Innovative Skills for an Old Vocation

Innovative Skills for

Technical Development

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 to teach 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 Overview of the Technical Development

In order to consolidate the understanding of a department foreman in the shoe industry for the "technical development" of the shoe models and to point out and understand the importance of technical development in the course of the production process and in order to also solve any problems, every foreman should already have a basic knowledge of technical shoe model development. Through their increasing understanding of workflows and processes, they acquire the ability to adapt to or introduce changes in methods and systems in design and production, new structures in work organisation and new requirements in organisational development, and to help shape technical or organisational change in the company.

The department supervisor must internalise the knowledge of the structure of a basic model and understand the designs.

The foundation for the pattern making of the basic model is laid in the last copy. Built on that last copy the technical "model" is developed.

The prospective master in the shoe industry will practice this process in the same way as a trainee in the shoe industry (compare ICSAS project).

The subsequent fit of the upper parts in production also depends to a large extent on this work process.

After the creative department/designers, have drawn their ideas on paper or on so-called "plastic cover", a last copy is made, which brings the last from its 3-dimensional state into a processable 2-dimensional template. The tape copy with adhesive tape has the advantage that a model can be drawn directly and the proportions are immediately visible.

Fig. 1: Last and taped last for last copy © PFI

2.1.1 Upper development

A model design is broken down into producible parts and production instructions are created for them. The technical modellers (employees) in this department work closely with the designers to ensure an efficient, producible production process. A model design is created in a medium size, e.g. for women's shoes in size UK-4 ½.

1. Step 1 is to create a basic model - depending on the type of construction with allowances for the lasting edge in case of cemented or Strobel construction.
2. Step 2 is the detailing, the breaking down of the basic model into the individual cutting templates with allowances such as folded edges, closing seams, under edges, reductions, preliminary drawings and various markings for eyelets, rivets, etc. This method of working is usually created digitally using a CAD systems. The data is then transferred to the cutting table.

Fig. 2: Basic model for cutting templates © PFI

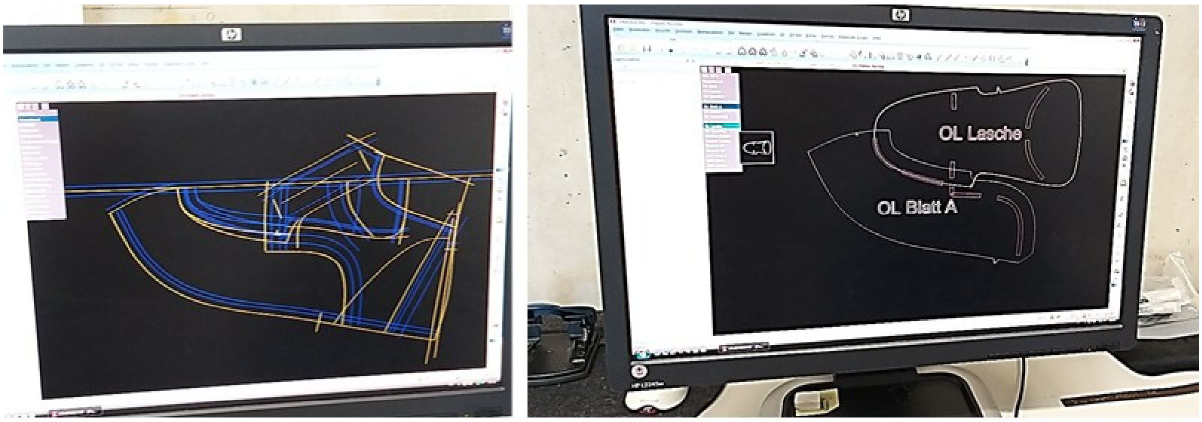

Fig. 3: Cutting template for individual parts in the CAD system © PFI

3. Step 3 occurs at the cutting table where the cut for the upper leather, lining leather, and reinforcing materials is made.

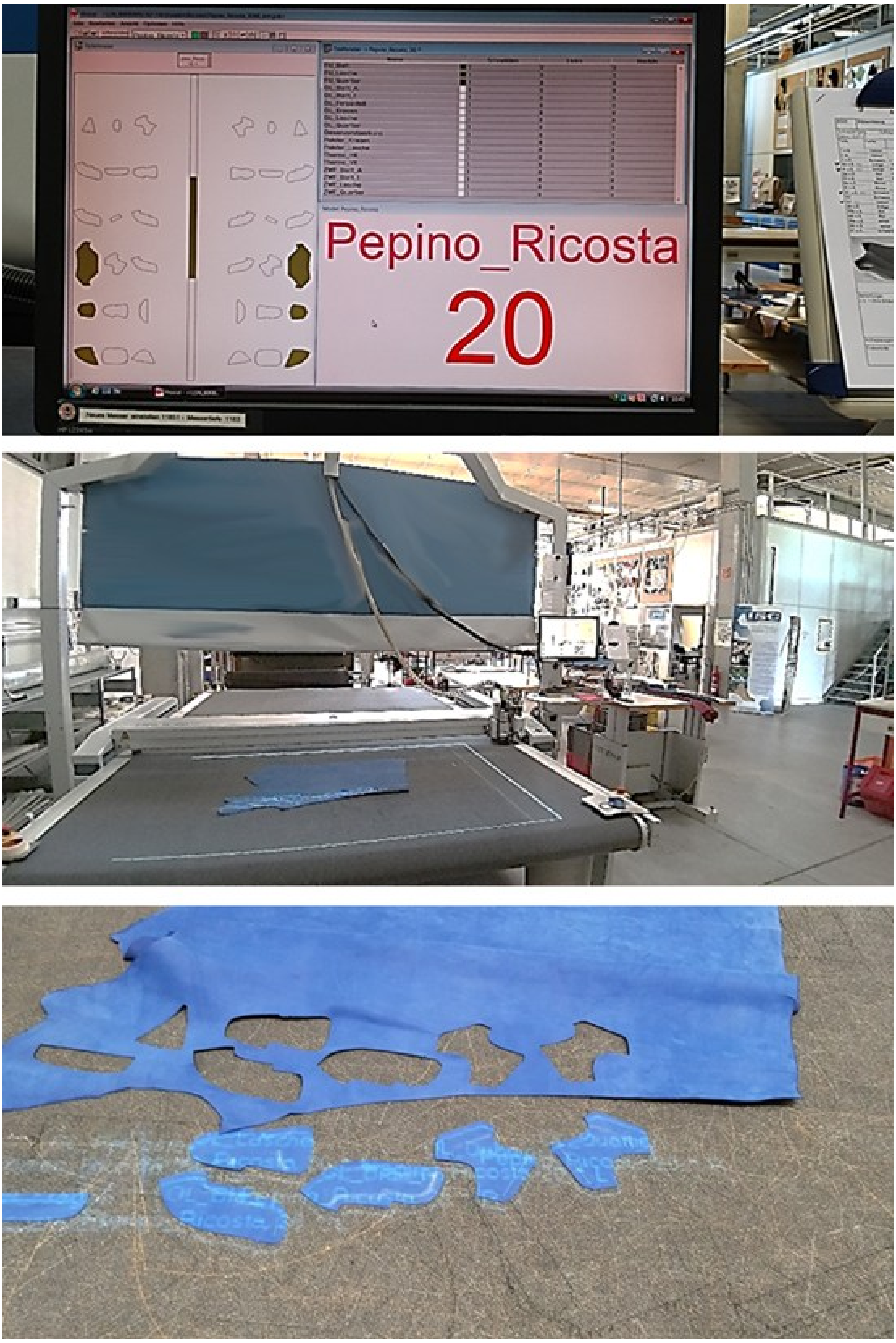

Fig. 4: Automatic cutting table © PFI


Fig. 5: Assembled pieces © PFI

If a model design is included in the collection, the duplication into the assortment sizes must be created - the so-called grading - i.e. the model design must be created proportionally smaller and larger in length and width. The grading is often done in the technical department. Together with the plant manager, the department supervisor is also involved in creation of the work flow charts of each model. They must determine the optimal and most efficient work flow for the sample model and for the subsequent production.

Another important aspect is the choice of reinforcement materials in a shoe / upper model - depending on different upper materials, the plant manager and supervisor will determine the respective reinforcement material. These decisions will have a decisive influence on the production process, with the corresponding machinery and know-how of the production staff.

Not only the designs / upper parts are created and developed by the creative department, but also the outsole design and heel design complete a shoe model. This is usually done in the same department, but by different employees.

2.1.2 Bottom development

This department is responsible for transforming the creative ideas into physical objects - i.e. prototyping outsoles or heels and all additional bottom components (insoles, cover soles, inlay insoles, heel covers, wedges and cover patches.

The outsoles and heels, wedges

According to a design template, a construction is created on the CAD which, e.g. for a moulded sole made of PU or rubber, already has the correct dimensions for the corresponding injection mould. The first model cast is called a " Maquette " (Italian). After this cast, the appearance and proportions are examined, possibly revised and further processed for series production.

The insoles

The insoles are made according to the type of construction and the heel cracks. There are often standard specifications for this, such as the insole material thickness (Texon), steel joints, or reinforced panels, to be milled at specific angles.

The cover soles, footbeds

Shock absorbers are also developed in this department. These bottom parts are then made ready for series production.

Both developments - upper design and bottom design are worked out in CAD systems

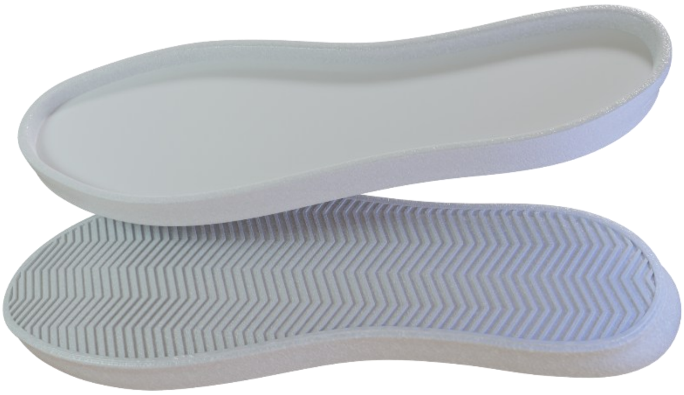

Fig. 6: CAD Outsole rendering © PFI

Production readiness

For the production readiness these bottom parts are also graded and again processed in the respective departments by technical designers.

After the sample development of the bottom parts, e.g. outsoles, heels, etc. in the sample sizes (for women's shoes 4 ½ or 37, for men's shoes 7 ½ or 41), the so-called group sizes are graded - i.e. separate samples are sent through all departments of the company before the actual production. These group sizes - small, medium, large - are the dress rehearsal for series production to ensure the correct proportions of the finished upper/shoe and to correct any errors or discrepancies. The department foremen are significantly involved in this phase/work process. The department foremen help to decide on an efficient work sequence and may also give the designers advice on how to optimise production.

Usually, at least the group sizes pass through the company for each new bottom group. In a fashion-oriented company, this can mean 20 or more new bottom groups.

The industrial and department supervisors are in close contact with the responsible staff in the technical development department and closely monitor the accuracy of fit of the upper and lower parts and their progress over time, which in turn is important for production planning.

3 Globalisation in Footwear Technical Development

Key principle

Globalisation in footwear technical development refers to the expanding geographic distribution of design studios, material suppliers, manufacturing partners, and consumer markets — and the technical, organisational, and regulatory complexity that this distribution creates for the product developer. It amplifies the technical workload by multiplying the number of contexts in which a single specification must perform.

