.3 Roughing and cementing robotised cell

Robot carries a roughing tool and a glue dispenser following CAM trajectories on last set in position. Cell is manually fed in input and emptied in output.

Fig. 40 – DESMA roughing and cementing robotised cell

6.2.4 Sole cementing robotised cell

A robot is responsible for the preparation of adhesive (spray or liquid) on the soles. The peculiarity of this cell is that the trajectories are not fully precomputed off-line but are readjusted (both 2D and 3D) from a measurement system that identifies the geometry and defines the actual path of the robot.

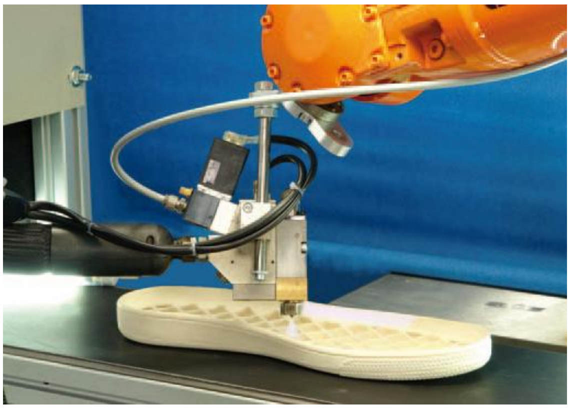


Fig. 41 – DESMA sole cementing robotised cell

6.2.5 Pick and place robotised cell

A robot is responsible for the pick and place and manipulation of the last along production steps, especially for injection.

Fig. 42 – DESMA manipulating robotised cell

6.2.6 Sole injection robotised cell

A robot is responsible for the injection of a sole – so replacing expensive multistation injection carousel when not needed - by carrying an injection station.

Fig. 43 – DESMA injection robotised cell

6.2.7 Sole trimming, finishing and last pulling robotised cells

A robot is used in each of the following operations: sole trimming – performed after injection to remove extra material - finishing – i.e. polishing and brushing - and last pulling by means of specific fingers.

Fig. 44 – DESMA trimming robotised cell

7 Requirements

In this chapter we summarize the main requirements initially identified by the consortium when considering the introduction of robotics in the production of shoes.

7.1 Quality

Quality is a key aspect of European footwear industry, and should remain being one of the differential factors with respect to low cost countries production.

ROTTA

Product's quality is assured during the whole process. Quality control starts from the raw material acceptance (with major emphasis on leather and sole). Then the control is carried out along the production process in each workstation by the workers. Defects on cutting, presence of nails and scars are not accepted and imply the rejection of the product. To the aim of the reduction of non quality costs, a strong collaboration with the suppliers has been developed in order to emphasize conformity controls. The result is that less then 2% of leather (square meters) and 1% of heels or soles are rejected.

All the products are visually inspected at the end of any single sub-task and the presence of any defect (f.i. wrinkles) causes the immediate rejection from the manovia. Those products with minor non conformities are sent to the re-working area; the rest are permanently re-jected.

The final inspections are conducted as verification of the previous quality controls and just before manual packaging. Only the 0,1% of the non conformed products can be found after final inspections. Otherwise a corrective action shall be implemented on total quality controls.

In the above mentioned final inspection, the main defects (on a base of 75000 pairs and one year of observation) are (figures in number of pairs):

- Roughing: 1200
- Assembling: 300
- Gluing: 500
- Stains: 500
- Cuts: 100
- Stitching: 250

Total: 2850 pairs.

PIKOLINOS

The main aspects they inspect are:

-Sewing.

-Alignment of Outsole.

-Defects on leather.

-Glue Stains.

Type of defects:

-Deviant sewing.

-Stretchability of the leather: loss of elasticity of the leather

-Mounting defecting.

Only few severe defects (knocks on shoes) cannot be repaired.

There is a quality supervisor in each factory manufacturing for PIKOLINOS.

This person is in charge of process key operations and final product inspection.

Process supervision

SISCAM is the standard quality report used in each factory in order to guarantee the quality in cutting, stitching and mechanic processes (see example below).

