Executive summary:

The IDEA-FOOT project addresses the reference scenario of typical European SMEs working in the footwear industry and in particular in the market segment of classical and casual shoes. Global markets are asking for the reduction of the Time to Market, the increase of products diversification in conjunction with a small batch production, and a high fashion content and quality of the product. The actual design and production processes are, to a great extent, not suitable for this small batch and variegated production. In particular the actual design and industrialization processes follow a serial model, in which the shoe model under development is necessary for the sequential make up of the other shoe components to be assembled. Moreover, the production process still has an handicraft connotation; even when automatic machines are present in the shopfloor, the operators have to program them manually for each batch of shoes, and the semifinished shoes and components handling is done by means of very conventional manual conveyors.

The actual design and production processes are largely independent, and both of them need the physical prototypes of the semifinished shoes in order to be accomplished. In the design phase the semifinished shoe model is necessary for the sequential development of the other shoe components to be assembled, whereas in the production process the semifinished product is necessary to program the semiautomatic machineries for each batch of shoes. The necessity of the physical prototypes to have the geometrical information necessary for the design and production phases is the main technological problem of the SMEs involved in this project.

The project IDEA-FOOT will introduce both process and technical innovations. The main elements of the process innovation are:
- The introduction of a 3D standard for the shoe components
- The use of digital standardized models to carry out the design and production phases, eliminating the necessity of the physical prototypes
- The introduction of a parallel model for the shoe development and production

The technical innovations, which as it will be explained in the following have a close relationship with the process innovation, are related to:
- The development of CAD software modules which make easier the design according the defined standards
- The development of a CAM software which uses a standard data format for the description and the transfer of the geometrical data of the shoe components to the production
- The realization of automated production cells using an innovative layout, in which the materials handling is done by automatic manipulators and the machines are compliant with the developed CAM software

Project Context and Objectives:
The footwear industry, and in particular casual and dress shoe targeted factories as the ones involved in this project, needs integrated design and production process innovation in order to reduce the Time-to-Market and the production costs, to increase products diversification in conjunction with a small batch production, and a high fashion content and quality of the product. The fulfilment of these objectives makes the SMEs involved in this project to gain competitiveness in the global market which is addressing a customer-driven model. The actual design and production processes result to be not suitable for a small batch and variegated production due to the fact that the design process is very time consuming and that the production process is highly dependant on labour.

Moreover the footwear market is highly globalized and the EU industry is facing very thorough competition from low labour cost countries. During the last decades, the EU industry has been gradually pushed towards the higher end of the market by cheap footwear from these low labour costs countries. Beside that EU industry is the global leader as regards high quality footwear with 190 million pairs exported worth around 4 billion EUROS.

The EU production differentiates itself from its competitors beyond the price on which they are unable to compete. The key characteristics of the EU production are mainly the quality of production, as defined by the superior technical quality of the products, but also their aesthetic characteristics and "fashion content", the capacity to develop highly demanded brands and with the capacity to build a strong image thanks to a combination of tradition, promotion and marketing.

Today competition from far-east countries is on low labour cost, impacting on 40% of the footwear price. Driven by such an odd challenge, there is a strong tendency of companies to delocalize the production activities, with the consequent effect of lowering the quality of the products and compromising the organizational effectiveness. This project does not agree with such a tendency, and embraces instead the values affirmed by prominent EU research lines, such as Manufuture.

"The manufacturing activity in Europe represents today approximately 22% of the EU GNP. It is estimated that in total 75% of the EU GDP and 70% of employment in Europe is related to manufacturing. This means that each job in manufacturing is linked to two jobs in manufacturing related services. European manufacturing has great potential as part of a sustainable EU economy, but its success will depend upon continuous innovation in products and processes".

IDEA-FOOT partners covers the most important stakeholders within the value chain of the footwear sector (from shoe producers, to component producers to software providers, etc), and each SME is interested in using and exploiting the results according to their specific role in the value chain.

IDEA-FOOT results consist of a set of solutions aiming at improving design and production process to obtain rapidly and efficiently small series of shoes. In particular the following results (Rx) for the IDEA-FOOT have been identified in the following:
R1: Innovative Method for the definition of standard modules: methods to standardize geometrical features during design of the shoe

R2: Library of standardized features: set of standardized geometrical features of shoe components
R3: CAD modules: CAD modules to support the easy development of the standardized components of the shoe
R4. Set of CAM software modules: CAM software modules, formats and communication protocols between CAD and the involved production machines
R5: Innovative integrated production cell: the production cell include machines, a last manipulation systems and software interfaces

In this context the new method for the integrated design and production of the shoe, based on the standardization of the shoe components, and the automated production process promoted by IDEAFOOT will permit the SMEs involved in the project to obtain a competitive advantage based on:
- the reduction of the time necessary to develop new products
- the reduction of the Time to Market
- the reduction of production costs, and the possibility to maintain the production in the origin country, without the need of delocalization
- the increase of productivity
- the reduction of the time necessary to produce pre-series models of shoes, necessary to taste the market before the production
- the possibility to have more pre-series models in the sample set
- the flexibility of the production, since the standardization does not limit the style
- the possibility of accepting many small or medium-size orders
- the fact that new markets will be developed, following tastes and specific needs of consumers
- an higher level of satisfaction for consumers, who will accept to pay more for high quality shoes

Demonstration activities have been performed in order to validate the project results and demonstrate the competitive advantage deriving from their exploitation. In particular the validation of the integrated design and production process took place in the BZModa plant, where a predefined number of shoe models have been designed according the standards and then produced in small batches by means of the automated production cell. All SMEs have been directly involved in these demonstration activities. These activities allowed to evaluate the real time savings for the design and production processes, and to evaluate the quality of the produced batches of shoes.