The growing interconnectedness of various economic sectors, including markets, production networks, and labour, and the associated technologies and governmental regulations on an international scale, has given rise to what is commonly referred to as "globalisation". In terms of design, manufacturing, movement, education, and compliance systems, the footwear industry has been impacted by globalisation, which offers opportunities to develop new methods.

This geographic distribution has direct consequences for how footwear products are technically developed: specifications must be legible across different factory contexts, materials must be sourced and validated across multiple supply chains, and compliance requirements must be managed across divergent regulatory environments — all within commercial development timelines.

Footwear industry global production statistics for 2022[1]:

- Asia: 87.4% of world footwear production
- South America: 4.8%
- Africa: 3.7%
- Europe: 2.7%
- North America: 1.4%

According to the APICCAPS World Footwear Yearbook 2025[2], global footwear production reached 23.9 billion pairs in 2024, and Asia accounted for 88% of global production.

That means nearly 9 out of 10 pairs of shoes worldwide are manufactured in Asia, while **Europe** accounts for a relatively small share of total volume but **remains important in technical development, premium footwear, prototyping, and high-value production**.

3.1 Markets and consumers

Market and consumer diversity across a global product distribution network is the principal driver of **specification complexity** in footwear technical development. The same product must meet **different regulatory requirements**, **satisfy different aesthetic preferences**, and a**ddress different functional needs** across different markets[3,4].

[1] RunRepeat. (n.d). Footwear Production Statistics. Retrieved from: https://runrepeat.com/
[2] APICCAPS / World Footwear Yearbook 2025. Retrieved from: https://www.aplf.com/2025/
[3] World Footwear (2020). Footwear Consumer 2030 Global Trends. Retrieved from: https://www.worldfootwear.com/media/wf_uploads/wf20191132716572.pdf
[4] Munguía Romero, M. J., Kapsali, V., Wang, L., & Busfield, J. J. C. (2025). An analysis of sustainability and performance indicators in Eco-Conscious trainers' brands. Sci Rep.

Shifts in consumption toward **casualisation, functional performance, and lifestyle positioning** are blurring traditional product category boundaries in footwear. Products that were once clearly athletic, casual, or formal now frequently combine construction and material characteristics from multiple categories[5,6,7]. This hybridisation creates **technical development challenges**: a hybrid product may need to meet performance standards from multiple categories simultaneously, requiring a testing regime that has not previously been applied to this construction type. The technical developer must actively define the relevant test standard matrix for hybrid products, rather than defaulting to a single category's requirements (Footwear Design Strategies, 2020[8]).

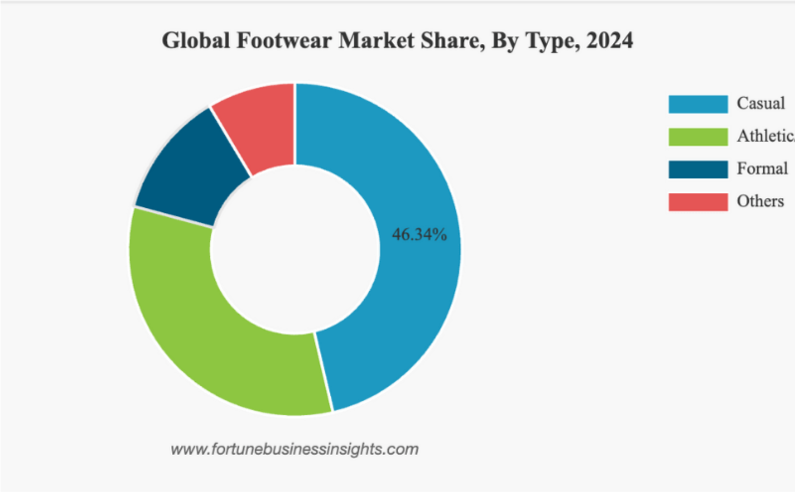

Fig. 7: Global footwear market share for 2024. Source: https://www.worldfootwear.com/media/wf_uploads/wf20191132716572.pdf

3.2 Economic and social factors

Globalisation both **supports growth** and **creates social tensions in the footwear sector**. The geographical shift in footwear manufacturing to lower-labour-cost locations, driven by Global Value Chains (GVCs), has altered how firms organise themselves to attain competitive advantage in terms of cost and value (Roza et al., 2011[9]). By using **offshore and domestic sources** to produce footwear, firms can create **additional value** and respond to changing consumer demands in real time.

Economic and social changes at the global level create the most immediate and disruptive pressures on footwear product technical development, because they can force **material substitutions, factory changes,** and **supply chain restructuring** in the middle of a development programme.

[5] Shukla, M., & Misra, R. (2021). Online footwear sales: Drivers and challenges with a perspective of emerging markets. International Journal of E-Business Research, 17(4), 1–22. https://doi.org/10.4018/IJEBR.2021100105
[6] World Footwear. (2020). Footwear Consumer 2030 Global Trends. Retrieved from: https://www.worldfootwear.com/media/wf_uploads/wf20191132716572.pdf
[7] Munguía Romero, M. J., Kapsali, V., Wang, L., & Busfield, J. J. C. (2025). An analysis of sustainability and performance indicators in Eco-Conscious trainers' brands. Sci Rep.
[8] Adulyanukosol, A., & Silpcharu, T. (2020). Footwear design strategies for the Thai footwear industry to be excellent in the world market. Journal of Open Innovation: Technology, Market, and Complexity, 6(1), 5. https://doi.org/10.3390/joitmc6010005
[9] Roza, M., Van den Bosch, F. A. J., & Volberda, H. W. (2011). Offshoring strategy: Motives, functions, locations, and governance modes of small, medium-sized and large firms. International Business Review, 20(3), 314–323. https://doi.org/10.1016/j.ibusrev.2011.02.002

Geopolitical tensions, trade conflicts, and supply chain disruptions — with the COVID-19 pandemic, US-China trade tariffs, and regional conflicts as the most impactful recent examples — can force **mid-development substitution** of **specified materials or components** when planned supply routes are disrupted. The technical developer must **maintain pre-qualified alternative materials** for critical Bill of Materials (BOM) components so that supply chain disruptions can be absorbed without restarting the development programme. Building supply resilience into the specification strategy — through dual-qualified materials and multi-sourced components — is a technical development risk management practice.

The **relocation of footwear production** is an ongoing process that technical developers must continually navigate. Each production relocation requires **re-qualification of the construction specification** at the new factory. The same construction may perform differently across different equipment, workforce experience levels, and climatic conditions (affecting adhesive open times, moisture behaviour, and cure rates).

3.3 Demography

The ageing population in developed markets has driven product specifications focused on **comfort, durability, and medical technologies** in the footwear industry. The young population in emerging economies has driven a **fashion-focused approach**, alongside the rapid adoption of **digital technologies**.

Additionally, **foot morphology** varies meaningfully among consumer populations across regions. Data from foot-scanning studies show differences in width, instep height, toe box volume, and arch profile among Asian, European, and North American populations. A **product developed for global distribution**, therefore requires either **a compromise last geometry** validated across populations, or **market-specific last variants** — both of which multiply the technical development workload for the same style.

3.4 Compliance

Footwear companies are subject to many regulations and standards regarding the quality, safety, and workplace practices of their footwear, as well as the environmental impact of those products. Demonstrating compliance with various certification standards and audits is becoming increasingly global. As a result, companies must **integrate compliance** into their **technical and operational processes**.

Footwear sold in different markets must comply with different safety, chemical, and performance standards. In the European Union, the **General Product Safety Regulation (GPSR), REACH chemical regulation,** and **EN ISO footwear test standards** define the minimum requirements.

For the product technical developer working on **globally distributed products**, the **compliance matrix** must be established at the brief stage rather than discovered during testing. Each material and construction choice must be evaluated against the most restrictive applicable standard in the product's target markets. Where divergent standards cannot both be met with a single specification, market-specific variants must be documented and managed as separate tech pack versions.

3.5 Supply chain and traceability

The **fragmentation of the global footwear supply chain** across multiple countries and supplier tiers creates a **traceability challenge** that is fundamentally a technical development responsibility, as it begins with the specifications in the **Bill of Materials (BOM)** (Chang, 2025[10]).

A footwear product may have its upper materials from Taiwan or Brazil, its midsole compounds from Germany or Japan, its outsole rubber from China or Thailand, its hardware from Italy, and its thread from India — before all components are assembled in Vietnam or Indonesia. Tracing each component to its **origin**, verifying the **conditions** under which it was produced, and confirming its **compliance** with applicable **chemical and social standards** requires a **supply chain documentation structure** that must be built into the BOM at the development stage.

The EU Digital Product Passport (DPP)[11] regulation, expected to come into force progressively from 2026, will require **product-level traceability data** to be **machine-readable and publicly accessible**. This will make supply chain transparency a legal requirement for products sold in the EU, not merely a brand preference. Technical developers must begin **designing BOM documentation workflows** — **supplier codes, material origin records, certification tracking** — that are compatible with the emerging DPP data structure.

From a technical development process perspective, supply chain traceability is managed through:

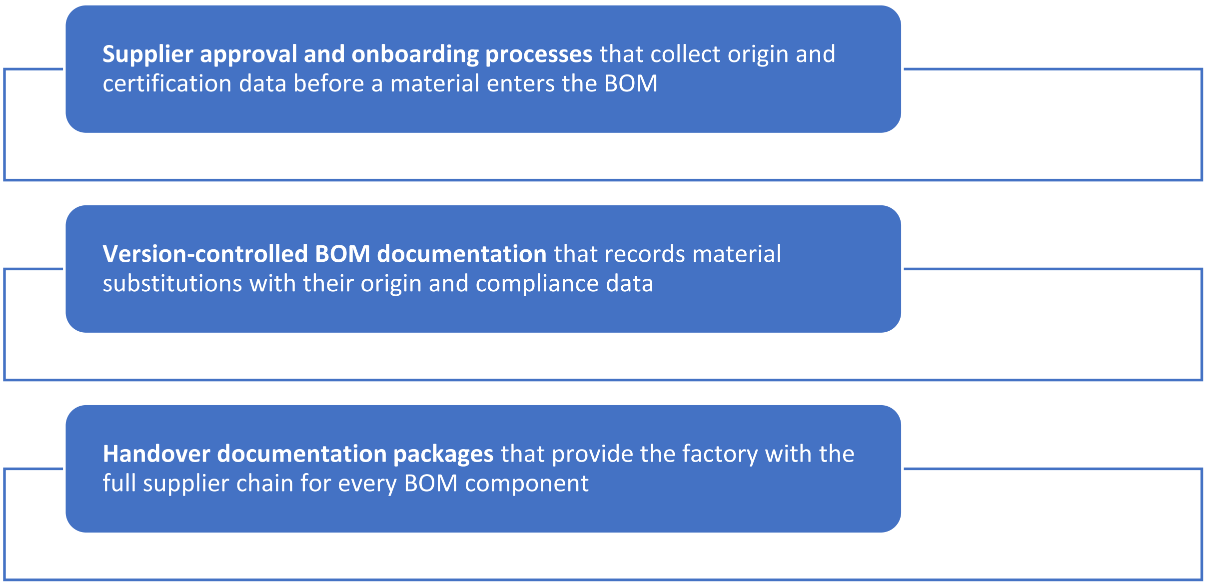

Fig. 8: Supply chain traceability in the technical development process

[10] Chang, C.-W. (2021). Supply chain movement risk in the sneaker industry: An empirical study. Qual Quant. doi:10.1007/s11135-021-01166-y

[11] European Union. (2024). EU's digital product passport: Advancing transparency and sustainability. Publications Office of the European Union. Retrieved from: https://data.europa.eu/en/news-events/news/eus-digital-product-passport-advancing-transparency-and-sustainability

4 Sustainability in Footwear Technical Development

Key principle

Footwear technical development in the context of sustainability is the intersection of **environmental, health, safety, resource efficiency, and social compliance** for manufacturers (footwear factories). Technical development sustainability is the process by which a manufacturer integrates **environmentally sound** and **responsible manufacturing practices** (the 'green') into all aspects of manufacturing.

