



Innovative Skills for an Old Vocation

Innovative Skills for Assembly

WP 04



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1 Introduction

This manual is a joint product of all partners from the Erasmus+ project "Innovative Skills for an Old Vocation" (ISOV, 2024-1-DE02-KA220-VET-000254492, <https://isov-project.eu/>). As all sectors, the sector of industrial footwear production faces the mega-trends of globalisation, digitalisation and sustainability. Main aims of the project are the development, pedagogical structuring and piloting of courses for apprentices, students and/or employees in industrial footwear production in Germany, Portugal and Romania, based on scientifically developed impact analyses on which of the dimensions of the trends influence which of the 18 Spheres of Activity (SoA) of the sector. The courses and the manuals refer to 12 chosen concrete SoA in which the participants are working, are supposed to work, or want to work.

Basic materials for the courses are the manuals. As the estimated impact of the dimensions respective sub-dimensions of the trends differ between partner countries and as the equipment of training providers with modern technology is differing, as well, the manuals follow a modular structure:

Chapter 2 documents the, partly shortened or updated, "state of the art" manual from previous projects "Integrating Companies in a Sustainable Apprenticeship System" (ICSAS, <http://icsas-project.eu/>) respective "Developing Innovative and Attractive Continuous Vocational Education and Training (DIA-CVET, <https://dia-cvet.eu/>).

Chapters 3-5 illustrate the expected impact of the various (sub-)dimensions of the 3 trends in the near future (up to 5 years) on the work-processes of the chosen SoA.

This approach has the huge advantage that, for example, if the sub-dimension "additive manufacturing" is estimated to have high impact on a certain SoA and a training provider has no 3-d printer, he can, with respect to this sub-dimension, rely on the "old" manual referring to subtractive manufacturing – but still impart the impact of other subdimensions, where the equipment is available.

Finally, chapter 6 offers a case study of apparent good practice, demonstrating not only what, but also exemplarily how to teach.

Or, to put it different, this manual should not be read as a "receipt", where all condiments should be added or imparted in a fixed row and a defined quantity – but as a "toolbox", aiming at inspiring trainers to impart not only "state of the art" knowledge, skills and competences (KSC) – but to prepare their apprentices, students or participants in continuous vocational education and training (CVET) for upcoming work-processes.

2 Manual from previous project

2.1 Assembly in Footwear Manufacturing

Shoe assembly is one of the final stages of footwear manufacturing (only followed by finishing and boxing for shipment).

In the assembly room, the shoe bottoms (i.e. soles respectively soling components) are mounted to the lasted uppers. During the assembly process, the shoes are still on the last (see manuals on the preceding operations, Pre-lasting and Lasting) to give the shoes their final shape and inner dimensions to provide optimum fit.

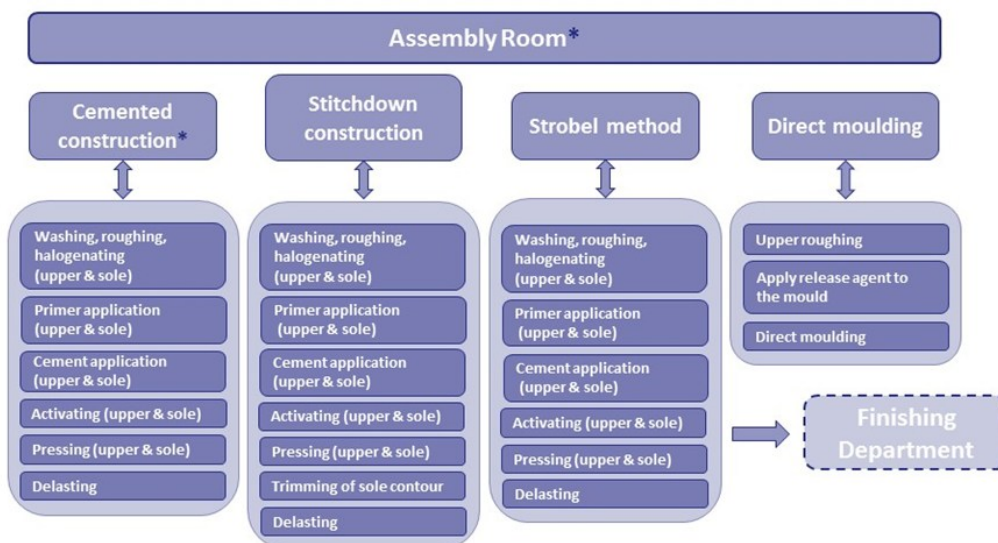


Fig. 1: Sequence of operations in assembly for the most common footwear construction methods (Credit: ISC)

The operational sequence in footwear assembly largely depends on the shoe construction method. In the scope of the ICSAS project, all companies involved produce leather footwear manufactured using the cement-lasting method, meaning that upper and shoe bottom are bonded with adhesives.

The shoes are delasted once the sole is attached respectively before the heels are attached.

2.2 Assembly Room (Cemented Construction)

The lasted uppers (semi-finished shoes) enter the assembly room on trolleys, together with the bottom components and the work ticket. The bottom components are / can be: Outsoles, heel and heel top pieces supplied by the internal warehouse and leather heel covers supplied by the cutting room.

2.2.1 Roughing (Manual)

The first operation in the assembly room is (manual) roughing of the lasted shoe bottom, i.e. of the lasting allowance.

In the case of Gabor, the serial production sites are located in Slovakia or Portugal. There, roughing is performed by automated roughing machines. The Gabor Rosenheim site is dedicated to

prototype production, which implies frequent tool changes. Therefore, manual roughing is the method of choice here.

Roughing smoothens potential creases on the lasting edge and removes the grain layer of the leather (which can contain a relatively high percentage of grease; grease is an adhesion inhibitor, meaning that the presence of grease can considerably deteriorate the bond quality between upper and sole).

In the LSA example, a heat-activated adhesive was used, mixed with a curing agent to reinforce the bonding strength.

To start with, the lasting edge is scoured with coarse sand paper and then with a finer sand paper quality on a roughing disk. Manual roughing requires a lot of precision and the appropriate pressure of the lasted upper against the roughing disk.

The result of the roughing process is a surface increase for bonding. The adhesive can “wet” a roughened material better, which leads to enhanced bond strength.



Fig. 2: Manual roughing (coarse sand paper). Credit: ISC



Fig. 3: Manual roughing (finer sand paper). Credit: Gabor



Fig. 4: Perfect roughing result: Only the grain layer has been removed. The structural strength of the upper leather is maintained and the contact area for the adhesive bond has been enlarged. Credit: ISC



Fig. 5: Example of an over-roughed upper: the white interlining is showing through. The strength of the sole bond will now completely depend on the structural strength of lining and interlining. Credit: ISC



Fig. 6: If roughing dust remains on the roughed surface, it will be covered with glue in the next step, which will ultimately weaken the bonding strength. Credit: ISC

The shoe in the LSA example at Gabor features a $\frac{3}{4}$ sole (meaning that the heel seat area does not have to be roughened). For full-length soles the complete bottom is roughened. For shell soles, not only the bottom but also the sides need to be roughened. In order to mark the roughing height, the sole is placed onto the lasted upper and the sole edge is marked with a marker pen. The lasting edge is roughened as well as the lateral upper areas which will later be covered by the shell sole.