FACTORY: x11				TECHNICIAL: ANTONIO TITOS			DATE:	16/11/2010	
CUTTING		STITCHING		LASTING		FINISHING		FINAL PROD.	
TIME		TIME:	8.30	TIME:	varios	TIME:	varios	TIME:	14.00
No. CHECKED		No. CHECKED	110	No. CHECKED	100	No. CHECKED	100	No. CHECKED	375
DEFECT CODE	CUTTING DEFECTS	DEFECT CODE	STITCHING DEFECTS	DEFECT CODE	LASTING DEFECTS	DEFECT CODE	FINISHING DEFECTS	DEFECT CODE	FINAL PR. DEFECTS
		3	1	4	3	1	5	1	3
								6	2

COMENTARIOS
seguimiento a todos los procesos de mecanica.

Fig. 45 SISCAM quality assessment check list

These checklists are reported to PIKOLINOS every day. Repetitive defects are analyzed and actions implemented to avoid them in the future.

Final product inspection

According to SISCAM results, a percentage of final products is sent for a final quality inspection. There, final appearance is checked, including glue stains, leather damages, welted, seams, etc.

Fig. 46 Welted and seams

Another option could be final inspection outsourcing in cases in which product is mature and process supervision is not necessary.

In case of internal production (Vabene), 2 supervising tasks are included at the end of the line :

- Supervising and repair: little mistakes as glue exceed or leather damages are identified and cleaned or repaired.
- Quality control: final aspect: glue stains, leather damages, welted seams are checked

Robot introduction

As an average, 80% of shoes need small retouching at the end of the line. These operations are done at the end of the line, just before packaging. The introduction of robots shouldn´t increase this percentage in any case. On the contrary, as most of these small faults are due to the low stability in some processes (such as roughing or gluing), it is expected that the use of robots will contribute to reduce these retouching operations.

Special attention has to be put when designing grippers that are in touch with the leather, in order to guarantee that there is not any damage on it. The operation of last removal is one of those operations with potential risk.

7.2 Impact in production process

ROTTA

The production line looks like PIKOLINOS' manovia, and the manufacturing process is basically the same.

The major difference is a larger use of automatic machines in ROTTA due to the market segment ROTTA's shoes are addressed to. They require extremely high precision during critical processes (roughing, gluing, sole and heel application).

Currently two processes are partially or totally outsourced: upper stitching and last making. The last making is, in case of fashion products, critical when starting a new collection:

- To reduce time to market
- Because new lasts can be copied by competitors.

PIKOLINOS

The average time employed to produce a shoe pair is 0.709 min. Bottleneck operations are upper finishing and laces and shoes tree. In the first case training and experience is a must for developing the task. It is really difficult to find out skilled workers for these tasks.

Robot introduction

A basic requirement for both companies is the possibility to combine current production procedures with the robotized solutions proposed by ROBOFOOT. This is a must because it will not be possible to have a universal system that can cope with all shoe variants. On the other hand, in case of a failure in any of the elements included in the robotic approach, it would be possible to substitute, at least temporarily, by human force.

This requirement is linked to the need of maintaining the existing production means (manovia and machinery) as they are now. However it is allowed the redesign of some operations to facilitate the introduction of robots.

An additional consideration is the need of providing solutions that are 'compact' in size. In fact, the layout of most companies is characterized by a lack of space to introduce additional machines/robots.

Fig. 47 Need of compact solutions: current chiller exit and inking area at PIKOLINOS

As some of the operation will continue being done by human operators, it has to be assumed that there is not a fixed position of the shoe in the fingers of the trolley. As a consequence the robot has to identify the pose of the shoe (with last) in the manovia.

It is foreseen a modification in the last, introducing a device that makes possible an efficient grasping. This device has to be designed in such a way that existing machinery can be used with minor modifications. Although in the future new lasts can be produced according to this design, it is strongly recommended that already existing lasts could be re-worked to allow their use in ROBOFOOT. The system has to cope with the fact that both end users use Lampo Hinging mechanism in most of the cases.

Although last production is normally outsourced, it might be interesting for shoe producers to have the means for fast production of single or short last batches, mainly for new trials.