4.1 Green awareness

Research shows that the footwear industry is among the most environmentally impactful sectors due to its intensive resource consumption, reliance on synthetic materials, and waste generation. Therefore, sustainable footwear development focuses on reducing the environmental impact of shoe production through **biodegradable materials**, **recyclable components**, **digital prototyping**, and **responsible manufacturing systems** (Andrade et al., 2024[12]; Martawidjaja et al., 2025[13]).

Sustainability progress in footwear technical development is accelerated by **industry partnerships** — collaborative frameworks that develop **shared tools, standards, and verification systems**. The **Higg Index** (Sustainable Apparel Coalition[14]), the **ZDHC Foundation**[15], the **Leather Working Group**[16], and the **Zero Carbon Forum** [17], produce **technical standards and measurement tools** that directly affect how products are developed and specified.

For the technical developer, these partnerships translate into **mandatory reference frameworks** (Fig. 9).

Fig. 9: Industry partnerships and collaborative sustainability frameworks supporting footwear technical development

[12] Andrade, B., Dos Santos, A., & Broega, A. C. (2024). From material to socio-technical innovations: A meta-scenario proposition for footwear sustainability. In Springer Series in Design and Innovation. Springer. https://doi.org/10.1007/978-3-031-53122-4_32

[13] Martawidjaja, M., Chainando, N., Simarmata, T., Harito, C.. (2025). The current development of sustainable materials for a greener footwear industry: A Review. IOP Conference Series: Earth and Environmental Science. 1488. 012008. 10.1088/1755-1315/1488/1/012008.

[14] Worldly. (n.d.). Higg Index. Retrieved from: https://worldly.io/tools/higg-index/

[15] ZDHC Foundation. (n.d.). ZDHC Foundation. Retrieved from: https://www.zdhc.org/

[16]Leather Working Group. (n.d.). Leather Working Group. Retrieved from: https://www.leatherworkinggroup.com/

[17] Zero Carbon Forum. (n.d.). Zero Carbon Forum. Retrieved from: https://www.zerocarbonforum.com/

4.2 Sustainability and circular economy in footwear technical development

Sustainable design and circular economy principles are becoming essential components of modern footwear technical development. **Growing environmental concerns, resource limitations, stricter regulations,** and **changing consumer expectations** are driving the footwear industry to **rethink traditional product development** and manufacturing models. Instead of the conventional linear approach based on "take–make–dispose", footwear companies are increasingly adopting circular strategies focused on **reducing waste, extending product life, improving material efficiency**, and **enabling recycling or reuse**. Within technical development, this transformation influences every stage of the product lifecycle, including **material selection, pattern engineering, manufacturing processes, product durability, disassembly,** and **end-of-life management**.

4.2.1 Sustainability challenges associated with shoe lasts

The shoe last is a **basic tool** for both pattern making and footwear manufacturing.

The upper is spatially stretched on the last (lasting), then the sole is attached (soling) and the footwear is finally finished (finishing). By using this tool, last, the upper and the bottom patterns are designed, the working devices of some footwear industry equipment are built, and the bottom components (soles, heels, insoles, etc.) are obtained.

A shoe last is a three-dimensional mould that represents the shape and structure of the **human foot**. It is one of the most important tools in footwear production because it determines the fit, comfort, shape, and style of the final shoe product. Every type of shoe—sports shoes, formal shoes, sandals, or boots—requires a specifically designed last. Modern footwear manufacturing relies heavily on accurate **shoe last design** for mass production and customisation (Ma & Luximon, 2013[18]).

The shape and the size of the last determine the **inner shape** and **size** of the finished footwear and, therefore, its fitting. The dimensional comfort of the footwear (fitting) is determined by the accurate correspondence between the foot and the inner space of the footwear (Costea & Mihai, 2016[19]).

The lasts used in footwear industry may be classified according to various criteria and categories. These criteria are:

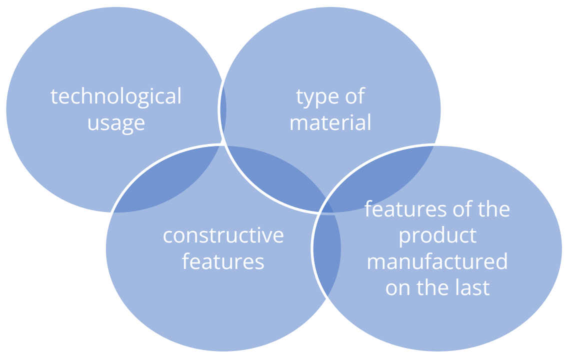

Fig. 10: Classification criteria for footwear lasts

[18] Ma, X., & Luximon, A. (2013). Design and manufacture of shoe lasts. In A. Luximon (Ed.), Handbook of footwear design and manufacture (pp. 177–196). Woodhead Publishing. https://doi.org/10.1533/9780857098795.177

[19] Costea, M., Mihai, A. (2016). Basics of footwear modelling and pattern making, TEHNICA-INFO, Chișinău, Moldova, ISBN 978-9975-63-394-9

The **increasing focus** on **environmental sustainability** has created new challenges for the footwear industry. Shoe lasts are now evaluated not only for performance and production efficiency but also for their environmental impact, material use, energy consumption, and contribution to waste generation (Fig. 11).

The main functions of shoe lasts are:

- Determining shoe shape and aesthetics;
- Ensuring proper foot fit and comfort;
- Supporting ergonomic performance;
- Assisting in sole attachment and assembly;
- Standardising production processes.

Without properly designed lasts, footwear may cause discomfort, poor posture, or reduced durability.

Plastic shoe lasts are currently the most widely used type in industrial footwear manufacturing.

The common materials used to produce them are Polyethene (PE), Polypropylene (PP), and High-density plastics.

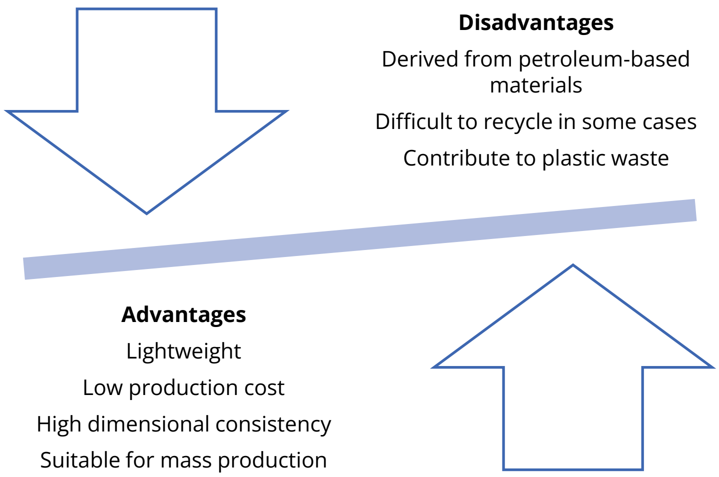

Fig. 11: Advantages and disadvantages of plastic shoe lasts

Plastic lasts create **major sustainability challenges** because most are produced from non-renewable fossil resources. Disposal at the end of life contributes to industrial waste accumulation (Chua, 2019[20]).

Recent developments in additive manufacturing have introduced 3D-printed lasts for customised footwear production. These could be a good alternative, but they come with several disadvantages: high equipment costs, limited material options, and some printing materials being non-biodegradable.

[20] Chua, J. (2021). The circular shoe: An impossible challenge?, Vogue Business. Retrieved from: https://www.vogue.com/article/the-circular-shoe-an-impossible-challenge

3D printing can significantly reduce waste because material is added only where needed. It also supports mass customisation, reducing overproduction. However, sustainability depends on the type of filament or resin used (Denkena, 2005[21]).

Traditional footwear production consumes large quantities of wood, plastics, and synthetic materials. Many lasts become **obsolete** due to changing fashion trends or production updates. Unused or damaged lasts often become industrial waste. Plastic lasts are especially problematic because they may **not biodegrade naturally**.

The footwear industry already faces major recycling difficulties because shoes contain many glued and mixed materials. Similar issues apply to lasts and related production tools. Manufacturing that lasts using CNC machining, injection moulding, or metal processing consumes significant energy. This increases greenhouse gas emissions associated with footwear production.

Most footwear factories lack closed-loop recycling systems for lasts.

Fig. 12: Main sustainability challenges associated with shoe last

Sustainable Solutions for shoe last production

Bio-Based Materials	Reusable and Modular Lasts	Additive Manufacturing
• Bioplastics • Plant-based polymers • Recycled composites	• Reduced waste • Lower production costs • Increased flexibility	• Lower material waste • Reduced transportation • Localised production • Customised manufacturing

These materials can reduce dependence on fossil fuels. Modular lasts allow interchangeable sections, reducing the need to manufacture entirely new lasts for each design. 3D printing enables on-demand production and decreases excess inventory.

Shoe lasts are essential tools in footwear manufacturing because they determine shoe fit, comfort, and structure. Traditional lasts made from wood, plastic, or metal each have advantages and limitations. However, growing environmental concerns have highlighted the sustainability challenges associated with material use, waste generation, and energy consumption.

Modern technologies such as CAD design, 3D printing, machine learning, and digital foot scanning are transforming shoe last production toward more **sustainable approaches**. Despite these advances, the footwear industry still faces major obstacles in achieving circular manufacturing and reducing environmental impact.

The future of sustainable footwear production will depend on innovative materials, recycling systems, digital technologies, and environmentally responsible manufacturing strategies.

[21] Denkena, B., & Scherger, S. (2005). A concept for shoe last manufacturing in mass customisation. CIRP Annals, 54(1), 341–344. https://doi.org/10.1016/S0007-8506(07)60118-8

4.2.2 CAD for footwear - component of sustainability

Integration of **modern technologies** such as digital modelling, 3D scanning, and simulation tools enables designers and pattern makers to develop complex shapes and customised footwear solutions (Firtikiadis et al., 2024[22,]; Sandhu et al., 2025[23]).

Computer-Aided Design (CAD) has become one of the most important technologies in modern footwear development. The footwear industry traditionally depended on manual sketching, handcrafted prototypes, and physical pattern modification, processes that required considerable time, labour, and material resources. The introduction of CAD systems transformed footwear production into a digital engineering process where design, simulation, prototyping, and manufacturing are interconnected through computational technologies.

The first industrial applications of CAD in the shoe industry appeared during the 1980s, when manufacturers began exploring digital systems for pattern generation and shoe modelling. Early studies already recognised that CAD could significantly improve precision and production efficiency in footwear manufacturing. Research published in Computers in Industry discussed how CAD systems enabled manufacturers to digitise shoe geometry and standardise design operations that had previously relied heavily on manual craftsmanship (Mermet, 1982[24]).

One of the principal contributions of CAD in footwear development is the creation of accurate **three-dimensional shoe models**. Modern CAD software allows designers to digitally construct every component of the shoe, including the upper, sole, heel, insole, and internal support structures. Unlike traditional drafting methods, CAD systems enable **continuous modifications** without rebuilding the entire design from the beginning. This flexibility considerably reduces product development time and improves geometric consistency across different shoe sizes and collections.