The roughened surfaces are cleaned to remove remaining roughing dust particles (e.g. with a compressed air pistol).

Roughing / Effects	Checkpoints
• Expands contact area for bonding • Anchoring effect (mechanical interlocking) • Removes the eventually weak and / or greasy surface layer (grain layer of the leather), release agents, blooming chemicals, plasticisers etc.	• Is the surface evenly roughed and not over-roughed? • Leather: Has only the grain layer been removed? • If roughing effects diminishes (which can happen i.e. with PUR soles): re-rough • Clean off roughing dust

Fig. 7: The effects of roughing and important checkpoints. Credit: ISC

2.2.2 Cementing (Manual)

In the LSA example at Gabor, a heat-activated adhesive mixed with a curing agent to reinforce the bonding strength was used for upper cementing.



Fig. 8: Primer application. Credit: Gabor

Cementing means to apply an adhesive coat (in the example a PU adhesive). This is done in two steps: primer and main application. At Gabor Rosenheim, this is done manually with a brush. In serial production, automated cementing machines are used.



Fig. 9: The bottom filler's function is to level out the difference in height between the lasting edge and the insole. Credit: Gabor

Important: too much adhesive does not mean better bonding! If the adhesive layer is too thick, it cannot dry properly within the given drying time, which will weaken the bonding quality. Drying time in this example: 10 minutes. The primer coat must be allowed to dry completely before further processing.

Once the primer coat has dried, a bottom filler is inserted. Its purpose is to compensate the height difference between insole and lasting allowance which could be perceptible for the wearer of the shoe.

Then the main adhesive coat is applied to the roughened lasting allowance (not to the bottom filler, though) and the sole. This operation is performed at a workplace with an exhaust system to protect the worker from inhaling harmful volatile substances contained in solvent-based adhesives.

Depending on the soling material, there are different methods of pre-treatment to prepare the sole bond. In this example, a TPU sole is used, which requires washing to remove grease and other contaminations prior to adhesive application. A PU sole, for example, would require a chemical roughing process. Very important: Respect the drying times.



Fig. 10: Cement is applied to the sole. Credit: Gabor

Pre-treatment of Soles

Before the actual gluing process, most soling materials require a pretreatment:

PU – cleaning or roughing, primer

TR (TPR) – halogenating or UV curing

PVC – cleaning

Rubber – roughing, cleaning, halogenating

EVA – roughing/brushing, primer

TPU – cleaning, primer

Leather – roughing, primer

Note on Cleaning / Washing:

Cleaning is usually done with solvents. Primers are special – in general – solvent-based adhesives which must be selected according to the soling material. Please read the paragraphs on harmful substances in the material data sheets carefully before you decide which cleaning agent to use and how to protect the health of workers.

Fig. 11: Common pretreatment methods for different soling materials prior to adhesive application. Credit: ISC

2.2.3 Preparing a Covered Heel

Covering plastic heels with leather or covering insole edges with leather strips are preparative operations which are done in the “bottom parts preparation room” (aka “stock fitting”).



Fig. 12: Clamping device used for covering heels with leather. Credit: Gabor

In order to be covered with a leather piece of corresponding dimensions, the heel is first dipped into adhesive and then clamped into a holding device.

The leather part is supplied (cut and split) by the cutting room.

Spray adhesive is applied to the back of the leather cover. The leather cover is wrapped around and pressed against the heel. The edges meet at the heel front. Excess material is trimmed. At the heel seat edge as well as towards the tread surface the leather is folded over the edge.



Fig. 13: This is what the covered heel will look like on the shoe. Credit: Gabor

2.2.4 Preparing a Piped Insole

For the LSA, Gabor showed how a piped insole is produced (again, this is normally done in the “bottom parts preparation room”). The storage for insoles which will be piped is part of the assembly room.



Fig. 14: Insole and piping strip to be glued around the edge. Credit: Gabor

Neoprene adhesive is applied both to the insole and to the leather strip with a brush. The piping strip is folded under strain around the insole edge. Both ends are rubbed down in order to ensure that the overlapping strip ends do not cause a pressure point.

2.2.5 Attaching the Sole

Soles and uppers are heat-activated. Then the soles are attached to the lasted uppers on a two-station sole press (for left and right shoes).



Fig. 15: Finishing the piped insole. Credit: Gabor



Fig. 16: Sole activating device

The softer the soling material, the less pressure is to be applied. Pneumatic sole presses are commonly used for attaching soft soling materials. For hard soles, hydraulic sole presses are preferable because they can generate higher pressure.

Important: Even pressure distribution.



Fig. 17: Hydraulic sole press. Credit: ISC



Fig. 18: Double membrane pneumatic sole press.
Credit: ISC

2.2.6 Delasting

The next operation is delasting (taking out the last).

2.2.7 Attaching the Heel

The heel is screwed on and the operator checks whether the shoe stands straight (with a rubber pad compensating the still missing heel tip).



Fig. 19: Machine for screwing on heels. Credit: Gabor

2.2.8 Attaching the Heel Tip

The last operation is to press the heel tip onto the heel (it will simply snap into place).

The heel tip has a pin with linear grooves to avoid excess pressure when attaching the heel tip.

The heel is held in place by four tacks to prevent rotation around the screw.

Important: Do not nail into the steel shank of the insole.

3 Globalisation in Assembly

Globalisation has changed consumer preferences and behaviour. The availability of international products and the influence of global brands have changed the way consumers make decisions.

This phenomenon has had a significant impact on markets, promoting trade liberalisation, increased competition and cultural exchange.

3.1 Demographic Factors

- Global mobility

Globalisation has changed how assembly line workers (those who have been working in the company and national or international newcomers), view their profession.

The need for labour and global mobility has brought workers of various nationalities to production centres (such as São João da Madeira, Felgueiras and Benedita), transforming factories into spaces for sharing values and social integration.

Shoe assembly in the global era requires more than technical expertise; it requires an understanding of the new ethical, environmental, and cultural values that global consumers place on each pair of shoes.

3.2 Economic and Social Factors

- Information exchange
- Technical skills

Communication and culture play a fundamental role in the economy and the organisation of societies, especially in a globalised world. It is not limited to the movement of goods and capital; it also involves the constant exchange of information, values, ideas, and forms of cultural expression.