The aim of the project IDEA-FOOT was the introduction of a new method for the integrated design and production of the shoe, in which the key elements are the standardization of the shoe components and the transfer of the geometrical information from the design to the production process in a digital standard data format. An important enabling technology used in this project is an innovative polymeric insole, which is suitable for a 3D standardization, simplifies and reduces the number of operations necessary during the production, and results in a more precise shoe assembly.

The main objectives of the IDEA-FOOT project are:
- The development of design methods to reduce the time for the design and industrialization of new shoe models, which include the introduction of the innovative polymeric insole, the definition of 3D standards for the shoe components, and the redefinition of the design process according to a parallel model
- The development of CAD modules, which make easier the design of standard components

- The development of a CAM software, which is able to integrate the design and production processes, using an adequate digital standard data format
- The study of an optimal production lay-out for the automated production cell
- The development of an automated production cell, which receives the production parameters and tool paths from the 3D CAD model by means of the CAM software, and is integrated with an automatic manipulation system for the materials handling

The following table summarizes the objectives of the IDEA-FOOT project in relation to the project results and to the deliverables, which are used as indicators of their fulfilment.

THE ROLE OF EACH PARTNER

BZModa (I) is an Italian SME producing shoes for the international market. BZModa is the project coordinator has been involved mainly on the following activities:
Definition of shoe standards, participation in the definition of requirements for automated system, definition of the production layout, Definition of CAD-CAM interfaces, test of standards, test and validate IDEA-FOOT new integrated production cell with small shoe series.

Brustia (I) is an Italian SME producing shoe making machineries, and over the years has specialized in heel nailing/heel attaching machines in a complete series for lasting (machines for pulling over and lasting, heel seatside lasting, heel seat lasting machines).

The company is mainly involved for providing machine characteristics, participation in the definition of new machines features, adaptation of machines, participation to tests.

ROSI ita UNO (RO) is a Romanian SME providing semifinished components for the shoe sector like cut leather and stitched uppers. The company is involved in the definition of standards on leather working, leather operations, definition of communication standard during design and production of upper, test of IDEA-FOOT technologies for design and production in the supply chain.

Red21 (E) is a Spanish SME providing CAD software to footwear companies. In the project the company will design and develop CAD improvements and integration with the cutting machine and in general with the production line.

Politecnico Calzaturiero (I) is an Italian training and research center supporting footwear companies in implementing innovation and participate to the project as RTD perfomer. The company will support SMEs in the definition of standards of geometrical features of shoe components from 2D to 3D; implementation of CAD plug-in for standards; participation in the definition of the new integrated production cell; support to SMEs in the project; training and dissemination /support to project management

CISAS (I) is a center of the University of Padua specialized in robotics and automated systems. This RTD Performer supported SMEs in the definition of the layout of the production system; Design and develop of the new integrated production cell; design and develop interfaces for the integrated production cell.

Inescop (E) is a Spanish center specialized training and research for footwear companies supporting SMEs in implementing innovation. As RTD perfomer has support the following activities: definition of standards for some shoe components, implementation of CAD plug-in; test of standards, dissemination and training.

ITIA-CNR (I) is the Institute for Industrial Technologies and Automation of the National Council of Reseach. As RTD Performer participated to the definition of the layout of the production system; in the development of CAM specific features; and in the the demonstration activities.

C2I2 (E) is a Spanish EIG supporting the project with activities of collection of requirements, Demonstration and Dissemination.

Project Results:

IDEAFOOT project results are the following:
R1: Innovative Methods for the definition of standard modules: methods to standardize geometrical features during design of the shoe
R2: Library of standardized features: set of standardized geometrical features of shoe components
R3: CAD modules: CAD modules to support the easy development of the standardized components of the shoe
R4. Set of CAM software modules: CAM software modules, formats and communication protocols between CAD and the involved production machines
R5: Innovative integrated production cell: the production cell include machines, a last manipulation systems and software interfaces

Method for definition of standards of shoe components
The method for the definition of standard modules of shoe components is a remarkable step forward in order to optimize the design process within a shoemaker company.

The method represents a rigorous way of making the correct steps to formalize the knowledge in the company about the shoe structure (last, heel, sole, insole). The method defines scientifically the steps that a company has to do in order to develop the standards for each component.

The method gives the advantage to formalize part of the implicit knowledge which is available in the companies. Without a methodology, companies are not able to proceed with a standardization of components as a preliminary step for improving design process.

The method for standards definition can be applied with generality to other typologies of shoes, and therefore can be broadly used in the dissemination process.

Standards main features
The proposed innovation is based on the definition of some specific shoe parameters for the last, the insole, and the heel (like for example lower leg, entry, shoe neck, toe fit, arch-line) which do not vary and on the same time to do not compromise the style of the shoe and which can be the same along the different shoe models. For this reasons it is important that any time the company has to develop a new shoe collection it starts from the shoe components modules already existing and not varying along the models.

The benefits of applying these standards are linked to the fact that they do not reduce the possibility to personalize the footwear because most important components will still have degree of freedom in their development.

The standards are the ultimate step in the design of new footwear with a concurrent engineering approach: starting from a standard last, it is possible to build all the components according to the style of the fashion seasons. At the end of the design, it is possible to delegate the production of the components to the various actors of the productive process. This allows building a model in less time, with an increase in quality and with a more efficient exchange of information.

The 3D standards are the missing link to allow a company to work in an integrated and autonomous way, as it allows designing and modifying the most critical component which is the last. The interfaces between the insole and the last therefore become three-dimensional.

The possibility to control the whole design process, where suppliers produce components (lasts, heels, insoles, soles) designed by the shoe company allows to reduce the waiting time which usually characterized the process when assigning the design of components to different companies.

The parameters that have been considered for the design of the most important components are:
- For the last the measures are lower leg, entry, neck, fit, arch-line
- For the insole, the arch of the last and arch-line as well as the ball of the foot. These parameters are important in order to obtain the 3D standard of insole, necessary if the company wants to produce plastic insoles.
- For the heel it is taken into consideration the concavity, Heel circle and the inclination

Innovative CAD modules for design in footwear companies

Innovative CAD modules are programs suitable for a particular phase of the design process. These modules allow to design quickly and accurately the components of a new model, reducing the time to market, costs and increasing the quality of the final product.