Fig. 13: ICAD3D+. All-in-one. Pattern making + 3D Modeling.
Source: *https://icad.inescopsolutions.com/icad-evolve/*

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[22] Firtikiadis, L., Manavis, A., Kyratsis, P., & Efkolidis, N. (2024). Product design trends within the footwear industry: A review. Designs, 8(3), 49. https://doi.org/10.3390/designs8030049
[23] Sandhu, K., Subburaj, K., Pal, M., Sarkar, P., & Singh, S. (2025). Footwear innovation: From conceptual design through to advanced manufacturing techniques. Academic Press.
[24] Mermet, J., & Roche, J. J. (1982). The introduction of CAD in the shoe industry. Computers in Industry, 3(3), 181–186. https://doi.org/10.1016/0166-3615(82)90002-1

A particularly important aspect of footwear CAD is surface development, which involves transforming **complex three-dimensional shoe geometries into two-dimensional patterns** suitable for manufacturing. Since shoe uppers are produced from flat materials such as leather and textiles, accurate flattening of curved surfaces is essential. Tam et al. developed a specialised CAD method for footwear surface development that minimises geometric distortion during the conversion from 3D surfaces to manufacturable 2D components. Research demonstrated that computational surface analysis significantly improves fitting accuracy and material utilisation in footwear production (Tam et al., 2007[25]).

Pattern making is a crucial stage in footwear production, translating design concepts into technical components that can be manufactured. It involves creating flat patterns that correspond to the three-dimensional shape of the shoe last.

Pattern-making techniques convert the 3D geometry of the last into two-dimensional components used to cut materials for the upper (Motawi, 2020[26]).

Typical steps in footwear pattern making include:

1. Last preparation and tape covering;
2. Design line drawing on the last;
3. Pattern development and flattening;
4. Pattern correction and allowance adjustments;
5. Grading for different sizes.

Pattern making ensures an accurate fit, proper assembly of components, and efficient use of materials in production.

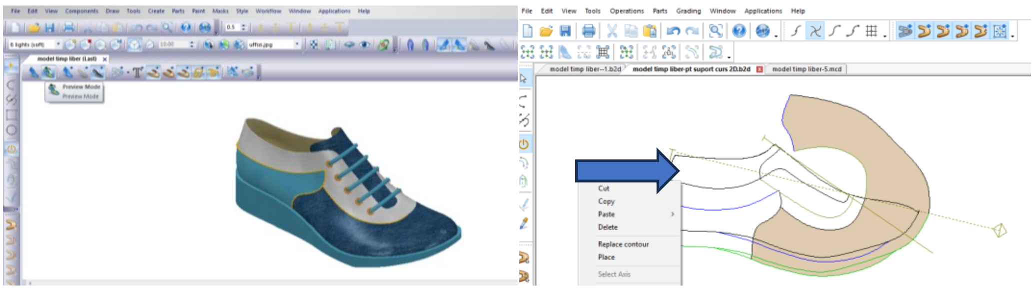

Fig. 14: Conversion of 3D footwear geometry into 2D pattern components. Source: TUIASI

CAD systems also play a critical role in **digital prototyping** and **virtual visualisation**. Before the implementation of CAD technologies, footwear companies frequently produced **multiple physical prototypes** during product development. This process **increased production costs and generated substantial material waste**. Modern CAD software allows virtual shoe prototypes to be created, analysed, and modified entirely within a digital environment before physical manufacturing begins.

Research on CAD/CAM systems for footwear production demonstrated that digital workflows significantly **reduce development time** while **improving communication** between designers, engineers, and manufacturers. Digital prototypes can be evaluated from multiple perspectives,

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[25] Tam, A., Joneja, A., Tang, K., & Yao, Z. (2007). A Surface Development Method with Application in Footwear CAD/CAM. Computer-Aided Design and Applications, 4(1-4), 67-77. https://doi.org/10.1080/16864360.2007.10738527
[26] Motawi, W. (2020). Footwear pattern making and last design. Sneaker Factory / Wade Motawi Publishing. ISBN 0998707074, 9780998707075

allowing rapid corrections in aesthetics, ergonomics, and structural geometry before tooling or manufacturing begins (Bodi et al., 2021[27]).

Another major contribution of CAD is its integration with Computer-Aided Manufacturing (CAM) and CNC technologies. In contemporary footwear engineering, CAD models are directly connected to automated production systems capable of manufacturing moulds, dies, and cutting patterns with high precision. The **integration** between **CAD, CAM, and CNC** machinery forms the foundation of digital manufacturing in the footwear industry.

López et al. proposed a STEP-NC framework specifically adapted for footwear manufacturing, establishing a direct relationship between CAD models and CNC production systems. Their study showed that CAD-integrated manufacturing workflows improve automation, reduce machining errors, and facilitate communication between software and production equipment (Gomez-Hernandes et al., 2021[28]).

CAD has also contributed substantially to footwear customisation and orthopaedic applications. Through 3D foot scanning technologies, individualised foot geometries can now be incorporated directly into CAD environments. Engineers can digitally design orthopaedic insoles and customised footwear structures adapted to the anatomy and biomechanics of specific users.

In recent years, CAD systems have become increasingly associated with advanced **simulation methods** and computational engineering tools. Contemporary footwear CAD platforms often integrate finite element analysis (FEA), allowing engineers to study stress distribution, material deformation, and cushioning behaviour directly within the design environment. This integration enables virtual testing of footwear performance before physical prototypes are produced.

Modern CAD technologies are particularly important in the production of knitted and smart footwear. Recent research published in Processes investigated innovative three-dimensional CAD strategies for knitted footwear manufacturing. The study highlighted how digital modelling improves structural optimisation, knitting precision, and integration between textile engineering and shoe geometry. Researchers emphasised that modern footwear CAD systems now combine geometric modelling, material simulation, and production planning within unified digital environments[29].

Recent computational systems also enable CAD models to be reconstructed directly from 3D scans using deformable fitting algorithms. These technologies facilitate digital replication of physical objects and accelerate **reverse engineering processes** in footwear design and customisation (Wu et al., 2021[30]).

Beyond scientific research, CAD technologies are widely used in the development of commercial footwear by major international companies. Sportswear brands such as Nike, Adidas, and New Balance increasingly rely on computational CAD workflows for sole optimisation, digital

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[27] Bodi, Ilo & Piperi, Erald & Kaçani, Jorgaq. (2021). Design and production of footwear using CAD/CAM systems, https://www.researchgate.net/publication/357050958_Design_and_production_of_footwear_using_CADCAM_systems

[28] Gómez-Hernández, J.-F., Davia-Aracil, M., Sanchez-Romero, J.-L., & Jimeno-Morenilla, A. (2021). An approach to implement STEP-NC in the footwear industry. Computers in Industry, 125, 103384. https://doi.org/10.1016/j.compind.2020.103384

[29] Hinojo Pérez, J. J., Valdés-Martínez, J., Juan-Fernandez, B., Calabuig-Barbero, E., & Gomez-Hernández, J. F. (2024). Innovative and Efficient Three-Dimensional Design Strategies for Optimizing the Industrial Production of Knitted Footwear. Processes, 12(12), 2698. https://doi.org/10.3390/pr12122698

[30] Wu, R., Xiao, C., & Zheng, C. (2021). DeepCAD: A deep generative network for computer-aided design models. Proceedings of the IEEE/CVF International Conference on Computer Vision (ICCV). https://doi.org/10.48550/arXiv.2105.09492

prototyping, and integration with additive manufacturing. Recent industrial discussions presented at CDFAM conferences highlighted how companies are adopting algorithmic design, robotic fabrication, and parametric CAD systems to create customised midsoles and digitally manufactured uppers (Ishimtsev et al., 2020[31]).

Discussions among professional designers indicate that CAD tools are especially valuable when managing multiple shoe sizes and maintaining **geometric consistency** across collections. Designers frequently emphasise that computational modelling significantly reduces repetitive manual modifications during industrial production workflows.

Today, CAD is no longer simply a digital drawing tool in footwear engineering. It has evolved into a comprehensive technological platform connecting design, biomechanics, manufacturing, simulation, customisation, and artificial intelligence. Through its integration with CAM systems, additive manufacturing, and computational optimisation, CAD continues to reshape the footwear industry toward faster development cycles, higher manufacturing precision, and increasingly personalised products.

A footwear **technical data sheet** (or tech pack) is a comprehensive document that acts as a blueprint for manufacturing shoes, detailing every material, component, colour, and construction method. It ensures factories produce the design accurately, serving as a contract to prevent unexpected, costly errors and to check quality during sampling (Motawi, n.d[32]).

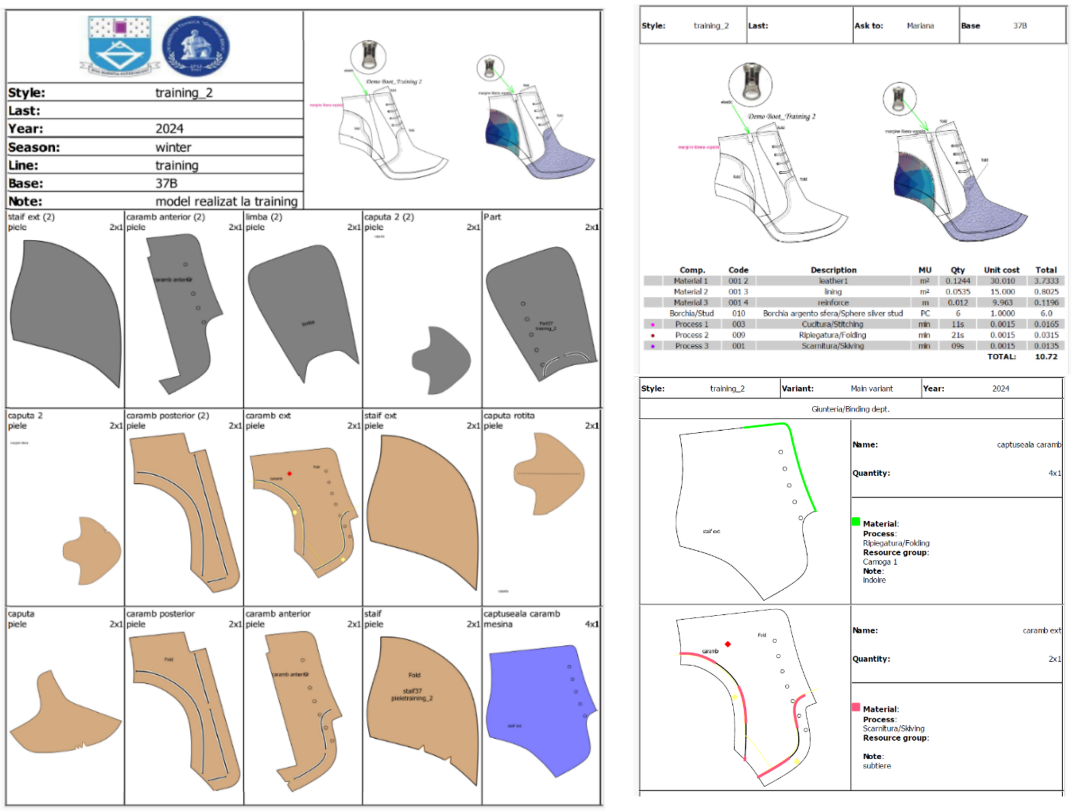

Fig. 15: Technical Data Sheet obtained in Caligola COMELZ. Source: TUIASI

[31] Ishimtsev, V., Bokhovkin, A., Artemov, A., Ignatyev, S., Niessner, M., Zorin, D., & Burnaev, E. (2020). CAD-Deform: Deformable fitting of CAD models to 3D scans. arXiv. https://arxiv.org/abs/2007.11965

[32] Motawi, W. (n.d.). How to make a shoe production specification. Retrieved from: https://shoemakersacademy.com/how-to-make-a-shoe-production-specification/

4.2.3 Product diversification

Footwear product diversification plays an essential role in the design and manufacturing processes of modern footwear. Through **modifications** of design elements, **pattern development,** and material selection, designers and pattern makers can generate a wide range of products from a single base model.