In shoe assembly, the implementation of this theme can be based on:

Teaching technical terms related to assembly in Portuguese
Performing all operations after their demonstration, following the process step by step. This represents non-verbal language, which is essential when it comes to know-how
At the same time, providing training/education using the host country's Language, to streamline and facilitate communication
Develop more graphic and easy-to-understand teaching learning materials, separating each task/job as much as possible
Equipment technology should be integrated gradually and interspersed with tasks and activities
Create work teams with local and foreign members to enhance integration/inclusion, promoting healthy interaction and the sharing of knowledge and cultures

3.3 Change in Qualifications

- Evolution of qualifications and employability
- Technological evolution

The globalisation of markets has been causing significant changes in the footwear industry, requiring companies to be more adaptable, innovative and competitive.

These changes require an update of the qualifications of the employees involved in the different stages of the production process. To meet the demands of a global market, it is essential that workers develop up-to-date technical skills, the ability to adapt to new equipment, and knowledge related to quality standards, sustainability, and safety at work. The company promotes continuous training and professional development for its employees in order to keep pace with developments in the sector and ensure high standards of quality in footwear assembly. Updating qualifications may include training in new assembly techniques, use of specialised machinery, interpretation of technical specifications and compliance with international requirements.

How to achieve these goals?

Adapt training to trainees, based on established objectives

Update equipment and technical procedures, considering the various types of models and their characteristics

Promote continuous training for the entire team, to enhance the versatility of functions and job rotation for all positions

3.4 Markets and consumers

- Innovation in materials and components

Globalisation has profoundly transformed the way market's function and consumers behave. Borders between countries have become more permeable to trade, information, and the movement of people and goods.

In a global market, companies compete not only with others in their own country, but also with international brands. This competition encourages innovation, improved product quality, and lower prices.

Due to the wide variety of materials and components used in shoe manufacturing, it is also essential to have diverse manufacturing processes, regulations and equipment programming.

Currently, the types of footwear consumed by the market are so diverse that they "require" constant updating of materials, shoe lasts and manufacturing processes.

3.5 Regulation and Legislation

- The Legislative Framework
- Corporate Social Responsibility (CSR)

The global competitiveness of Portuguese assembly is based on certification. These international standards act as a “passport” to foreign markets and should be observed and respected. Some of the key standards to be implemented in footwear companies, encompass the following:

ISO 9001 (Quality Management): Ensures that assembly processes are repeatable, controlled and focused on customer satisfaction;

ISO 14001 (Environmental Management): Relevant for the treatment of cutting waste (leather and synthetics) and production effluents;

ISO 45001 (Occupational Health and Safety): Focuses on the prevention of occupational diseases, such as repetitive strain injuries (RSI) and exposure to chemical vapours on the gluing line.

Regarding to regulations and legislation and in accordance with technical specifications, it is very important to observe:

Drying times for adhesives
Clear information labels on all containers used
Personal protective equipment
Collective protective equipment – proper lighting conditions, enough space between equipment for workers, proper local exhaustion systems, promote cleaning and organisation of workstation
Health and safety at work
Preventive maintenance of equipment

Corporate social responsibility (CSR) is the idea that companies should operate in accordance with principles and policies that have a positive impact on society and the environment.

The organisation must promote a working environment based on respect, equal opportunities and non-discrimination among all employees.

Through CSR initiatives, footwear manufacturers work to limit their environmental impact, contribute to solving social problems (such as poverty and inequality) and ensure that their brand identity reflects their values.

Corporate social responsibility initiatives generally fall into four categories: environmental, ethical, philanthropic, and economic. All types of CSR (Corporate Social Responsibility) contribute to the company's overall CSR strategy.

4 Sustainability in Assembly

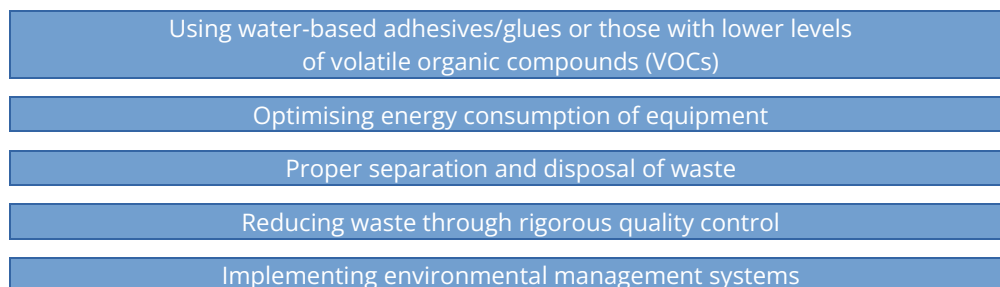
Sustainability in footwear assembly is a fundamental principle for reducing the industry's environmental impact and promoting responsible production practices. At this stage of the process, it is essential to adopt methods that ensure the efficient use of resources, minimising the waste of raw materials and optimising energy consumption.

5 Green Awareness

- Education for sustainability
- Eco-Labeling for footwear & digital transparency

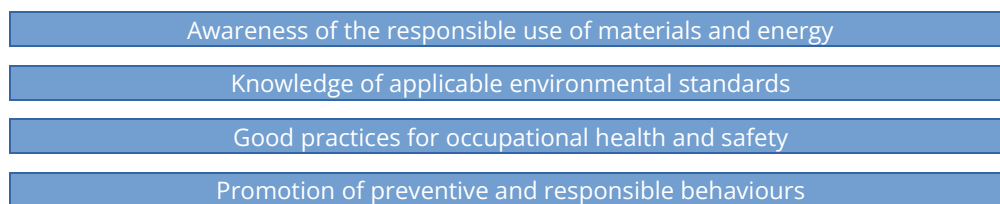
Sustainability currently represents one of the main challenges and opportunities for the footwear industry. In this context, increasing environmental and social demands, the footwear assembly phase plays a crucial role in reducing environmental impacts, optimising resources, and promoting responsible practices throughout the value chain. Within this framework, education for sustainability and consumer empowerment are complementary and strategic dimensions.

The assembly of footwear involves the joining of various components—upper, insole, and other structural elements—using mechanical, thermal, or chemical processes. This phase can generate environmental impacts associated with energy consumption, use of adhesives/glues and solvents, waste production, and carbonated emissions. Adopting sustainable practices in lasting involves:



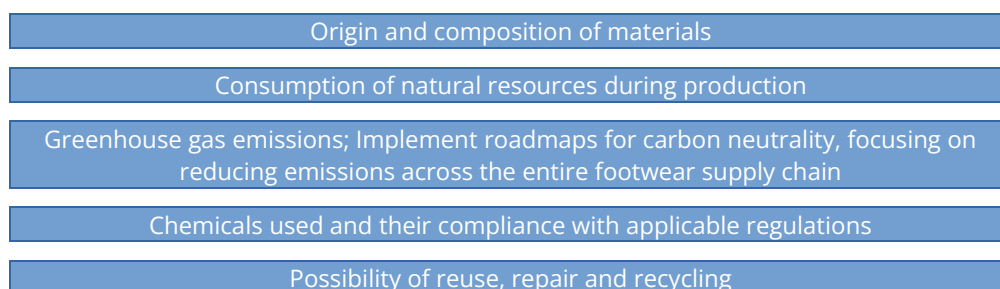
These measures contribute to productive efficiency and reduce the environmental footprint of the final product.