The modules developed or tested in the project IDEAFOOT are described below.

Rhino plug-ins

Rhino plug-ins are modules, written using Visual Basic or Python programming languages, that facilitate the creation of all components and do the repetitive operations necessary to design a new shoe.

After introducing standardization, that is a necessary step in order to control the accuracy of all design phases of a new model of shoe, the following plug-ins to support design activities have been developed which are:
1) Orient last, to put automatically the last in the 3D space.
2) Flattening module, that flattens the bottom of the last to obtain the upper surface of the insole.
3) Module for the creation of standards database to be applied on the flattened bottom surface of the last.
4) Module to automatically apply standards, that applies the standard realized.
5) Module for the feather line of the bottom surface, that automatically builds the feather line of bottom surface of the insole starting from upper surface of the insole.
6) Module for Sole design, that builds the sole with variable thicknesses.
The following pictures show the Rhino plug-ins that are part of the CAD software.

Add-ons for the iCAD3D

The software tool incorporates elements necessary for the integration of 3D design of shoe with rest of elements and has a 100% correspondence with the manufacturing last. It also permits to generate the trajectories for future robotic operations. Flattening of models is highly improved compared to other CAD systems.

This software can be used by footwear designers and footwear manufacturers for a more accurate design and faster development of models. Relevant reduction of time to market is made possible by the use of this software.

Some features of the components are the following:
- IcadFOR. last design: it provides 3D+ software with geometrical data related to the passing to three surfaces that are necessary for 3D+ development. The curve and the angle of the heel seat, as well as the heel height, are provided for heel design.
- IcadTAC. heel design and production: this module allows the creation of 3D heels and cones in a simple and intuitive way, using a great number of tools for both artistic and 2D insole-based design. This module allows exporting the models to different types of highly-standardized graphic formats and simulating breakage tests. European standards for measuring fatigue resistance to bending or impacts for heels in women's footwear.
- By using the sole curve of a last, it is possible to generate the curve of the heel seat or the curve of the cone seat. By using the last waist, it is possible to obtain the angle of the heel/cone seat and by using the sole surface, you can obtain the profile of the heel surface.
- icad3dp. design and production of footwear soles: The sole software developed by Inescop allows the design and production of footwear soles, outsoles and cones, increasing productivity and reducing design times by means of some specific tools for sole design. These specific tools allow the automation of tedious tasks that the designer must carry out to design the final prototype. This software includes a set of specific tools to carry out inverse engineering processes from sole digitizing with a laser digitizer (IcadDIGI). These tools reduce prototype design time, their use being crucial in complex models where geometry makes this process too difficult.

3D+. technical and artistic design for footwear: 3D+ software is a CAD system that develops 3D footwear models from a digital last. Both technical and artistic points of view are used, thus taking into account production aspects and obtaining virtual models in your computer. Moreover this software can generate cut files from the graded pieces in different machine formats, both directly cutting on leather and cutting patterns on cardboard.

During the project it was improved the integration of the different programmes that take part in the whole footwear design process, both for men's and women's footwear, according to the user needs. For instance, combining the last sole surface and the last upper surface for the design of dished soles.

From design to production

The IDEA-FOOT CAM module is designed to generate a machine independent description of the shoe model, able to support:
- the generation of various machine specific part programs
- self documentation of the shoe model
- integration of the information in the company's ICT environment

Based on such a requirement, the CAM module offers some dialog forms aimed to identify the basic information needed to integrate the shoe model into a broader information system, by mean of the common RDF based description which also supports the factory operations.

The following picture shows a simple example for which collects basic information regarding the shoe model, the size, etc, which will be included in a more complete product specification during CAM exportation.

The CAM module stores various information collected during the shoe model design, based on structural geometric information, additional technological information, explicit machine parameters and part program identification.

Such a set of information is expressed following the simple rules of the RDF data model, realizing a very informative mesh of data.

The syntax adopted to serialize the CAM data file is 'n-triples', which is the simplest among the ones proposed by the RDF standard. The output file is a simple text file and it could be easily read and processed by any tool.

Automated production plant for fashion footwear

In the framework of the IDEA-FOOT project, an automated plant for the production of classic and casual shoes has been designed, realized, tested, and validated.

In the automated plant, manipulators are used both for pick and place and for shoe bottom processing operations, and the manipulators, the pallet conveyor, the oven, and the production machines are integrated/synchronized and monitored by means of a centralized S/W customized for this project (in collaboration with technology providers).

The layout of the automated production plant, in which subcell A and subcell B are evidenced, is presented in ig. 8. Study of an optimal production layout of the production system has been based on the comparison of many different approaches in order to understand how to integrate new the automated production cells composed of machines, last manipulation system and software interfaces within the full system. The new automated plant covers all the operations of the assemblying phase before bonding phase.

In subcell A a first manipulator is used in order to pick the last from the man-robot exchange station, place the chip of the last in front of the RFID R/W head, load and unload the heel seat and side lasting machine, and finally place the last in the pallet conveyor.

In subcell B a second manipulator is used in order to pick the last from the pallet conveyor (after that the last has been processed in the oven and that the manual operations have been performed), perform the bottom processing operations (grinding, hammering, roughing, cleaning, cementing), and then place it in the aspirator.