Pattern making is a critical stage that enables the translation of design concepts into manufacturable components. By adjusting upper patterns and design lines, designers can efficiently create diverse footwear collections while maintaining production efficiency.

The footwear industry is characterised by **rapid changes** in fashion trends, consumer preferences, and technological innovation. As a result, product diversification has become **a key strategy** for maintaining competitiveness and responding to market demands. Product diversification in footwear refers to the process of developing multiple models or variants from a basic design by modifying elements such as shape, materials, construction techniques, and decorative details. These modifications are often achieved through design development and pattern-making techniques (Harnagea & Harnagea, 2015[33]).

From a technical development perspective, diversification is most efficiently achieved by establishing a **standardised base construction**, including a **shared last, common outsole tooling, and unified sole structures**. This engineering approach enables the development of multiple footwear models with minimal additional technical investment. The role of the technical developer is to define the boundaries of variation — **identifying which design elements can be modified without affecting construction methods, tooling systems, fit consistency,** or **compliance requirements**.

A well-engineered base may support numerous footwear variations while sharing the same outsole tooling, fit standards, and quality validation processes. This significantly **reduces development time, tooling costs, prototype iterations**, and **manufacturing complexity** across the product range.

Product diversification is closely linked to consumer expectations, as footwear must simultaneously satisfy aesthetic preferences, functional performance, and ergonomic comfort (Narkbupha, 2012[34]).

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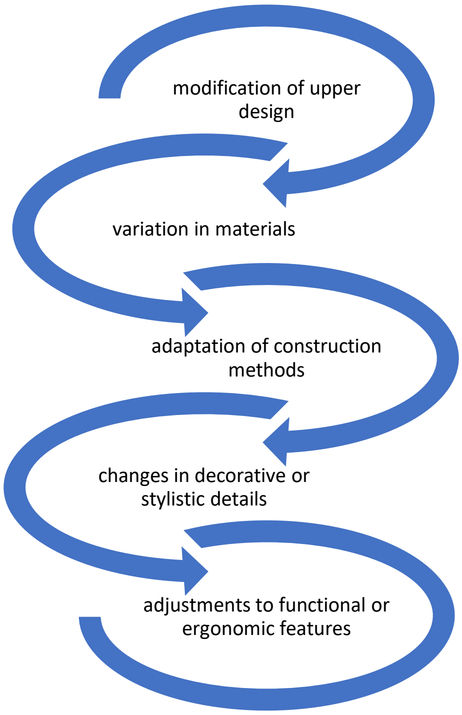
[33] Harnagea, F., & Harnagea, M. C. (2015). Diversification of footwear through development of the shoe uppers. Revista de Pielărie Încălţăminte, 10(3).

[34] Narkbupha, N. (2012). Factors determining athletic footwear design: A case of product appearance and functionality. Procedia – Social and Behavioral Sciences, 36, 520–528. https://doi.org/10.1016/j.sbspro.2012.03.057

Footwear technical development and involve **interdisciplinary knowledge** from product design, biomechanics, materials science, and manufacturing technology. Modern approaches combine traditional craftsmanship with digital tools such as computer-aided design (CAD), parametric modelling, and additive manufacturing to create diversified products that meet aesthetic, ergonomic, and functional requirements (Firtikiadis et al., 2024[35]).

Product diversification in footwear design and pattern-making involves creating multiple shoe models from a basic prototype or pattern. This process allows manufacturers to increase their product portfolio while minimising production costs and design time. According to research on footwear development, diversification can be achieved through:



One of the most effective ways to diversify footwear products is through modifications of the upper pattern. Starting from a base pattern, designers can create different models by adjusting design lines, proportions, and structural elements.

For example, a single woman's court shoe pattern can be diversified by modifying the vamp shape, quarter design, opening geometry, fastening systems, decorative elements, or material combinations, resulting in multiple commercially distinct products derived from the same technical foundation.

Examples of **diversification methods** include:

modifying vamp shapes (round, pointed, or square)
changing quarter height
introducing straps, buckles, or lacing systems
altering openings and cut-outs
adding decorative stitching or overlays

Research demonstrates that altering the configuration of upper patterns significantly affects both the aesthetic identity of footwear and the material consumption during manufacturing (Harnagea & Harnagea, 2015[36]).

By systematically modifying these elements, designers and patternmakers can generate multiple footwear models while maintaining the same last and basic construction technique.

[35] Firtikiadis, L., Manavis, A., Kyratsis, P., & Efkolidis, N. (2024). Product design trends within the footwear industry: A review. Designs, 8(3), 49. https://doi.org/10.3390/designs8030049

[36] Harnagea, F., & Harnagea, M. C. (2015). Diversification of footwear through development of the shoe uppers. Revista de Pielărie Încălţăminte, 10(3).

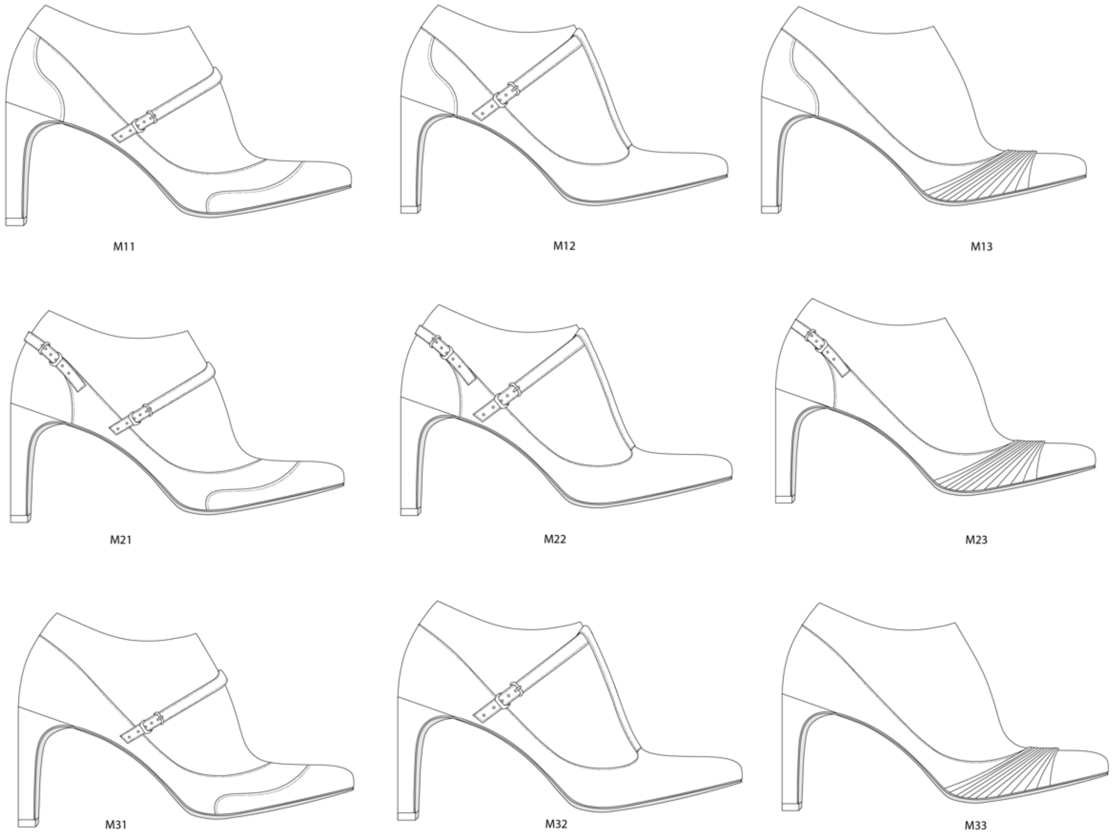


Fig. 16: Court Matrix type diversification. Source: TUIASI – Raluca Lupu

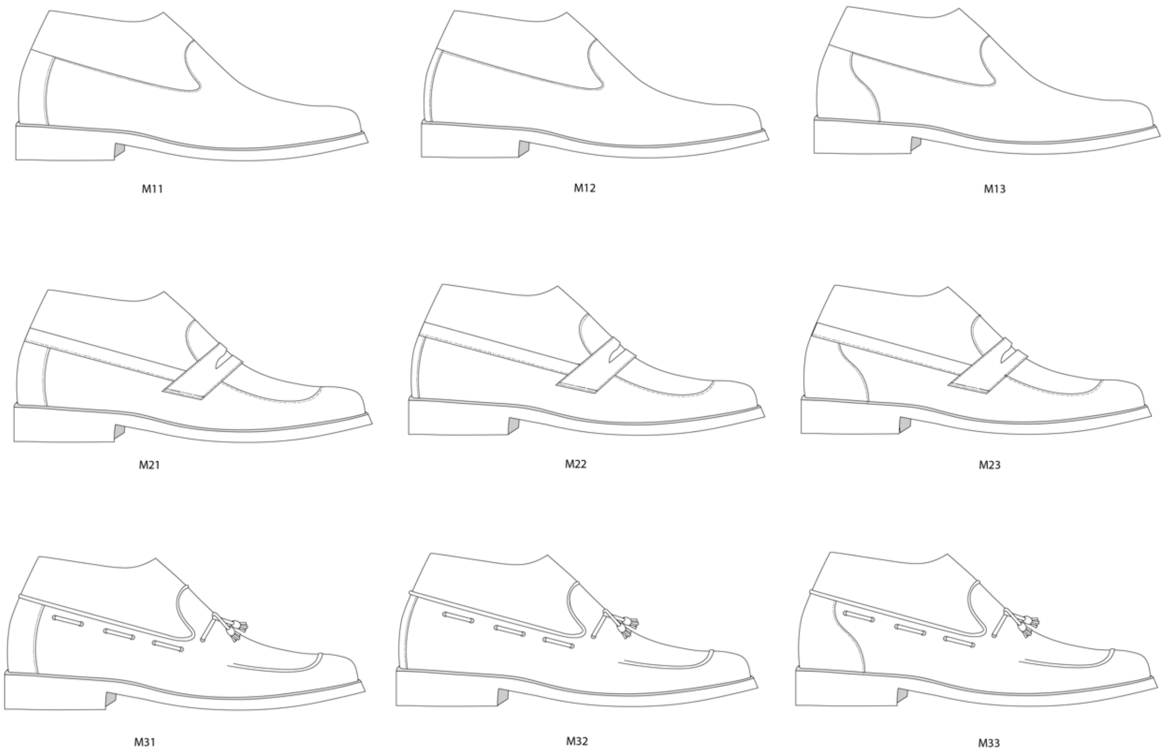


Fig. 17: Loafers Matrix type diversification. Source: TUIASI – Raluca Lupu

4.2.4 Material consumption optimisation

Material consumption optimisation is an essential aspect of footwear manufacturing, directly influencing **production costs**, **sustainability**, and **resource efficiency**. The footwear industry relies on various materials, including leather, synthetic fabrics, rubber, foam, and textiles. Since these materials account for a significant portion of production costs, optimising their use is a critical objective for designers and manufacturers.

In footwear production, material consumption optimisation involves **reducing material waste while maintaining product quality, functionality, and aesthetics**. This process involves **efficient pattern design, accurate cutting,** and **advanced manufacturing planning techniques** (Ma & Luximon, 2013[37]). The optimisation of materials is particularly important because footwear manufacturing involves irregular shapes and complex patterns that can generate considerable **waste** if not properly managed.