Education for sustainability involves integrating environmental, social, and economic principles into the organisational culture. In the footwear lasting sector, this training should encompass all levels of the company, from management to line workers. Training should include:



By reinforcing workers' environmental awareness, a culture of continuous improvement and shared responsibility is promoted.

Eco-labelling is a mechanism that allows the environmental performance of a product to be communicated clearly and credibly. In the case of footwear, the eco-label should provide relevant information on:



Digital transparency is the practice of making data, algorithms, and digital processes accessible, clear, and understandable to everyone, building trust between businesses and consumers. It involves sharing how data is collected, used, and protected, ensuring ethics, security, and accountability.

Essentially, it is about ensuring that technology use is fair and transparent in the digital age.

5.1 Sustainable Design & Circular Economy

- Reusability, repairability, disassembly & recycling
- Sustainable, biodegradable & regional materials selection

Sustainable design and the circular economy are key principles to consider in footwear manufacturing, helping to reduce environmental impact and optimise the use of resources throughout the product's life cycle. The integration of these concepts must begin at the design stage, directly influencing the decisions made during the manufacturing process.

Reuse, repair, disassembly and recycling are fundamental pillars of a sustainable approach to footwear manufacturing, contributing to waste reduction and resource recovery throughout the product's life cycle. The integration of these principles must be taken into account from the design stage right through to the final manufacturing processes. Wherever possible, elements that retain their functional performance should be incorporated into the assembly, thereby reducing the need for new raw materials. Choosing suitable fastening methods, as well as using durable materials, helps to extend the lifespan of the footwear and reduce its environmental impact.

Disassembly is a critical aspect of efficient end-of-life management. Footwear should be designed and constructed in such a way as to allow the different materials to be separated easily, avoiding the excessive use of permanent or difficult-to-separate bonds. This facilitates both repair and recycling, which in turn, should be promoted by selecting materials compatible with existing processes and by correctly sorting the waste generated during assembly. It is essential to implement internal procedures to ensure that this waste is properly channelled to authorised operators.

In shoe assembly process, what can be done to make this happen?

Ensure that workers have access to the technical data sheets for all materials used in the manufacture of footwear

To know and understand the technical characteristics of all components used in footwear assembly

Replace conventional materials with eco-friendly options, such as cork, leather made from fruit and plant waste, and others, with the aim to reduce the carbon footprint

Recycle metal and other materials and reuse them

Provide training in the dismantling of footwear, using the best techniques for the task

Wherever possible, preference should be given to sustainable and biodegradable materials, characterised by lower consumption of natural resources, lower pollutant emissions and sourcing from certified supply chains, without compromise quality and performance of footwear. The use of recycled or renewable raw materials is an effective way of reducing dependence on primary resources.

During assembly, it is important to ensure their recyclability or biodegradability. The choice of adhesives and other consumables should also lower environmental impact.

According with this topic, it is important to follow the procedures below:

Using high-quality materials
Availability of replacement parts
Provision of clear maintenance and repair instructions
Minimise the use of permanent adhesives and complex mixtures of materials
There is adequate segregation of components after disassembly
Give preference to materials or materials with recycled content

5.2 Energy and Process Efficiency

- Green energy integration and smart energy systems
- Efficient machinery and Lean management

The shoe assembly phase is energy-intensive, involving equipment such as presses, adhesive activation ovens, sewing machines, air conditioning systems, and air compressors. The integration of green energy and smart energy systems is a strategic measure to reduce the carbon footprint of the production process, improve operational efficiency and reinforce the organisation's commitment to sustainability.

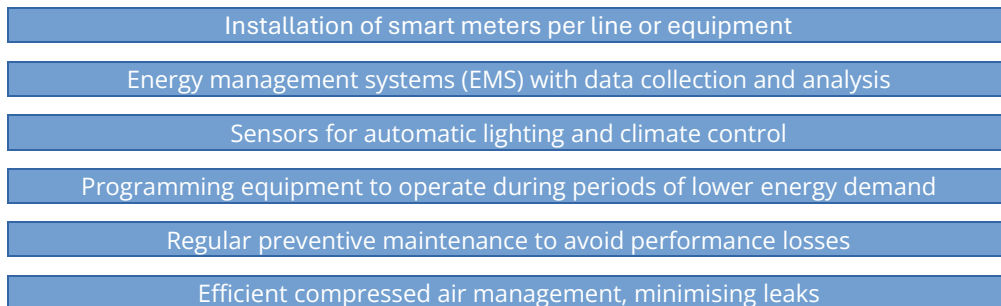
This chapter sets out guidelines for the adoption of renewable energy sources and the implementation of smart energy management solutions in the assembly area.

Green Energy Integration: refers to electricity or thermal energy from renewable sources, such as solar, wind, hydro or biomass. Its integration in the assembly phase can be achieved through:

Installation of photovoltaic systems for self-consumption
Purchase of certified electricity from renewable sources
Use of solar thermal systems to support processes that require heating
Contracting energy suppliers with guarantees of renewable origin

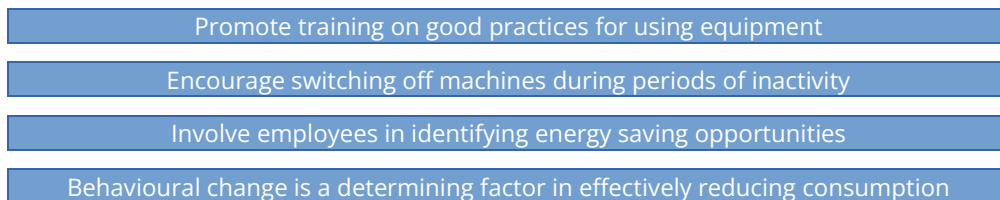
The adoption of these solutions contributes to reducing greenhouse gas emissions associated with the energy consumption of the production unit.

Smart Energy Systems: enable real-time monitoring, analysis and optimisation of energy consumption. In footwear assembly, their implementation should include:



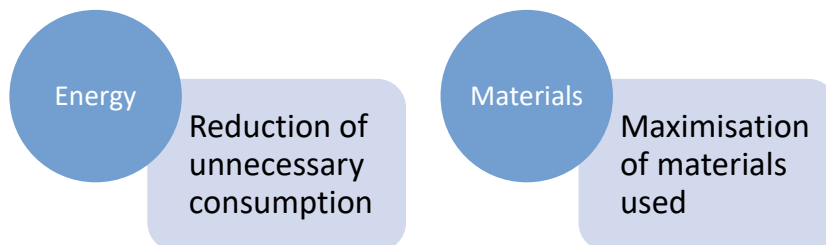
Continuous monitoring enables the identification of inefficiencies, waste and opportunities for improvement.