Components of the automated plant:

Centralized S/W and visualization pages
- Read and write process parameters in RFID tags

- Visualization of plant layout and activation-deactivation of different stations
- Visualization of machine states and article code in the toe lasting and in the heel seat and side lasting machines
- Visualization of machine states in the man-robot exchange station

Subcell A
- Man-robot exchange station functionalities and signals communication with the robot
- Robot manipulation operations:
1. Pick the last from the man-robot exchange station
2. Place the chip of the last in front of the RFID R/W head
3. Load/unload the heel seat and side lasting machine
4. Place the last in the pallet conveyor
- Process data and article code reading from the RFID R/W station and data communication to the heel seat and side lasting machine
- Heel seat and side lasting machine functionalities and signals communication with the robot
- Pallet conveyor functionalities and signals communication with the robot

Subcell B
- Oven functionalities
- Pallet stop and release functionalities at the manual stations
- Process data and article code reading from the RFID R/W station and data communication to the robot of subcell B
- Generation of robot programs from CAD files
- Robot manipulation and processing operations:
1. Pick the last from the pallet conveyor
2. Perform the grinding operation
3. Perform the hammering operation
4. Perform the roughing operation
5. Perform the cleaning operation
6. Perform the cementing operation
7. Place the last in the aspirator
- Aspirator functionalities

The centralized software has been customized for this project in partnership with DESMA, as a technology provider, and it is used for the integration/synchronization and for the monitoring of the manipulators, the pallet conveyor, the oven, and the production machines.

The centralized software has the following functionalities:
- Read and write process parameters in RFID tags
- Visualization of plant layout and activation-deactivation of different stations
- Visualization of machine states

A short summary of the most important innovation in the different components of the pilot plant is here given:

- The PLC of the toe lasting machine (9) has been expanded by integrating an RFID reading unit and its related electronics and by interfacing the I/O of the machine with a cell / line controller for the handling of all the necessary status signals (machine conditions, alarms and so on). The innovative content in the modifications made to the toe lasting machine is related to its integration with the automated plant from a communication point of view. The machine is equipped with a RFID R/W head

that is used to read the RFID tag of the last and automatically recall the corresponding machine program. The communication process starts when the process parameters for the toe lasting machine, for the heel seat and side lasting machine, and for the other stations of the automated plant are written in the RFID tag of the last in the first RFID R/W station of the plant.
- The heel seat and side lasting machine (13) was extensively modified in some of its most relevant building modules in order to adapt it to receive the shoe to be lasted from a robot and to release the fully lasted shoe , in such a way that the robot can grasp it and remove it from the machine. This implied a complete redesign of the entire strut assembly, that now features additional movements to clear the shoe off the main mechanical components of the machine, so that the robot can remove it and to adjust the working height of the strut to the different kinds of shoe and of lasts used. The following pictures document the CAD design work that was done to complete this activity.
- The first manipulator is used in order to pick the last from the man-robot exchange station (11), place the chip of the last in front of the RFID R/W head, load and unload the heel seat and side lasting machine, and finally place the last in the pallet conveyor.
- The second manipulator is used in order to pick the last from the pallet conveyor (after that the last has been processed in the oven and that the manual operations have been performed), perform the bottom processing operations (grinding, hammering, roughing, cleaning, cementing) (18-22), and then place it in the aspirator (23-24).

WORK PERFORMED DURING THE PROJECT

The work performed since the beginning of the project have seen all the partners involved to reach the planned milestones and can be summarized as follows:
- Study of an optimal production layout of the production system in order to understand how to integrate new the automated production cells composed of machines, last manipulation system and software interfaces within the full system (WP210)
- Introduction of a new method for the integrated design and production of the shoe based on standardization and on digital data transfer of data from design to production (WP220). The standards have been the basis to define innovative plug-ins and add-ons for the CAD software used by the companies to develop their products (WP221).
- Definition of the electromechanical, software, and communication interfaces to the shoe manufacturing machineries, and the process parameters, tool paths, and batch information to be passed to them, taking as input the results of WP 210 and WP221 and the requirements from the shoe manufacturing companies (WP310).
- Development of an adapted toe lasting machines that could be electronically and logically integrated in the manufacturing cell and of a more heavily modified version of a seat and side lasting machine mechanically, electronically and logically integrated in the cell (WP320).
- Design and production of the mechanisms to lock the lasts to the manipulation systems and the relevant last interface, taking as input the results of WP 210 and the manipulation requirements from the shoe manufacturing companies and the shoe manufacturing machineries company (WP410).
- Design and production of the man / robot exchange station to feed the automated production plant, taking as input the results of WPs 210 and

410, and the manipulation requirements from the shoe manufacturing companies and the shoe manufacturing machineries company (WP420).
- Study and implementation of the manipulation system to unload the toe lasting machine and the manipulation requirements from the shoe manufacturing companies and the shoe manufacturing machineries company (WP430).
- Design and integration of the automated manipulation systems to load and unload the heel seat and side lasting machine and the pallet conveyor, and to perform the shoe bottom processing operations (WP440).
- Integrated test of the manufacturing machineries, the manipulation systems, and the centralized and CAM S/Ws of the automated plant, taking as input the results (WP510) and validation of the overall approach to integration of design and production of small batches (WP520)
- Continue dissemination activities and definition of the exploitation plan (WP120).
- Definition of training activities to support SMEs in the implementation and use of the project results (WP130).

VALIDATION OF THE RESULTS

The validation of the project results was held with the collaboration of all the partners. Design and Production validation was based on three important parameters of the shoe: Heel height, shoe size and last extension.

The flow of activities to be performed for the setup of the production parameters and for the production itself are presented here below.

Phase 1- design and develop shoe models using CAD plug-ins developed within the project.

Phase 2- Importing the CAD file (.igs) on the centralized control software and generating the robot program

Technicians at the shoe producers premises have created a new CAD plug-in that, starting from the insole bottom surface, generates different surfaces (with different offsets) for each bottom processing operation (a surface for grinding, another one for hammering, another one for roughing and the last one for cementing). Then the operator loads these files with the centralized software, which generates the paths for the robot. All the paths are automatically inserted in a robot program, which is identified by a robot program number.