In recent years, sustainability concerns have increased the importance of efficient material utilisation. Companies now focus not only on reducing costs but also on minimising environmental impact through **improved production methods** and **responsible resource management** (Fletcher & Tham, 2019[38]).

Pattern making plays a key role in optimising material consumption. By carefully designing patterns, manufacturers can significantly reduce material waste.

Important pattern design and pattern making strategies include:

- reducing the number of pattern pieces;
- designing shapes that fit together efficiently;
- minimising empty spaces between components;
- maintaining consistent seam allowances;
- using symmetrical patterns where possible.

Motawi (2020)[39] explains that the pattern engineer must consider both the three-dimensional form of the shoe last and the efficient two-dimensional layout of pattern pieces during design development.

Another important technique involves modifying design lines to simplify patterns while preserving the shoe's visual identity. Simplified patterns often result in improved material efficiency and reduced production time.

Nesting refers to arranging pattern pieces on a material surface in the most efficient configuration. The objective is to maximise the use of available material and minimise waste.

Traditionally, nesting was performed manually by experienced technicians. However, modern footwear manufacturing increasingly uses computer-aided design (CAD) systems that automatically calculate **optimal pattern layouts**.

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[37] Ma, X., & Luximon, A. (2013). Design and manufacture of shoe lasts. In A. Luximon (Ed.), Handbook of footwear design and manufacture (pp. 177–196). Woodhead Publishing. https://doi.org/10.1533/9780857098795.3.177

[38] Fletcher, K., & Tham, M. (2019). Earth logic: Fashion action research plan. The J J Charitable Trust, ISBN: 9781527254145

[39] Motawi, W. (2020). Footwear pattern making and last design. Sneaker Factory / Wade Motawi Publishing. ISBN 0998707074, 9780998707075

According to research on automated nesting systems, digital optimisation algorithms can significantly improve material utilisation compared to manual methods (Tsai & Hung, 2016[40]).

Computerised nesting offers several advantages:

- improved accuracy in layout planning;
- faster processing time;
- reduced human error;
- better overall material utilisation.

Modern footwear manufacturing relies heavily on digital technologies to optimise material consumption. Important technologies include:

→ Computer-Aided Design (CAD)

CAD systems allow designers to develop digital patterns and simulate layout configurations before physical cutting. This helps evaluate material usage and adjust patterns if necessary.

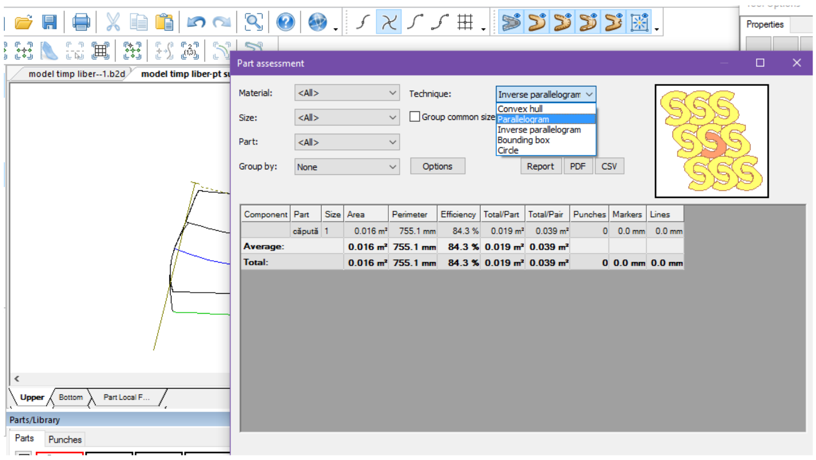


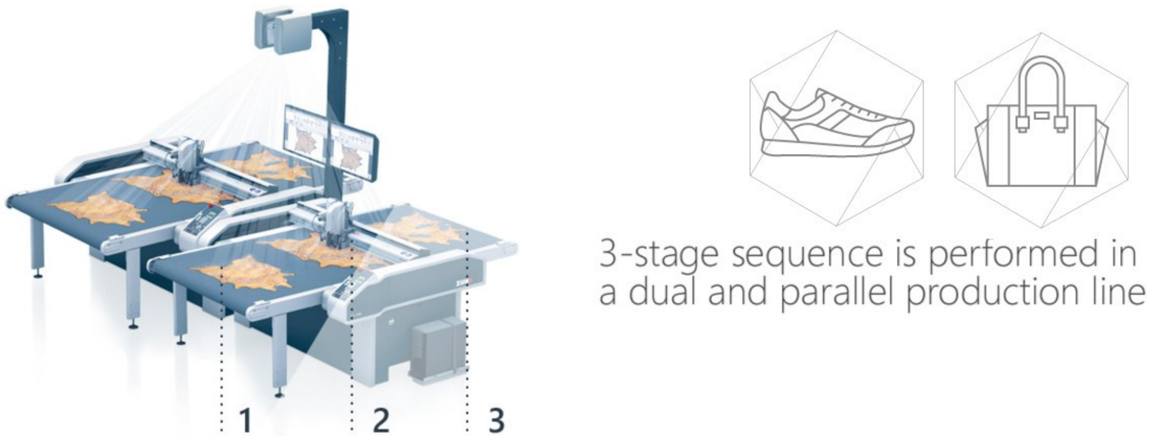
Fig. 18: Simulation of layout for theoretical consumption. Source: TUIASI

→ Computer-Aided Manufacturing (CAM)

CAM systems integrate digital design data with automated cutting machines. These machines can precisely cut components according to optimised nesting layouts, reducing material waste.

An example of a leather-cutting machine is the ZUND model, which features a double-head cutting system for flexible production. For demanding medium production volumes, the system adopts an innovative approach: the 3-stage sequence is performed on a dual, parallel production line.

[40] Tsai, C.-Y., & Hung, C.-C. (2016). A novel two-stage nesting algorithm for irregular shapes in the leather cutting industry. Computers & Industrial Engineering, 93, 160–168. https://doi.org/10.1016/j.cie.2016.01.010



1. Capture, Recognition and Automatic Nesting; 2. Automatic Cut; 3. Parts Picking

Fig. 19: Zund cutting machine. Source: https://mindtech.pt/industries/footwear/mindcut-footwear-leather-goods

→ 3D Footwear Design

Three-dimensional modelling allows designers to visualise footwear structures and **optimise pattern shapes** before production. This reduces design errors and improves efficiency in material utilisation (Firtikiadis et al., 2024[41]).

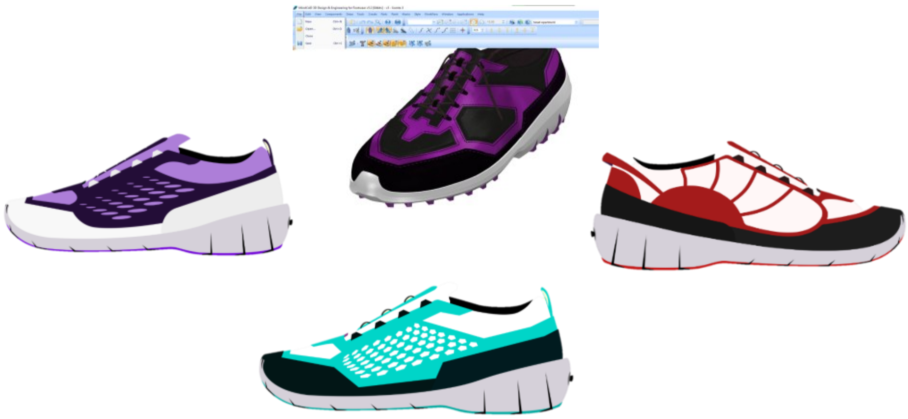


Fig. 20: Footwear 3D modelling. Source: TUIASI – Scortanu Rares

Material **optimisation** is closely connected with sustainability in the footwear industry. Waste reduction not only lowers production costs but also decreases environmental impact.

Footwear manufacturing involves significant consumption of natural resources, including leather, synthetic polymers, water, and energy. Efficient material use contributes to sustainable production by:

- reducing landfill waste;
- lowering carbon emissions;
- minimising resource extraction;
- improving circular economy practices.

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[41] Firtikiadis, L., Manavis, A., Kyratsis, P., & Efkolidis, N. (2024). Product design trends within the footwear industry: A review. Designs, 8(3), 49. https://doi.org/10.3390/designs8030049

Fletcher and Tham (2019)[42] emphasise that sustainable design strategies must include careful material selection and efficient production methods.

Companies increasingly adopt eco-design approaches that prioritise durability, recyclability, and reduced material consumption.

Optimisation strategies include careful **material selection, efficient pattern design, improved layout planning, and the use of digital technologies** such as CAD and automated nesting systems. Pattern makers and designers play an essential role in minimising waste by developing patterns that maximise material utilisation.

Platforms that use AI technology for design and illustration tools are revolutionising the creative process. Designers can turn their hand-drawn sketches into **realistic-looking renders** and create three-dimensional models of their ideas with AI-powered design & illustration tools. Designers working in Industrial Design and Product Development can use these platforms to facilitate their creativity when generating, visualising, and refining concepts through iterative design. An example is **Vizcom**[43], which offers many of the same product efficiencies and technical advantages to its users, including sketch-to-render, real-time rendering, 3D modelling, & collaborative workspace, thus providing a fast path from concept to prototype.

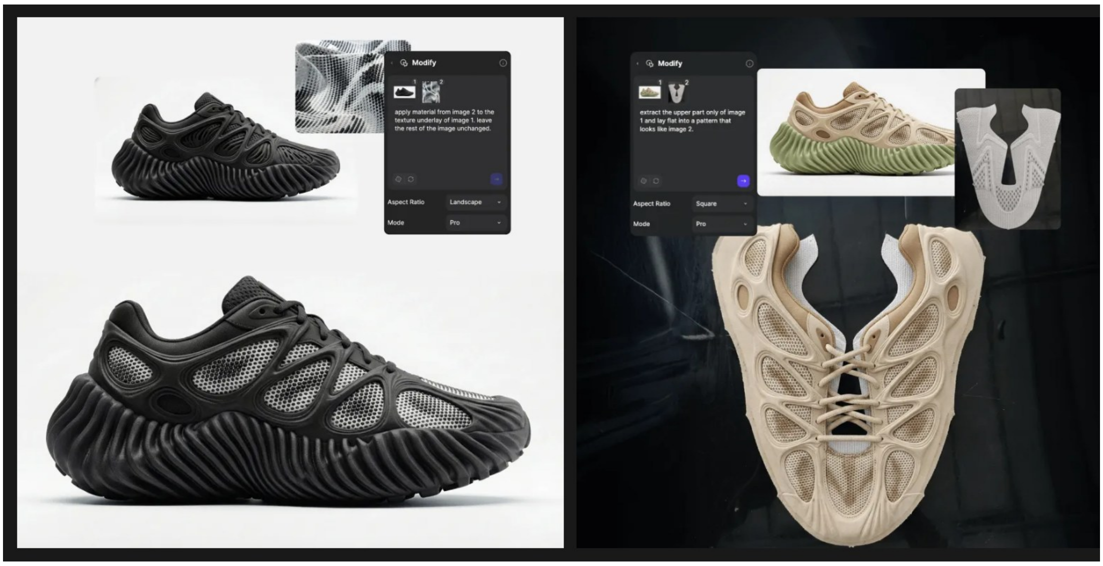


Fig. 21: Concept creation using Vizcom. Source: https://vizcom.com/solutions/footwear

As the footwear industry continues to evolve, the integration of advanced technologies and sustainable design principles will become increasingly important for achieving efficient, environmentally responsible production.