In the footwear industry, the workers should be involved in tasks like these:



Sustainability principles should be integrated into the heart of industrial operations, focusing on the synergy between the use of high-efficiency machinery alongside with some principles of Lean Management. In a footwear manufacturing context it focuses on maximising value for the customer through continuous improvement and the systematic elimination of waste.

Traditionally, we talk about time or defects, but Lean Sustainability expands this concept to:



To turn theory into reality on the factory floor, the following guidelines should be implemented:

- 5S Policy - Lower risk of work-related injuries and increase motivation of employees.
- TPM (Total Productive Maintenance) - Machines are kept in optimal conditions, leading to a drastic reduction in defective products.

The convergence between Lean Management and Technological Efficiency creates an ecosystem where profitability and environmental responsibility harmonise. By eliminating waste, the company not only protects its profit margins but also preserves the future.

5.3 Resource Efficiency and Sustainable Materials

- Reducing emissions, water and electricity consumption
- Selection of sustainable, biodegradable and locally sourced materials

The integration of sustainability principles in footwear assembly, is essential to reduce the sector's environmental impact and promote more efficient and competitive production. This commitment translates into reduced pollutant emissions, rational water management and optimised electricity consumption.

To achieve these objectives, the following measures must be taken:

Reducing atmospheric emissions begins with choosing safer materials and products

Implement mechanised cleaning systems that use less water

Replacing glues and solvents by water-based alternatives helps reduce volatile organic compounds (VOCs) and improves air quality in assembly areas. Whenever possible, choose adhesives with low solvent content, reducing the emissions

Regular monitoring and maintenance of compressors and machines with electric motors ensures cleaner and more efficient operation, preventing overloads and energy leaks

Collect and reuse water used to wash equipment, after filtering it properly

Keep taps and hoses in good condition to prevent leaks

Electricity consumption represents a significant part of the assembly's energy footprint. To reduce it, it is essential to:

Use modern machines equipped with high energy-class motors and automatic speed regulation systems

Install LED lighting in all production and support areas, with motion sensors in circulation areas

Switch off equipment when not in operation and promote preventive maintenance to avoid energy losses due to malfunctioning

Switch off equipment when not in operation and promote preventive maintenance to avoid energy losses due to malfunctioning

Every operator has an essential role to play. Following procedures, identifying energy losses, and suggesting improvements contributes to cleaner and more economical assembly. Sustainability does not depend solely on management — it also depends on the attention and commitment of all professionals on the production line.

Selection of Sustainable, Biodegradable and Regional Materials:

The choice of materials has a direct impact on the sustainability of the footwear assembly process. Opting for sustainable, biodegradable and regionally sourced raw materials helps to reduce the environmental footprint, improve production efficiency and enhance the value of the final product.

Sustainable materials are sourced and processed in a way that minimises the consumption of natural resources and the generation of waste.

In footwear assembly, this translates into:

- Using adhesives, threads, insoles and heel counters produced with recycled or low environmental impact components;
- Choosing suppliers that guarantee responsible practices, environmental certifications (such as ISO 14001) and traceability of materials.

Biodegradable materials are those that decompose naturally without leaving toxic residues. Whenever technically possible, they should be considered in assembly.

Examples include:

Fabrics and linings made from natural fibres, such as organic cotton, jute or linen

Foams and insoles are made from plant-based materials, replacing petroleum-based foams

Bio-polymer-based components used in comfort insoles or lightweight heel counters

Biodegradable sewing threads, based on recyclable polyester or treated natural fibres

These materials are ideal for brands that focus on products with a controlled life cycle and reduced environmental impact.

The use of regionally sourced materials is one of the most effective ways to reduce transport-related emissions and support domestic industry.

When assembling footwear, it is recommended to:

Prioritise local suppliers of certified cork, textiles and leather

Work with national component manufacturers (adhesives, insoles, laces) that adopt environmental practices and provide compliance documentation

Establish long-term partnerships, promoting a sustainable and integrated production chain

5.4 Chemical Safety

- Compliance with restricted substances
- Innovations in green chemistry

Compliance with restricted substances is one of the pillars of sustainability and safety in footwear production. This principle ensures that manufactured products comply with environmental legislation, protect the health of workers and consumers, and maintain the company's reputation in the international market.

In footwear assembly, the use of glues, solvents, and other chemical products is common. Many of these materials may contain regulated substances due to their toxic or polluting potential.

Compliance with lists of restricted substances (such as the European REACH regulation, the RoHS Directive, or international brand requirements) is essential to ensure that no component or final product contains prohibited compounds in quantities above legal limits.

Compliance also reinforces the company's commitment to sustainability, ensuring a safer working environment and reducing the environmental impact of production.

Good Practices in Assembly: to ensure compliance with these restrictions, it is essential that assembly operators and production managers follow good daily practices:

Use only products approved by the company, with updated and certified safety data sheets (SDS)

Store adhesives, solvents, and lubricants correctly in ventilated, identified, and properly segregated areas

Avoid mixing materials or products from unknown suppliers, even in small quantities

Wear appropriate personal protective equipment (PPE), such as gloves, masks, and safety glasses, when applying chemicals

Record any incidents or unusual odours that may indicate the misuse of non-compliant substances

Collaborate with quality control, allowing for the collection of samples and periodic checks of materials

Sustainability in the footwear industry is increasingly based on the integration of responsible chemical management practices and the implementation of technologies based on the principles of green chemistry. In the assembly phase — a critical stage of the production process where adhesives, primers, solvents and finishes are applied — chemical safety must be ensured through strict control of substances, optimisation of formulations and mitigation of occupational and environmental risks.

Compliance with regulatory and legal requirements is essential to ensure the use of properly registered, classified and labelled substances.

It is recommended that compounds classified as CMR (carcinogenic, mutagenic or toxic to reproduction) be systematically replaced by less hazardous alternatives, in line with the lists of Substances of Very High Concern (SVHC).

Innovations in green chemistry have enabled the development of safer and more environmentally compatible technical solutions. Noteworthy examples include water-based adhesives and glues, solvent-free polyurethanes, and derivatives of bio-based raw materials, which significantly reduce emissions of volatile organic compounds (VOCs) and improve the working environment.

At the operational level, the application of life cycle assessment (LCA) and chemical risk analysis methodologies allows for the objective quantification of environmental and occupational impacts, facilitating decision-making in the selection of formulations and assembly technologies. Investment in efficient ventilation systems, ongoing training for operators and regular monitoring of exposure to organic vapours, complements this integrated approach to chemical safety and sustainability.

5.5 Social Responsibility

- Fair labour practices
- Community engagement and diversity, equity and inclusion

Sustainability in the footwear industry is not limited to environmental efficiency or resource management — it also includes, essentially, a commitment to social responsibility and the promotion of fair labour practices. The footwear assembly stage, which is often labour-intensive,

requires solid policies that guarantee decent working conditions, safety and the well-being of employees.

Socially responsible companies adopt labour standards and codes of conduct in line with international conventions, such as those of the International Labour Organisation (ILO), ensuring the prohibition of child labour, forced labour and any form of discrimination. Strict compliance with national and European labour legislation must be complemented by social auditing systems and anonymous reporting mechanisms, which reinforce transparency and institutional accountability.