Phase 3 – Creating the article and writing process parameters on the RFID tag

Before producing a shoe the technicians have to create a new article which contains the correct process parameters in the workstation near the first RFID R/W station. The article contains the operations that the robot has to do on the shoe associated with the tag, the number of robot program created by the centralized software, and the process parameters and article code for the operations that the heal seat and side lasting machine has to execute. All this information is then written on the RFID tag.

Phase 4 – Programming the heal seat and side lasting machine

Technicians have to program correctly the heal seat and side lasting machine, using the information associated with the article inserted in the RFID tag.

Such a programming can be aided by the CAM plugin-module developed in the project, which allows the CAD designer to:
- specify machine parameters and instructions for heel related operations, and
- to save a ready-to-use parameter file to be loaded on the machine.

The machine programming is based on tool-aided specification of named geometric references, on which the CAM module computes the machine set-up for some specific, process element, e.g. 'fingers' position and 'glue path'.
In addition to these reference CAD objects, the operator is allowed to specify all the machine parameters, which could vary for each shoe different model.

Such information are also saved into the shoe cad file so augmenting its semantic content, and are available to be exported in a neutral, open format, to be loaded in the company's product data repository for documentation of the production process.

The heel seat and side lasting operation needs to be programmed off-line, loading the parameters files on the machine before starting the production batch. Nevertheless, the parameter files could be loaded by the machine through an online intranet connection, as the CAM system is composed by a web compatible post-processor module.

Phase 5 – Checking the robot paths

Before producing a shoe there is the need to check the robot paths.

Subcell A: in subcell A the paths of robot are always the same (pick from the man-robot exchange station, move to the RFID reader, move to the heel seat and side lasting machine and to the conveyor). The FIFO picking system from the man-robot exchange station has been tested. The speed of the robot has been set up according to the working capability of the machines.

Subcell B: to test the subcell B, the first step is the accurate definition of the reference frame of each tool. This activity has been performed after the first tests in which the bottom processing operations were not sufficiently accurate. Indeed, the tools were not working according to the orthogonal plane of the shoe bottom surface and most of the time the distance tool-shoe bottom surface was not the correct one. This was corrected after the first tests.
The most important variables to be tested for each shoe model are: speed of the tools and accuracy of the paths provided by the centralized system (based on CAD files).

Phase 6 – Production

Technicians set the robots in automatic mode and the automated production starts.
Phases 2-5 have to be carried out for each new article and represent the setup phase of the plant, whereas Phase 6 represent the real production phase, in which all the articles previously inserted in the system in the

setup phase can be produced. The automated plant has a great flexibility, since the different articles can be produced in a whatsoever order with small shoe batches (ideally, the plant can produce batches of one shoe).

The tests lead to the validation both of the integrated design and production processes and of the new automated plant.

The evaluation of some batches of shoes produced was focused on the final quality of the product. The shoes quality is similar or better than with the traditional working method.

The new plant complies with the requirements of the project: the production is flexible and can produce a variety of shoe models, respecting at the same time the production time defined by the needs of the shoe producers. The automated plant has a great flexibility, since the different articles can be produced in a whatsoever order with small shoe batches (ideally, the plant can produce batches of one shoe). The final results are positively evaluated by the whole partnership. The benefits, for all the actors involved, are very interesting. The partnership thinks that this project is a starting point: the point of arrival will be the spread of this new approach in all the SME fashion companies, that can produce shoes using this method and improve their competitiveness on the market.

The new production plant does not compromise important operations useful to enhance the aesthetical and stylistic features of the shoes. Workers are substituted only in repetitive production phases where with the automation it is possible to have higher working precision and higher speed. This is valid for operations like putting glue on shoe bottom, hammering, roughing bottom surface and so ever. These are all operations which are usually delocalized to third countries for cost saving reasons. The automation of these steps will allow to increase the hiring of qualified personnel and will allow to keep in Europe part of the production which is usually supplied to other countries.

Potential Impact:

The project contributes to enhance SMEs' competitive strenght by supporting the creation of truly sustainable industrial systems through leveraging and optimizing the value of knowledge in the production process.

In fact IDEA-FOOT gives a strategic advantage to SMEs since it permits to shift from the resource- to knowledge-based approach where production process will communicate directly with the design process exchanging information and data thanks to the introduction of innovative engineering solutions.

The modularised and computerised production environment to integrate product and process innovation will permit to produce small series of products decreasing development and production time and consequentially related costs. Shoe companies participating to the project have benefit after the project thanks to the competitive advantage to start using the results just after the project as already planned in the exploitation agreement and IPR policy management.

The main economic impact is expected in the short term in the SMEs participants directly addressed by the IDEA-FOOT project covering the whole value chain of the footwear sector (from shoe producer to components providers) and the machine builder as well. Thus, from the economic point of view, an important reduction of production costs and time to market with a related increase of long term oriented quality is envisioned. Implementation of new technologies will permit to maintain part of the production in Europe reducing delocalisation and guaranteeing work places.

Given the multi-level objectives of the project, performance indicators are influenced all along the product and process lifecycle. At the beginning of shoe lifecycle, once defined product specifications, they are integrated for a new shoe model. The shoe producer can activate different collaborations in the value chain (last, insole, upper production and shoe assembly) in a dynamic way in order to industrialize and produce the final shoes according to design. Thanks to the introduction of new standards which will be shared along the value chain, shoe companies can reduce the overall time to design and industrialize the product. In fact most of the operations which are currently scheduled sequentially will be organized in parallel avoiding waste of time in waiting for response from partners. Process optimisation will be reached with the implementation of integrated production cell which will shorten production time and set up time.

The IDEA-FOOT results will impact on better organization of the workflow inside and among SMEs. At the same time the project will improve working conditions for operators, thanks to innovative layout of the production system. Better production conditions will impact also on companies competitiveness which will be positively affected by means of a better customer satisfaction.