4.2.5 Reusability, reparability, disassembly and recycling

Waste streams generated during manufacturing can be reused or recycled through production planning to create production loops, rather than being sent to landfill. Production-focused life cycle evaluation approaches identify "hot spots" in the production process for potential improvement; understanding the processes generating the most carbon-laden emissions (the carbon footprint of a facility), enables the identification of where to make technical improvements (i.e., energy

[42] Fletcher, K., & Tham, M. (2019). Earth logic: Fashion action research plan. The J J Charitable Trust, ISBN: 9781527254145

[43] Vizcom. (2026). Vizcom features: AI rendering, collaboration & design tools. Retrieved from: https://vizcom.com/product/

optimisation, redesign) (Rios et al., 2021[44]). In the footwear industry, circularity means moving away from the traditional take-make-dispose model toward **regenerative** and **recyclable production practices** (Fuentes et al., 2023[45]).

Conventional footwear construction — multi-material assemblies bonded with aggressive adhesives, reinforced with mixed-polymer components, and finished with surface treatments that resist separation — is designed for in-use performance, not for disassembly at the end of life. Circular economy design requires a **different construction logic**, **materials** selected for **compatibility with available recycling streams**; **adhesive** systems that allow **component separation**; **minimal material variety** to simplify end-of-life processing; and **structural design** that facilitates repair and component replacement.

The technical implications are substantial. Designing for disassembly may conflict with conventional performance requirements: a sole bonded for easy removal has a lower peel strength than one bonded for maximum durability. Mono-material upper constructions simplify recycling but constrain design options. The technical developer must explicitly navigate these trade-offs, document the construction logic in the tech pack, and validate that recyclability or repairability claims are achievable in the end-of-life processing context for which they are intended.

4.3 Energy, process and resource efficiency

Footwear production includes cutting, adhesive application, moulding, curing ovens, hydraulic presses, and finishing stations — each with distinct energy profiles. The technical developer's specification choices directly determine which of these processes are activated and at what intensity.

Energy usage must be measured and optimised to identify where electricity consumption can be reduced across equipment and process types (Fareri et al., 2023[46]). Footwear production facilities can utilise expert systems and digital analytics to implement an automated, centralised process for tracking energy conservation efforts. Smart energy systems — IoT-connected monitoring platforms that track energy consumption per process and per product in real time — are increasingly available in advanced manufacturing facilities. When a technical developer's specification is run in a data-rich factory environment, energy-consumption data for each construction choice becomes available, creating the feedback loop required to drive genuine energy optimisation through specification decisions (Ioshchikhes et al., 2024[47]).

Footwear production is often **energy-intensive**. Shifting factory energy towards renewables and reducing drying or curing temperatures through technical innovation (e.g., water-based adhesives that cure at lower temperatures) directly improves process efficiency and reduces emissions.

Rather than using high-temperature processes, manufacturers should consider implementing new technologies, such as **water-based glue systems** that cure at lower temperatures. This will

[44] Rios, L., Paggiaro, A. O., & Fernandes, R. A. Q. (2021). Quality of life, lifestyle, and working environment of women in the footwear industry. Revista Brasileira de Medicina do Trabalho, 18(4), 390–398. https://doi.org/10.47626/1679-4435-2020-517

[45] Fuentes-Medel, Y., Yan, L., & Buttler, K. (2023). 3 questions: A roadmap toward circularity in the footwear industry. Retrieved from: https://news.mit.edu/2023/3-questions-roadmap-toward-footwear-circularity-1027

[46] Fareri, S., Apreda, R., Mulas, V., & Alonso, R. (2023). The Energy Worker Profiler: From technologies to skills to realize energy efficiency in manufacturing. arXiv. https://doi.org/10.48550/arXiv.2301.09445

[47] Ioshchikhes, B., Frank, M., & Weigold, M. (2024). A Systematic Review of Expert Systems for Improving Energy Efficiency in the Manufacturing Industry. Energies, 17(19), 4780. https://doi.org/10.3390/en17194780

improve their process efficiency and significantly reduce their greenhouse gas emissions (Zhang et al., 2025[48]).

Some of the key technical product development considerations for footwear manufacturers regarding the use of renewable energy include:

- Specification of **curing and bonding processes compatible with variable energy supply** — UV-curable adhesive systems operate on demand without maintaining constant oven temperatures, making them better suited to renewable energy profiles.
- **Identification of energy-intensive steps in the construction specification** — hydraulic press cycles, thermoactivation, vulcanisation — and targeting these specifically for process redesign to reduce peak energy demand.
- **Selection of moulding processes and adhesive systems that operate at lower temperatures-** waterborne adhesive systems typically cure at 50-70°C versus 80-100°C for solvent-based equivalents, directly reducing oven energy consumption per pair.
- **Energy consumption data** — kilowatt-hours per pair for each construction type — incorporated into the product environmental footprint calculation, enabling technical developers to compare the energy impact of different construction choices at the specification stage.

Fig. 22: Technical product development considerations for integrating renewable energy in footwear manufacturing

The combination of **lean manufacturing** techniques and sustainability assessments results in an optimised reduction of process waste generation, machine idle time, and excess energy consumption — key components of a circularised factory operation. The main technical implications for product technical development are:

- **Identifying stages** where physical sample rounds, material approval delays, or documentation rework consume time **without adding technical value**
- **Standardised work for tech pack creation**- defined templates, mandatory data fields, and quality checks that prevent errors
- **Pull-based material approval**- materials are not entered into the BOM until genuinely needed for development
- **Error-proofing in specification**- checklist-based review of tech packs before issue to factory, ensuring critical parameters — allowances, adhesive type, pressing conditions, test requirements

Fig. 23: Technical product development implications of lean manufacturing and sustainability integration

[48] Zhang, B., Feng, C., Hu, Y., Li, F., Wu, T., Li, S., Yan, K., Feng, Z., Shi, Y., Tian, J., & Chen, L. (2025). High-resolution life cycle carbon footprint analysis for footwear products underpinned by on-site measured data. Resources, Conservation and Recycling, 220, 108376. https://doi.org/10.1016/j.resconrec.2025.108376

4.4 Social responsibility

Corporate Social Responsibility (CSR) means **ensuring safe, healthy work environments**. Research in footwear factories shows that inadequate handling of solvents and poor environmental conditions are associated with poorer quality-of-life outcomes among workers, including stress and physical ailments.

Social responsibility in **product technical development** processes includes:

Construction specifications that minimise ergonomic strain	Reduce the number of manual operations per pair, sequencing tasks to distribute physical load, and designing component shapes that are easy to handle and position correctly at each assembly station.
Adhesive and finish specifications that prioritise worker health	Choose waterborne systems, low-VOC primers, and solvent-free edge coatings reduce chemical exposure on the factory workforce compared to solvent-based alternatives.
Ethical sourcing criteria integrated into the material selection brief	Select leather from Leather Working Group-audited tanneries, cotton from GOTS-certified sources, etc.

Fig. 24: Social responsibility considerations in product technical development

5 Digitalisation in Footwear Technical Development

Digitalisation within the manufacturing sector involves integrating various forms of digital technology — **CAD software, robotic systems, Artificial Intelligence (AI), large datasets** collected from physical locations via sensors, **Virtual and Augmented Reality** (VR and AR) — to improve operational efficiency, dependability, and adaptability in production practices. These advancements represent the key components of Industry 4.0 and signify a major shift toward future operational models of manufacturing known as 'smart factories' (Nguyen et al., 2025[49]).

Key principle

In the context of product technical development specifically, digitalisation operates at three levels. At the design-to-specification level, 3D CAD, AI generative design, and digital material libraries compress the time from creative concept to technical specification.

At the specification-to-validation level, Finite Element Analysis (FEA) simulation, digital twins, and virtual prototyping allow performance and feasibility to be confirmed before physical tooling or sampling begins.

At the specification-to-production level, Product Lifecycle Management (PLM) systems, IoT factory data, and AR-guided assembly tools ensure that specifications are accurately communicated to and correctly executed by the production team.

5.1 New era of robots

The emergence of lightweight robotic arms — capable of rapid repositioning and reprogramming for different tasks — is reducing the capital commitment required to introduce automation into footwear production. This enables smaller factories and more frequent automation updates, but it also means that the production environment for which a specification is written may change more rapidly than before. Technical developers must design **specifications** that are **robust to variability in the production environment** — specifying process parameters in terms of outcomes (bond strength, dimensional tolerance, visual standard) rather than only in terms of input conditions (press temperature, dwell time), which may vary across different automation configurations.

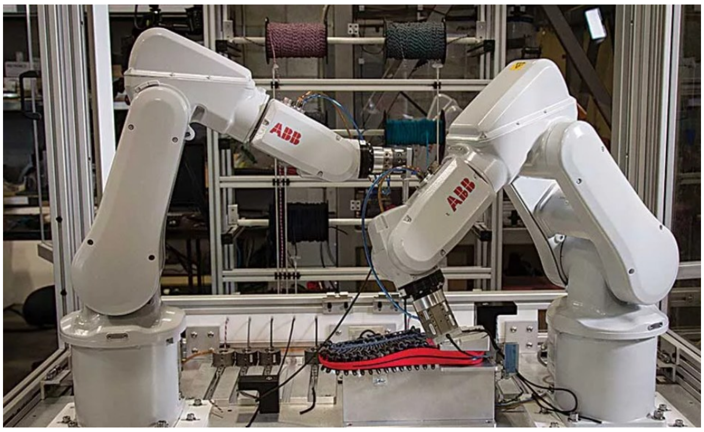


Fig. 25: UNEEK robotic cell. Source: https://www.assemblymag.com/articles/93672-shoe-manufacturer-automates-production-in-unique-way

[49] Nguyen, K., Ali, I., & Thanh Le, L. (2025). Digital transformation in manufacturing: Systematic review, current trends and future directions. Springer. https://doi.org/10.1007/978-981-96-3247-3

5.2 Artificial Intelligence in technical development

Artificial Intelligence (AI) in footwear technical development is moving from novelty to an operational tool. Its impact is felt across the creative-to-technical handover, in generative design for components, and in automating repetitive specification tasks.

Text-to-image and image generation AI tools (Midjourney, Stable Diffusion, Adobe Firefly) are used in early footwear concept development to rapidly generate and iterate aesthetic concepts before any technical specification begins (Shih-Hung Cheng, 2023 [50]). Research has demonstrated that AI-generated concepts increase creative diversity and accelerate the exploration phase of design. For the technical developer, this creates both an opportunity and a challenge: more concepts reaching the technical development stage faster means a **higher volume of design-to-technical handover work** — and a need for **efficient processes to evaluate the technical feasibility** of AI-generated concepts before committing development resources. This creates a hybrid workflow:

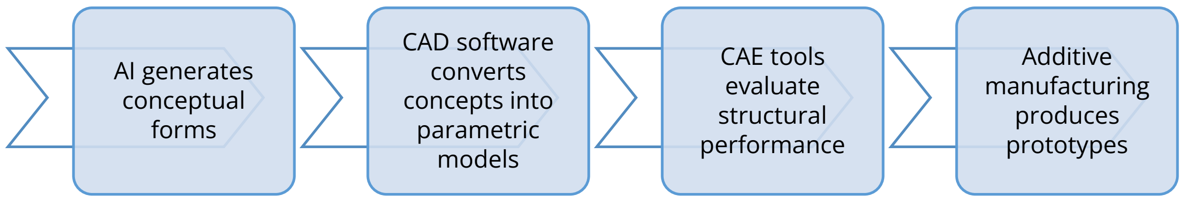


Fig. 26: Hybrid AI-assisted workflow for footwear concept development and technical evaluation

Text-generating and translating AI systems are increasingly being used in footwear technical development for three practical tasks:

- drafting and editing technical documentation (construction notes, quality criteria, test specifications);
- translating tech pack content between languages to improve factory comprehension;
- generating structured data from unstructured inputs (extracting BOM data from supplier data sheets, converting test report data into specification comparison matrices).