In the production context, it is essential to invest in adequate ergonomic conditions on assembly lines, preventing musculoskeletal injuries and reducing absenteeism. Occupational risk management should be integrated into an Occupational Health and Safety (OHS) System in accordance with ISO 45001, including periodic assessment of workstations, safety training and implementation of corrective measures.

Corporate sustainability in the footwear sector depends not only on production and environmental efficiency, but also on the positive social impact that companies generate in the communities where they operate. Active community engagement and the promotion of diversity, equity and inclusion (DEI) practices are essential components of a consolidated social responsibility strategy.

In the footwear manufacturing, these themes should be integrated into the work and community engagement, and may be reflected in the following indicators:

Promote gender representation: gender equality in the company and the presence of women in management positions

Commit with community local hiring rate indicates the company's contribution to the local economy and employment

Hire employees with disabilities or special needs: assesses the degree of inclusion and workplace accessibility

Organise a sufficient number of diversity and inclusion training courses held per year which demonstrates the company's commitment to internal awareness and the development of inclusive practices

Measure employee satisfaction index that could be obtained through internal surveys and meetings, on working conditions, recognition and sense of belonging

When analysed together, these indicators provide an integrated view of the footwear company's human and social impact, supporting the definition of continuous improvement policies. Their publication in sustainability reports reinforces the organisation's credibility, transparency and commitment to a fair, inclusive and participatory value chain.

6 Digitalisation in Assembly

The use of digital technology in the assembly represents a decisive step forward in the modernisation of one of the industry's most critical processes. Traditionally reliant on the manual dexterity and experience of operators, this process demands high levels of precision, consistency and control over variables such as the amount of adhesive, drying time and the pressure applied. The introduction of digital technologies makes it possible to transform these operations, making them more reliable, efficient and repeatable.

By using automated systems and smart sensors, it is possible to monitor and control key bonding parameters in real time. The application of adhesives can be adjusted with high precision, reducing waste and ensuring even distribution. At the same time, digitisation facilitates process traceability, enabling the recording of relevant data for each pair produced, which contributes to more rigorous quality control and a faster response to any non-conformities.

6.1 A New Era of Robots



Fig. 20: Shoe assembly robot – Credit: <https://serma.net/noticias/ferias/fimec/fimec-ratifico-el-buen-momento-de-brasil>

Historically, shoe assembly has relied on a high degree of human manual dexterity due to the malleable nature of the materials (natural leathers, fabrics, synthetics). The new generation of robots overcomes this limitation by combining 3D computer vision with haptic force sensors, enabling the machines to 'see' and 'feel' the shoe during the manufacturing process.

Integrating technologies that enable the exchange of information, working on the machine's software and technical features, allows the robot's programming and process. Example of this situation is the use of a simulator which detects the presence of the shoe, activates the robot that feeds the machine, and sends the necessary signals so that the machine has the information it needs to decide and select the appropriate setting.

The bonding of soles, a critical operation for the quality and durability of the final product, requires strict control of variables such as adhesive application, curing times and the pressure applied during the joining of components. Traditionally reliant on the experience of operators, this process is now becoming more consistent and predictable with the integration of robots equipped with vision systems, sensors and advanced software.

In short, modernisation of assembly lines does not render traditional know-how obsolete; on the contrary, it safeguards and enhances it. Operators' skills have evolved from manual tasks to the management of complex systems, placing production units at the forefront of Industry 5.0. Mastery of these robotic tools, detailed throughout this manual, is the key to efficient, safe production that is ready for the challenges of the future.

6.2 Artificial Intelligence

- Text generation and translation systems
- Quality control

Text generation and translation systems, based on natural language processing technologies, play a key role in the digitalisation of industrial processes, enabling the creation, adaptation and dissemination of technical information. In the context of assembly, these systems help to improve communication, standardise procedures and enhance operational efficiency throughout the production chain.

In the context of the digital transformation of the footwear industry, image editing tools are playing an increasingly important role, particularly in critical processes such as sole bonding. Although traditionally associated with fields such as design or marketing, these tools are now key components in machine vision and quality control systems, contributing directly to production efficiency and accuracy.

Shoe assembly involves a series of sequential and detailed operations, process sheets and supporting documentation. Traditionally, this information is prepared manually and may contain linguistic variations or inconsistencies that make it difficult to interpret, particularly in environments with multicultural teams.

The introduction of automated text generation systems makes it possible to create clear, consistent instructions tailored to different user profiles, based on structured data from the production process.

Integrating these systems with digital platforms, such as manufacturing execution systems or document management systems, enables instructions to be updated automatically whenever changes are made to the process, materials or footwear designs. This ensures that the information available at the workstation is always up to date and in line with production requirements.

The adoption of these systems also contributes to the training and upskilling of operators, providing explanatory content, step-by-step instructions and real-time contextual support. This makes it easier to learn new processes and adapt to different shoe models, thereby increasing the flexibility and productivity of the assembly line.

In short, text generation and translation systems represent a strategic tool in the digitalisation of assembly, promoting the standardisation of information, efficient communication and process integration within an increasingly global and digital industrial environment.

6.3 Big Data

Data-driven decision-making

Data-driven decision-making is one of the cornerstones of industrial digitalisation, enabling organisations to replace intuitive approaches with objective, evidence-based analysis. In the context of footwear assembly, this approach is particularly important, given the large number of variables involved in the process and their direct impact on the quality of the final product and production efficiency.

The digitisation of assembly operations enables the systematic collection of data from various sources, such as manufacturing execution systems (MES), sensors fitted to equipment, operational time records, quality indicators and operator feedback. When properly structured and analysed, this data provides a detailed insight into the performance of the production process.

The use of data analysis tools makes it possible to identify patterns, trends and deviations in the assembly process. For example, it is possible to detect variations in the execution times of certain operations, identify workstations with a higher incidence of defects, or analyse the relationship between certain materials and the quality of the assembly. This information supports more informed decisions, such as optimising the sequence of operations, reallocating resources or reviewing process parameters.

In addition, the implementation of real-time dashboards and key performance indicators (KPIs) enables production managers to continuously monitor the status of the assembly line. This visibility facilitates immediate decision-making in the event of deviations, reducing response times and minimising the impact on production.

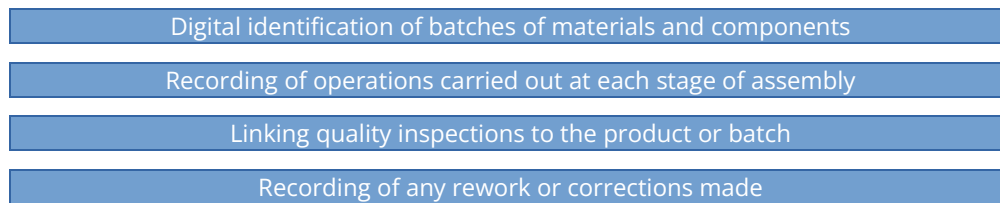
Predictive analytics is another key element in this context. By applying statistical models and machine learning algorithms, it is possible to anticipate problems such as equipment failures, production delays or assembly non-conformities. This capability enables proactive, evidence-based action, contributing to continuous process improvement.