Fig. 48 Production manovias: ROTTA (left), PIKOLINOS (right)

7.3 Efficiency: reduction of manufacturing time

The introduction of robots within the production line can have a positive impact on the efficiency of the production line.

However, it should be taken into account that the robotized production has to be integrated in the production line where ‘traditional’ production means coexist. So, reduction of individual operation time cannot be considered an objective unless we consider this reduction the foundation for combining two operations. Only in these circumstances it would be a really important improvement.

7.4 Production flexibility

Robotic systems can be key components in fully automated shoe manufacturing processes. Nevertheless, two concrete trends require for new and more flexible manufacturing technologies [BES01]:

- Demand for higher flexibility and adaptability on a process level: Due to changes in the habits and behaviours of (both industrial and private) consumers, product life cycles are getting shorter and more product variants have to be offered.
- Demand for higher flexibility and adaptability on a plant / on a supply chain level: Shoe manufacturing companies have to be able to “breath” with their manufacturing capacities, meaning that they are able to shortly react on changes on the market.

Flexibility is one of the main requirements in footwear industry, mainly for SMEs. It is worth thinking on some figures: each season is not unusual for a small company like ROTTA to produce 140 different models (200 samples), with up to 9 different sizes for each (right and left). In big companies such as PIKOLINOS, the figures are more significant, even: 600 new models of which 300 are finally produced. Due to the cost of lasts and the different models produced (remember that each season PIKOLINOS has to produce 120 new models of lasts) companies need to introduce a great amount of different models in the production line simultaneously (up to 14 in the case of PIKOLINOS). This is the only way to use production resources efficiently.

As a result, ROBOFOOT has to guarantee the production flexibility, handling a wide variety of models/sizes simultaneously and allowing frequent model changes.

7.5 Reduction of costs

ROTTA

The final cost of a shoe is 40 % influenced by labour costs.

PIKOLINOS

Shoe lasting and upper finishing are the operations with the highest impact on the final cost.

Cost distribution depends on season:

- In summer: Workforce: 22%, Material: 64%
- In winter: Workforce: 20%, Material: 67%

Although it is not the main reason for introduction of robotics in this sector, it will allow some workers to do tasks with higher added value and overcome the lack of skilled workers for some operations.

7.6 Working conditions

Currently there are several operations that have potential risk for workers:

- Presence of rotating parts: roughing and polishing
- Presence of dust: roughing
- Presence of solvents and chemical products: inking, waxing
- Effort in manual un-lasting. This operation requires the operator exerting a high force (up to 30kg) every minute that can result in different pains.
- Movements to move shoes from one station to other (for instance from the exit of chiller to the inking station and from here to the manovia)

Current protection measures include protective masks and gloves (not always used due to the lost of sensibility during operation), safety glasses (roughing), besides of suctions pipes placed over the working areas.

It is also mandatory the use of safety shoes in all mechanic operations.

Introducing robots has to help in reducing the potential risk of those operations to the minimum.

7.7 Usability and maintainability

There is no previous experience with robots neither in ROTTA nor in PIKOLINOS (it can be extended to most companies in this sector). As a consequence, the system has to be designed to allow its easy operation by workers. It includes the inclusion of diagnostic tools that allow an easy and fast recover in case of system failure.

Finally the system has to be easy to maintain by no specialists.

8 Conclusions

The main technological challenge for the footwear industry is to focus on higher value-added and eco-efficient and sustainable products, processes, materials and organizations. A significant effort on research and skills is needed in order to achieve these objectives. New business models, new materials and enhanced manufacturing processes are required.

Although there have been some attempts to introduce robots for shoe production in traditional handmade sector, they have failed because of the lack of answer to specific needs of most EU Footwear industry. These needs can be summarized as the need of higher flexibility, including the possibility to combine traditional production procedures with new robotized ones. The expectations for end-users include the ability to answer to the market needs faster, with high quality products, reducing cost and enhancing the working conditions of workers, avoiding some hazardous activities where they are exposed to dust and chemical products.

9 References

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