The main expected benefits for SMEs are:
- the reduction of the time necessary for the design and industrialization phases;
- the reduction of the Time to Market;
- the reduction of the production costs;

- the increase of productivity;
- the qualification of human resources employed in the design and production;
- the possibility to maintain the production in the country of origin instead of delocalizing the production in low labour cost countries.

The use of standards in the CAD design allows this phase to be faster. The development of the shoe components will be made according to a parallel model, saving up to 50% of the design time. Moreover the use of standards allows the standardisation of the process parameters and the tool path generation which are going to be transferred in a digital format to the automatic production machineries by the CAM software. In this way it will be possible to reduce the machineries set-up time and to increase quality and repeatability.

The lay-out of the production cell has been defined studying in detail each operation to be performed, to find the most efficient configuration in terms of production time and work in progress. The production plant is composed of a limited number of machineries, in order to demonstrate the benefits of the proposed integration between the design and production processes.

A final validation of the integrated design and production process has been successfully held at the shoe producer premises. This activity has permitted to give a first evaluation of the potential benefits in terms of time savings for the design and production processes, product quality and flexibility.

Economic sustainability: an important reduction of the production costs and time to market with a related increase of long term oriented quality is envisioned. Implementation of new technologies permits to maintain part of the production in Europe reducing delocalization out of Europe and assuring workplaces.

While in case of production the cut of production costs are really relevant thanks to the new production plant, in case of design decrease is more on the time consumed to engineer and industrialize the models than in the costs. In fact despite having internal development of the models, the approach will allow to avoid waiting time of externalized development to each product component producer. With the previous organizational model each supplier (last, heel, insole and sole suppliers) was involved in the development process and the transferring and waiting time from one company to another was taking a lot of time. Reduction of development time can be estimated in more than 50%.

Social Sustainability. The introduction of these new technologies requires the updating of the competences of the workers and the development of new skills. Work organization needs to change and the focus is not on single task jobs but based on qualified workers, who take over most of the tasks and responsibilities reducing the indirect work drastically. The introduction of new production cells requires the development of new competences both in the area of design where people have to learn to use new CAD modules in order to apply the new procedures and in the area of production where workers will be asked to do added value operations in the automated production cells.

The introduction of new automated cells eases the improvement of working conditions since it reduces the involvement of workers in risky operations and the direct contact with harmful substances. The automated cells allow to isolate some operations like cementing where toxic adhesive can be touched and their volatile content can be breathed, and leather roughing where leather powder can be breathed causing some health problems. The introduction of robotic technologies allows that operations which require physical efforts and the repetitive manipulation of pieces will be performed by manipulators improving working conditions. Moreover, the use of protections in the areas in which manipulators are working will allow to reduce work accidents in the manufacturing phase. New manufacturing strategies improvements should include job rotation and changes in workstation spaces among other issues related to work conditions.

Human-machine interactions have been studied to allow workers to optimize it avoiding any problem.

Environmental Sustainability. The sustainability of the processes is nowadays a relevant issue requiring that companies manage negative externalities caused by their production.

Thanks to the IDEA-FOOT project it will be possible:
- to integrate the design and production phases which means a better organization of the shoe development reducing scraps and material waste during the production phase;
- to reduce usage of nocive collants and solvents thanks to the optimization of the production process;
- to reduce scraps (for example leather and collants) generated by the prototyping phase due the incongruence between the 2D models of the stylists and the 3D prototypes which may require an iterative process (and the generation of many scrap prototypes).

Some performance indicators which have been measured by the companies are:

Lead time:
- Decrease in the lead time of design process thanks to concurrent development of the shoe components.
- Reduction of waiting time: all components are designed directly by the shoe producer and this allows to eliminate all the waiting time which is usually necessary for developing one component after the other transferring the physical models from one supplier to another (from last to insole to heel and to sole supplier).
- Reduction in set up time of production: Integration between design and production allows to make easier the programming of the production plant thanks to automatic acquisition of product data from CAD.
- Production time: automated manipulation of the items from one operation to another speed up operations.

Production quality:
- Precision of development parameters: precision of design phase allows to reduce the mistakes during assembling phase
- Precision of the repetitive operations: product quality is increased thanks to repetitive operations made by the robots.

Flexibility:
- Small batches: Increased capability of the production plant to produce small batches and to produce one after the other different shoe models without the need to change set up of machines
- Minimum order: to be accepted by the company is much smaller and can even accept a batch of one shoe pair production.

DISSEMINATION

Dissemination has been based on the following actions:

The IDEAFoot website (see http://www.ideafoot.eu online) has been implemented as a tool for communication with the wide internet audience. A restricted working area complete the website where all the partners involved in the project can find the most important documents of the project. Most of the websites of the project partners are linked to the project website.

The Newsletters have been based on project results updating and have been developed with the support of all the SMEs. The newsletters and flyer have been used for dissemination purpose during fairs and seminars.

Poster has been produced for the last meetings of the project and the events to which the project partners have been invited.

Beside technical internal meetings, during the project life, the consortium organized some conferences and seminars in order to spread project ideas and to validate the approach to the footwear production. The following events have been organized:

- 28/01/2011: Conference "IdeaFoot First year results" at Politecnico Calzaturiero - Padua, Italy Scientific community (higher education, Research) - Industry 20 participants
- 18/10/2011: Project seminar "IdeaFoot innovative approach to design and production in the footwear sector" at SIMAC-Lineapelle, Milan Fair, Italy Scientific community (higher education, Research) - Industry 20
- 23/02/2012: Project seminar "IdeaFoot: innovative solutions for footwear companies" at Inescop - Elda, Spain Footwear companies 15
- 06/03/2012: Project seminar "IdeaFoot Results" at MICAM, Milan Fair, Italy Footwear companies 15
- 24/03/2012: Conference Final Event of the project Ideafoot. Politecnico Calzaturiero - Padua, Italy Scientific community , Industry - Policy makers – Medias 77 participants