Finally, the adoption of a data-driven organisational culture is crucial to the success of this approach. This involves empowering staff to interpret analytical data, promoting the systematic use of data in decision-making, and integrating these practices into production management processes.

Traceability

Traceability is a key element in modern production management, enabling the tracking and recording of the movement of materials, components and products throughout the entire production process. In the context of the digitalisation of the footwear industry, traceability takes on an even more important role, as digital systems allow information to be collected, stored and analysed in a structured and accessible manner.

During the footwear assembly phase, traceability makes it possible to accurately identify the production stages each product has gone through, the materials used and the results of the quality checks carried out. Various components are combined to form the final product, such as the upper, the insole, the sole and other structural elements. Digital traceability makes it possible to link each of these components to the final product via electronic records. In practice, this may involve:



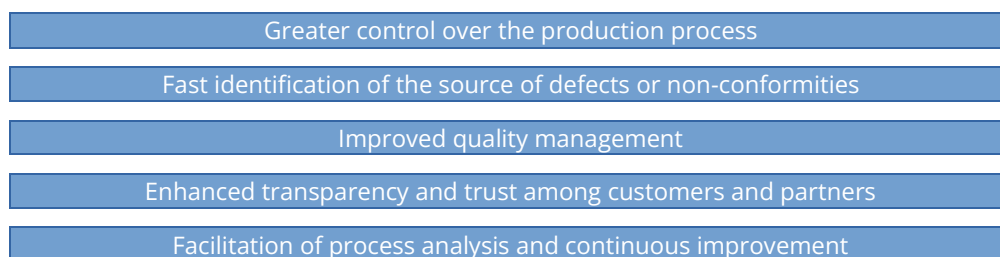
This information enables the product's journey to be tracked from the receipt of materials through to the completion of assembly.

Traceability support technologies allow the implementation of digital traceability systems may utilise various technologies, such as:

- barcodes or QR codes for identifying components and products;
- digital tags or electronic identification systems;
- production management systems, which centralise and organise the data collected;
- digital monitoring platforms, which record events and operations along the assembly line.

These technologies ensure that relevant information is recorded consistently and is easily accessible.

Digital traceability in footwear assembly offers a number of advantages for businesses, including:



Traceability is therefore an essential component of industrial digitalisation, enabling companies in the footwear sector to manage information relating to their assembly processes more efficiently and to ensure high standards of quality and reliability in production.

6.4 3D Printing

- Plastics; metals

The integration of digital technologies into the footwear sector is transforming traditional craft processes into high-precision workflows. Additive manufacturing (3D printing) does not replace traditional craftsmanship, but acts as an essential complement to innovation and customisation.

During the assembly phase, 3D printing (particularly material extrusion) is used to rapidly produce critical components:

- **Assembly Moulds:** Printing of customised moulds that serve as supports for moulding the uppers;
- **Functional Components:** Production of modular heels, soles with complex geometries and custom orthopaedic insoles that would be impossible to manufacture using standard injection moulding methods;
- **Support Tools:** Creation of specific guides and supports for assembly machines, optimising the fit of the upper to the last.

Strategic Benefits

The adoption of these technologies, promoted by organisations such as APICCAPS, offers clear competitive advantages:

- **Waste Reduction:** On-demand production that uses only the materials strictly necessary;
- **Agility:** A dramatic acceleration in product development, enabling new collections to be brought to market in record time;
- **Customisation:** The ability to produce shoes tailored to the specific anatomy of each end customer.



Fig. 21: Insole 3D printed by – Credit: Solidator



Fig. 22: Sole 3D printed – Credit: Solidator

6.5 The Convergence of Digitalisation and Science

- **Internet of Things (IoT)**

The integration of the Internet of Things (IoT) into assembly represents the convergence of ubiquitous digitalisation with computer science and sensor technology. Through a network of interconnected smart devices and sensors, the factory floor is transformed from a collection of isolated machines into a digital ecosystem that monitors, in real time, the physical and chemical variables critical to the quality of the shoe.

IoT sensors also monitor drying tunnels, reactivation stations, and the vibration and energy consumption used in presses and roughing machines. Data on relative humidity and precise temperature are transmitted, ensuring that the chemical bonding between the sole and the upper takes place under ideal laboratory conditions. The combination of digital connectivity with the precision of scientific sensors helps to reduce energy consumption and adhesive waste, ensuring that every pair of shoes is produced with a minimal environmental footprint and maximum technical compliance.

Smart tags and proximity sensors track each component (upper, sole, insole) along the production line. By digitising this process, the system can instantly detect if a material with incompatible physical properties is about to be assembled, thereby halting the operation and allowing an active component traceability.

The IoT also enables assembly lines to 'report' their productivity. If work flow analysis indicates a delay at a manual sewing station, the digital system automatically redistributes the flow of components to prevent line stoppages. It transforms the assembly process into a transparent and auditable one. This continuous data collection prevents millimetre-level deviations in assembly that could compromise the ergonomics of the footwear.

6.6 Virtual Reality and Augmented Reality on the Assembly Line

Virtual Reality (VR) creates a fully immersive environment, allowing users to interact with a digital setting without any physical risks or material waste. Unlike VR, Augmented Reality (AR) superimposes digital information onto the real world, making it particularly useful when carrying out manual and maintenance tasks.

Virtual Reality (VR)

- **Operator Training:** It enables training on complex machinery (such as nozzle assembly machines or robotic roughing machines) in a safe environment, before moving on to the actual production line;
- **Virtual prototyping:** Before physical production begins, designers and assembly technicians can analyse the shoe's dimensions and fit using an immersive 3D model, identifying any potential design flaws.

Augmented Reality (AR)

- **Real-time Assembly Instructions:** Using smart glasses or tablets, the operator receives visual guides superimposed onto the physical part, indicating, for example, the exact points where adhesive should be applied or the correct positioning of the trim on the last;
- **Assisted Maintenance:** In the event of a fault with an assembly machine, AR enables a remote technician to send step-by-step visual instructions directly into the local operator's field of view, speeding up repairs and minimising downtime;
- **Quality Control:** Immediate visual comparison between the finished product and the standard digital template using image overlay, making it easier to identify technical deviations.

7 Case study and Project work

7.1 Case study of a training model

Case Study – Traditional versus Modern Footwear Assembly at CFPIC

The Footwear Industry Vocational Training Centre (CFPIC) was established under a memorandum of understanding signed on 23 December 1965 in Portugal and began operations in January 1966. Its mission is to provide specialised technical training, which is essential to the development of the footwear industry and the progress of the national economy.

With the aim of responding swiftly and effectively to the industry's needs in terms of professional qualifications, the CFPIC actively contributes to strengthening the Portuguese business sector. To this end, it focuses on developing the skills and knowledge of its workforce, using innovative methodologies and state-of-the-art equipment in the training areas in which it operates.

In this regard, assembly is one of the most crucial stages in the footwear manufacturing process, directly influencing the quality, comfort, durability and final appearance of the product. Over the last few decades, technological advances in the footwear industry have led to the development of new equipment, materials and production methods, enabling traditional and modern assembly processes to coexist, each with its own specific characteristics, advantages and limitations.

Traditional assembly is characterised by a high proportion of manual work, requiring a high level of technical skill and experience on the part of the operators. This method allows for greater control over the shaping of the upper to the last and is frequently used in the manufacture of high-quality footwear, limited editions or models that require a more meticulous finish.

On the other hand, modern assembly relies on the use of automated equipment and technologically advanced systems, designed to increase productivity, ensure greater repeatability of operations and reduce the variability inherent in manual processes. Automation makes it possible to optimise manufacturing times, improve production efficiency and ensure consistent quality, making it a particularly suitable solution for medium- and large-scale production.

This model was selected for the case study because it is a model designed for and used in training. It is carried out entirely by trainees across various stages, such as cutting, pre-sewing preparation, sewing, assembly and finishing. The aim of this study is to highlight the traditional methods used and the improvements implemented in relation to the three areas covered by this manual.

	Technical Data Sheet	Model: Aveiro Ref: 39786 Date: 30/07/2026
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Assembly

N°	Operations	Resources	Materials	Notes
1	Apply adhesive, position and mould the counter reinforcements	Manual/Brush Reactivator Counter moulding machine	Solvent-based adhesive Fabric in cotton or nonwoven	2 to 3mm from topline + -10mm from the edge
2	Apply adhesive, position the toe puff reinforcement	Manual/Brush Reactivator	Solvent-based adhesive	+ - 10mm from the edge
3	Apply adhesive, glue the lining and mould toe puff	Manual/Brush Toe puff moulding machine	Solvent-based adhesive with 1 component	Temperature + - 100°C
4	Attach insole	Stapler machine	Staples	Distance from toe cap + - 2cm
5	Trim insole	Trim machine	-----	From 0,5 to 1mm within the edge of the last
6	Apply adhesive at the edge of the upper and insole	Manual/Brush	Solvent-based adhesive with 1 component	Apply + - 10mm from the edge Drying time + -10min.
7	Humidify and lasting the toe caps	Humidifier Toe cap lasting machine	-----	All toe caps should have the same length
8	Adjust the height of the counter	Manual/ Steel ruler	-----	Height of counter = $\text{Size} \times \frac{4}{3} + 8$
9	Reactivate, close the side seams and heel counters	Reactivator Machine for assembling side seams and counters	-----	Set the temperature according to the technical specifications
10	Remove staples	Manual/Lasting pincer	-----	Ensure that all staples are removed

Revised Technical Data Sheet

Assembly

Nº	Operations	Resources	Materials	Notes
1	Position and mould counters	Counter moulding machine	Thermoadhesive fabric based in nonwoven	2 to 3mm from topline + -10mm from the edge
2	Position and heat-press toe puffs	Heat-pressing machine	Thermoadhesive toe puffs	+ - 10mm from the edge
3	Glue the lining and mould toe puffs	Adhesive application robot Toe cap moulding machine	Water-based adhesive	Moulding machine with temperature + - 100°C
4	Attach insole	Tape application machine	Self-adhesive paper tape with 15 mm width	Apply + - 2cm from toe cap
5	Apply adhesive at the edge of the upper and insole	Adhesive application robot	Water-based adhesive	Apply + - 10mm from the edge
6	Moisten and assembler toe cap	Humidifier Toe and forepart lasting machine	-----	All toe caps should have the same length
7	Adjust height of the counter	Manual/ Steel ruler	-----	Height of counter = $\text{Size} \times \frac{4}{3} + 8$
8	Reactivate, close the side seams and heel counters	Reactivator Machine for assembling side and counters	-----	Check that the shoe fits the last properly

7.2 Structure of an assembling exercise

Practical Exercise – Assembly

Objective

To carry out basic footwear assembly operations, applying correct technical procedures and considering the principles of sustainability, industrial digitalisation and the demands of the global market.

Context

The footwear industry currently faces new challenges relating to:

- Reducing its environmental impact;
- The use of digital technologies in production processes;
- Competitiveness in international markets.
- During the assembly phase, operators must ensure quality, precision, efficiency and compliance with technical and environmental standards.

Practical Assignment – Situation

The trainee has been tasked with assembling a model of a sustainable casual shoe for export. The model has the following characteristics:

- The upper is made from recycled materials;
- Wherever possible, use water-based glue;
- Use digital production monitoring via barcode;
- Comply with the quality requirements defined for national and international markets.

Materials Required

- Prepared upper;
- Last;
- Reinforcements;
- Insole;
- Water-based adhesive;
- Assembly tools and equipment;
- Personal and collective protective equipment;
- Digital device for recording the process.

1. Preparing the Workstation

Organise the materials and tools;

Carry out the necessary adjustments for the operations;

Check the condition of the equipment;

Wear personal and collective protective equipment (where necessary);

Check the model's digital technical data sheet.

2. Assembly Operations

Carry out the following operations:

a) Preparation of the upper:

- Initial quality control of the sewn upper and check the conformity of the materials to be used;
- Check the size of the upper and the insole against the sample;
- Apply the assembly reinforcements in the upper (heel counter and toe cap);
- Shape the toe cap and heel counter.

b) Fitting the upper to the insole and last

- Secure the insole to the last;
- Moisten the prepared upper (toe area);
- Toe cap assembly;

- Reactivate the side and seat areas (to make them pliable);
- Side and seat assembly.

c) Quality Control

- Check the various symmetries, bonding and sealing of the assembled upper, as well as the quarter height and positioning on the last;
- Identify any nonconformities;
- Make the necessary corrections.

Sustainability

Whilst carrying out the work, the trainee must:

- Organise the workstations involved in the operations;
- Minimise waste of adhesive and other materials;
- Separate waste for recycling;
- Use resources efficiently;
- Keep the workstation clean and tidy.

Digitalisation

The trainee must:

- Consult the technical data sheet in digital format;
- Use the digital traceability system;
- Record times and operations carried out.

Globalisation

Assume that the product will be exported. The trainee must ensure:

- The quality requirements defined by the verification sample;
- Compliance with the model's technical specifications.

Assessment Criteria

Workstation setup;

Technical execution of the assembly;

Quality of the operations carried out;

Compliance with safety standards;

Application of sustainable practices;

Correct use of digital systems;

Organisation and cleanliness of workstations.

Final Reflection:

After completing the activity, answer the following:

What difficulties did you find during assembly?

How can digitalisation improve production efficiency?

What are the advantages of using sustainable materials in the footwear sector?

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