Moreover project partners gave invited speeches to conferences during the following events:

- 28/05/2011: Salone d'Impresa at Technological and Scientific VEGA Park, in Mestre Venezia where roughly 50 representatives of Industry were attending.
- 27/06/2011: Closing day of the Footwear modelist school at Politecnico Calzaturiero – (Padua, Italy) where more than 100 shoe and leather companies, students of footwear modelist school were present
- 25/07/2011: presentation during the meeting of the Leonardo projects on footwear sector technical meeting and dissemination event. At University of Transilvania - Brasov, Romania where 10 persons were present
- 27/03/2012: Master SIFA (Strategies and Innovation pour la Formation des Adults)- organized by University of Tour in Politecnico Calzaturiero - Padua, Italy. Students and professors of the Master

Invited speeches gave also the occasion to make cross-fertilization with other projects in similar areas, like Leonardo projects covering the issue of managing competences and know-how in footwear sector.

Footwear Sectorial fairs have been considered an important mean for dissemination: footwear SMEs usually participate along the year to important international sectorial fairs like MICAM in Milan for shoe producers which is held twice a year, SIMAC-LineaPelle in Bologna for machine producers. Being Italy the EU country with the largest number of shoe producers most of the events where organized there. Nevertheless these events can be considered international events since all EU countries participate to these fairs. These fairs have been a good occasion for mainstreaming the results of the project towards suppliers and customers and to promote a new way of organizing production. Within these fairs it was possible to organize press conferences, workshops and to distribute flyers for the promotion of the project.

Most important participations have been at:
- 09/03/2011 MICAM, Milan Fair, Italy: distributions of newsletters and flyers of the project. Networking with other companies in
- 10/10/2011 SIMAC-Lineapelle, Milan Fair, Italy: organization of a seminar, stands of companies, distribution of newsletters of the project. Organization of a press conference
- 06/03/2012 MICAM, Milan Fair, Italy: organization of project meeting, presentce at stands of companies and at stand of ANCI (Italian association of Shoe Producers) with distribution of newsletters of the project, press conference.

For what concerns scientific publications, mainly technical specialized magazines (like Tecnica Calzaturiera, Automazione Industriale) have been taken into consideration during the project to give evidence to industrial companies of project status and results. For what concerns scientific papers, the RTD performers preferred to postpone participation to conferences in Manufacturing and production systems area after the end of the project, when all results were ready and agreements on foreground could allow to disseminate part of the approach to the scientific community.

A video has been realized to disseminate project results: the video gives a good overview on the project results from the standards of the shoe components to the communication between design and production to assemblying of shoes based on the new automated plant.

CROSS FERTILIZATION WITH OTHER PROJECTS: during the project the following main cross activities have been possible:
- BZMODA is extending research activities on automation of the other operations of assembling process with other research project.
- Politecnico calzaturiero is working on some Leonardo projects (in the DG-Employment in the framework of Life Long Learning) aiming to formalize knowledge on production and some common activities will be possible and useful.
- ITIA-CNR is working on the topic of CAM data representation based on semantic web also in other EU projects like CoReNet, NetChallenge, VVF (in NMP programme).
- IDEAFOOT is included in Prosumer.net (CSA from the NMP framework). Prosumer.net activities are based on mapping RTD main of projects on consumer goods to map most important RTD topics for the future (see http://prosumernet.eu/ online).

EXPLOITATION

IDEA-FOOT results consist of a set of solutions aiming at improving design and production process to obtain rapidly and efficiently small

series of shoes. In particular the results of the IDEA-FOOT project are identified in:
R1: Innovative Methods for the definition of standard modules: methods to standardize geometrical features during design of the shoe
R2: Library of standardized features: set of standardized geometrical features of shoe components
R3: CAD modules: CAD modules to support the easy development of the standardized components of the shoe. In particular there are two kind of results:
R3.1: Plug-ins for Rhino
R3.2: Add-ons iCAD3D
R4. Set of CAM software modules: CAM software modules, formats and communication protocols between CAD and the involved production machines
R5: Innovative integrated production cell: the production cell include machines, a last manipulation systems and software interfaces. In particular there are two levels of results:
R5.1: Toe lasting machine and Heel seat and Side lasting machine for Integrated production cell
R5.2: Integrated production plant
Partners of IDEA-FOOT have already defined an initial strategy and agreed on exploitation of the results on the interests of the SMEs participants in the DoW of the project.
The strategy is based on the fact that IPRs will not be shared with the RTD performers; therefore the SMEs will keep full ownership since they have reimbursed at 100% the work of the RTD performers. RTD performers shall keep IPRs for further research on similar or different fields of application. RTD performers are allowed to make scientific publications on non confidential project results after previous agreement of the SMEs.

R1: Methods for the definition of standard modules

The method for the definition of standard modules of shoe components is a remarkable step forward in order to optimize the design process within a shoemaker company.

The method represents a rigorous way of making the correct steps to formalize the knowledge in the company about the shoe structure (last, heel, sole, insole). The method defines scientifically the steps that a company has to do in order to develop the standards for each component.

BZModa is the main partner interested to this result which will use it also for commercial reasons and partially it will be used by RED21 and RosiITA. The method has been defined in function of the standards that have been later developed. BZmoda will develop a service for other companies willing to define their own standards.

R2: Library of standardized geometrical features

The proposed innovation is based on the definition of some specific shoe parameters for the last, the insole, and the heel (like for example lower leg, entry, shoe neck, toe fit, arch-line) which do not vary with the style of the shoe and which can be the same along the different shoe models. For this reasons it is important that any time the company has to develop a new shoe collection it starts from the shoe components modules already existing and not varying along the models.

BZmoda will have the ownership of the standards using them also commercially while RosiITA and RED21 will use them on a royalty-free base for internal usage. RosiITA and RED21 will not advance any right on the income which BZModa can have from the sales of the standards or from the use of the methods for standards definition.

R3.1: CAD module- Rhino plug-ins

Rhino plug-ins are CAD modules to design quickly and accurately the components of new shoe models, reducing the time to market, costs and increasing the quality of the final product.

Rhino plug-ins are modules, written using Visual Basic programming languages, that facilitate the creation of all components to fasten repetitive operations necessary to design a new shoe.

The use of these plug-ins will support companies in updating their designing process, because the interfaces between shoe components will be more complete and precise. The exchange of data and the sharing of the information will be easier and more comprehensive, with advantages for suppliers, buyers and final consumers, which will benefit from a product of superior quality.

Importance of the use of plug-ins will make shoe producers independent from their suppliers during the design phase. In fact in the traditional design process, shoe producer involves also suppliers of last, heel, insole and sole each developing its own component. This process is sequential and increases the development time due to the need to wait that each partner allocate the time to make the work assigned.

BZmoda will have the ownership of the plug-ins using them also commercially while RosiITA will have access to them on a royalty-free base for internal usage.

R3.2: CAD Module: Add-ons iCAD3D

The software tool incorporates elements necessary for the integration of 3D design of shoe with rest of elements and has a 100% correspondence with the manufacturing last. It also permits to generate the trajectories for future robotic operations. Flattening of models is almost perfect. RED21 will be the main beneficiary of the tool and will use it for its activity of software provider for shoe sector.

R4: Set of CAM software modules

A set of software modules and methods to generate instructions for an operating machine, based on the CAD representation of a shoe. The system is based on the adoption of a neutral language, enabling the support of different machine models through the development of appropriate post-processors. The standard language adopted (RDF) is part of a general innovation process, based on state-of-the-art results from the web technology, whose pervasive power is expected to be the enabler of a broad adoption in the future.

The overall system is composed by a set of CAD functionalities, implemented as plug-ins of the Rhinoceros CAD system, plus a post processor for the translation from neutral to proprietary language.

These CAM modules will be mainly used by Brustia for improving the performance of its machines.

R5.1: Toe lasting machine and Heel seat and Side lasting machine for Integrated production cell

The two prototype of machines contain features that make them different from any other model present on the market, regarding two main aspects; their suitability for an integration in highly automated, centrally supervised manufacturing setups and the possibility, for one of the them (heel and side lasting machine) to work in a totally unattended way. There are no machines of this kind currently available , not even when considering these innovation aspects separately.

A robot is needed to attend the machine; its task is to retrieve the shoe to be processed from an "exchange station" (that can also incorporate a humidification function) to pass it to the machine (in the "loading / unloading" position) , wait until the machine completes its task and then retrieve the fully lasted shoe to transfer it to the next processing step. The two machines, the operator and the loading / unloading robot form a self contained "lasting cell" with a high degree of flexibility and a very high daily throughput

It is expected that Brustia will enjoy at least a 12-18 month advantage over the more direct competitors; it is likely that, is a demand will develop among shoe companies for this kind of manufacturing systems, other machine producers will follow along the path, but still will not happen in the short term future.

BZ Moda (the project coordinator) as main shoe end user will have the machine installed and tested in its manufacturing plant and has expressed an interest in the use of the two prototypes; interest was also expressed by C2i2, a partner of the project from Spain, which is an "interest group" representing a high number of shoe companies; a presentation of the project results to such companies was recently made as part of the dissemination activities of the project.

R5.2: Integrated production plant

The prototype of the integrated production plant is composed of 2 subcells:

- subcell A: the last is manipulated by a robot which picks it up from a man-robot exchange station (heating system) and takes it from the toe lasting machine to the heel seat and side lasting machine

subcell B: the last is manipulated and worked out along the following operations: grinding, hammering, roughing, cementing.

All the operations are managed by the central software control system.

Potential customers are shoe companies, in Italy and Europe, willing to automatize some phases of their production with efficient machines and manipulation systems. The integrated production plant is mainly proposed for fashion companies producing shoes with applied sole.

Shoe companies adopting this manufacturing model, will have more chance to compete in the global scenario thanks to their higher flexibility, reduced cost and greater control on the manufacturing process; this will contribute to maintaining shoe production in Europe or even to gain back manufacturing quotas previously outsourced to far away subcontractors.

BZModa (the project coordinator) as main shoe end user has the automated plant installed and tested in its manufacturing premises and will use it for internal production; BZModa together with Brustia and asking technical support to DESMA (to be involved again as subcontractor) are interested in selling similar production systems to other shoe companies. Special agreements among these partners will be studied in the next months.

A business plan has been developed based on these information and data on market which have been estimated. As mentioned in the previous chapter, the results will be used internally by the SMEs of the project.

Moreover there are 3 different level of marketability of the project results which will be implemented mainly:
1) Internal usage of the results: Bzmoda, RosiITA and RED21 will use the results of the project for their normal business i.e. respectively to produce shoes, shoe components and provide design services. Brustia will develop other similar machines for its customers.
2) Provision of services to other shoe producers: using project results it is possible to support other companies with consultancy services and engineering services to produce shoe samples and new collections. In particular shoe companies can subcontract to BZModa and RED21 the design of dedicated collections which will be done in a much faster and less expensive than to do it to a company with the traditional production system.
3) Sales of the project results: both Bzmoda and RED21 can sells plug-ins and add-ons of the CAD and provide services to companies for the definition of speicfic company standards. Sales of plug-ins can be done as they are now and can be personalized according to the customer needs. Moreover Bzmoda can sell similar production plant to shoe companies willing to apply a similar approach to their production. This can be done only in collaboration with Brustia and other project partners directly involved in the development of the automated plant. Brustia can sell the 2 developed machines to other shoe producers. Consultancy and sales of automated production plant is much more complex and will be based on the collaboration with other partners in order to provide to the customer the overall solution (hardware, software and integration).

List of Websites:
http://www.ideafoot.eu