The accuracy and reliability of AI-generated technical documentation must be carefully validated before use in production-facing tech packs. AI systems can produce plausible-sounding but technically incorrect specifications. Technical developers using AI writing tools must review all AI-generated content against their own technical knowledge and the relevant industry standards.

Integrating AI algorithms into production workflows enables ongoing **monitoring of production quality data and equipment performance** (presses, cutters, adhesive stations), and real-time modifications to improve production quality and reduce defects and downtime. AI technology is increasingly used on footwear manufacturing lines to optimise cutting, stitching, and assembly processes. For the technical developer, this feedback creates a closed-loop quality improvement system: production failure patterns identified by AI analysis can be **traced back to specification**

[50] Cheng, S.-H. (2023). Impact of Generative Artificial Intelligence on Footwear Design Concept and Ideation. Engineering Proceedings, 55(1), 32. https://doi.org/10.3390/engproc2023055032

parameters, enabling root-cause investigation and specification refinement based on objective production data.

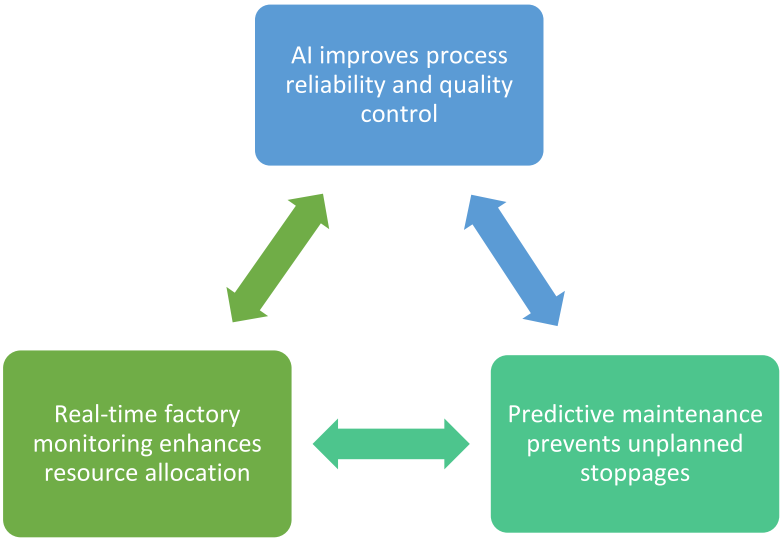


Fig. 27: AI-driven closed-loop quality improvement in footwear production systems

Generative design systems use AI optimisation algorithms to generate component geometries — particularly midsole lattice structures and outsole tread patterns — that satisfy multiple simultaneous constraints: **weight, cushioning performance, energy return, pressure distribution, and manufacturing method** (Hössinger-Kalteis et al. 2024[51]). The system explores the solution space far more broadly than a human designer can, producing design candidates that a human would not have conceived but that can be evaluated and selected using conventional technical judgement.

Data mining applied to historical development data — test results, sample feedback records, production defect logs — can identify patterns that improve future specification decisions. Which material combinations consistently cause peel-strength failures? Which construction methods generate the most factory queries? Which last families produce the highest rate of fit complaints? These questions can be answered systematically through data analysis, turning accumulated development experience into structured institutional knowledge.

5.3 Big Data

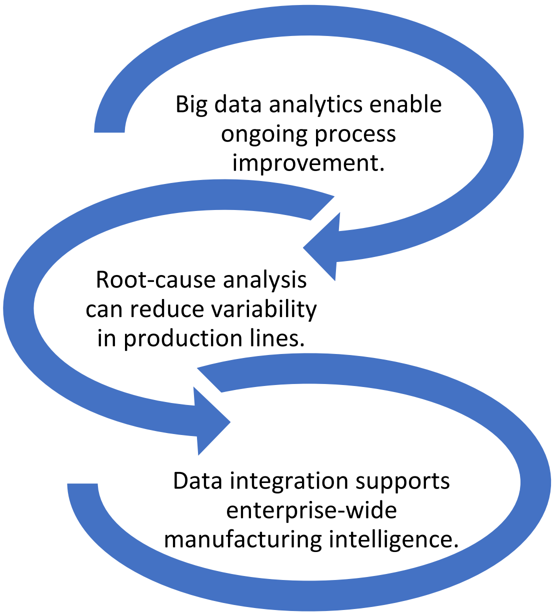
Analytic capabilities in the Big Data domain, applied to production processes, derive from thousands of sensors and other operational data associated with equipment, operators, or quality system(s). Using these **predictive** and **prescriptive analyses**, one can discover how best to utilise machine capabilities via optimised cutting layouts based upon raw material consumption as well as which parameters of operation produce low defect levels across a spectrum of process variations (Jagatheesaperumal et al., 2022[52]).

[51] Hössinger-Kalteis, A., Lackner, M., Lück, T. (2024). Design method for individualised 3D printed lattice shoe midsoles, Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications, Volume 239, Issue 7, https://doi.org/10.1177/14644207241291232

[52] Jagatheesaperumal, S. K., Rahouti, M., Ahmad, K., Al-Fuqaha, A., & Guizani, M. (2022). The duo of artificial intelligence and big data for Industry 4.0: Applications, techniques, challenges, and future research directions. IEEE Internet of Things Journal, 9(15), 12861–12885. https://doi.org/10.1109/JIOT.2021.3139827

In the context of footwear product technical development, big data creates a **closed-loop feedback system between technical specifications** and their **real-world performance in production**. Sensor data from cutting machines, lasting presses, adhesive application stations, and quality inspection systems — aggregated across production runs — is analysed against specification targets. Deviations that correlate with quality failures are traced back to specific specification parameters, enabling targeted specification improvement based on objective production evidence.

Personalisation and mass customisation platforms require a specific technical development approach: a **modular product architecture** in which each customisable element — upper material, midsole cushioning level, outsole compound, colourway — has been pre-validated independently and across all relevant combinations. The technical developer must engineer the configuration options, ensuring every permutation can be produced to the same quality standard without a separate development programme.



Factory operations are now being monitored 24x7x365 thanks to IoT technology, with sensors continuously sending measurements to a central analytics platform that provides complete visibility into your factory's performance. By combining IoT and analytics, factories gain access to real-time information that supports Digital Twin(s) and the implementation of **advanced manufacturing controls** (Viola et al., 2020[53]). For the technical developer, this data **closes the loop between specification and production** — and creates the foundation for **continuous specification improvement** based on production evidence.

5.4 3D Printing

Footwear production is increasingly utilising 3D printing technology for **last production** and **prototypes,** as well as for creating **manufacturing jigs, tooling, and speciality fixtures** that improve the efficiency of production steps. While many consumer shoes continue to be made using traditional craft methods, industrially produced components and tools made with 3D printing can **increase the precision of fixture manufacturing** and **shorten the setup time** for manufacturing processes (Mamun et al., 2025[54]).

In the **last production**, additive manufacturing enables parts to be produced digitally from scan data, eliminating the lead time and setup costs of traditional CNC machining or casting. This enables rapid iteration of last geometry in the development phase — a modification to toe spring

[53] Viola, J., & Chen, Y. (2020). Digital twin enabled smart control engineering as an industrial AI: A new framework and a case study. arXiv. https://doi.org/10.48550/arXiv.2007.03677

[54] Mamun, A., & Ahmed, L. (2025). Machine learning-guided additive manufacturing (AM) for nanotechnology: A review. https://doi.org/10.13140/RG.2.2.32127.73128

angle or instep volume that previously required a week's machining time can be implemented and evaluated in days. It also enables market-specific last variants to be produced economically for small-volume or customisation programmes that could not justify traditional last tooling investment.

In **prototype sampling**, 3D printing enables rapid production of **midsole, outsole, and component prototypes** directly from CAD data — without mould tooling. This allows performance testing of a new midsole geometry before committing to an injection mould; structural evaluation of an outsole tread pattern before cutting a metal die; and wear testing of a new heel construction before building a lasting jig. The reduction in tooling investment at the prototype stage both accelerates the development timeline and reduces the financial risk of technical development decisions.

In **production tooling**, 3D printing is increasingly used to produce lasting jigs, assembly fixtures, quality inspection gauges, and small-run production tooling. These applications reduce tooling lead times, allow rapid modification of jigs when specifications change, and enable local production of tooling at the factory rather than centralised manufacture and shipment. The technical developer must account for the material properties of 3D-printed tooling — typically lower durability than metal tooling — when specifying production volume thresholds and tooling replacement intervals.

The sustainability implications of 3D printing in technical development are significant:

- on-demand production of lasts and tooling eliminates speculative inventory;
- material-additive processes generate less waste than subtractive machining;
- digital distribution of the last files eliminates the carbon footprint of the international last shipment.

Research on 3D printing—where multiple robots coordinate to print and assemble parts-points to future possibilities for parallelising additive tasks on the factory floor, enhancing flexibility and accelerating production for specific components and assemblies.

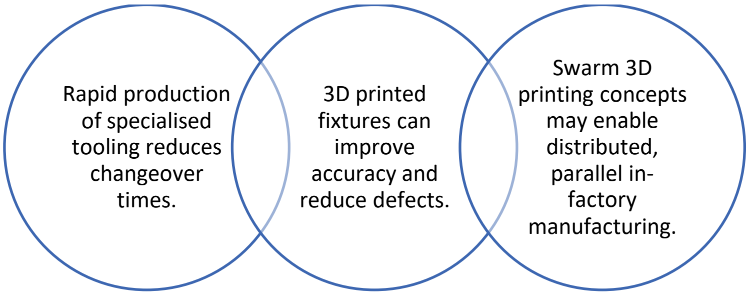


Fig. 28: Benefits of 3D printing in the footwear technical development stage

However, the sustainability of 3D printing depends critically on the materials used — many current printing materials are non-biodegradable, and the energy consumption of industrial printing processes is not negligible. Technical developers specifying 3D-printed components should evaluate the full lifecycle sustainability of the printing material alongside the process sustainability benefits.

5.5 Combination of digitalisation and sciences

Digital Twin technology creates a **virtual replica of physical production systems** that mirrors machines and processes in real time, enabling simulation, optimisation, and advanced diagnostics.

Digital Twins have been shown to enhance understanding of complex systems and support real-time control engineering for predictive and adaptive operations.

When combined with AI and Big Data technologies, Digital Twins support **smart automation** and **self-optimising production cells,** improving the flexibility and responsiveness of manufacturing lines (Yang et al., 2025[55]).

Using Digital Twin technologies when designing or developing products enables companies to **accelerate** their **design cycle, reduce** the number of **physical prototypes** required, and **digitally test** the **sustainability of materials, processes, patterns,** and **style details**. Digital Twin technology can help companies reduce waste and improve efficiency, while at the same time allowing them to use sustainable materials and improve their levels of accuracy and efficiency in processes that are related to quality, performance, and fit (Harrop, 2023 [56]).

Fig. 29: Virtual twin of products in the footwear sector. Source: https://apparelresources.com/technology-news/retail-tech/digital-twin-overlapping-real-world-with-virtual/

Incorporating Digital Twin technology into supply chain management allows companies to gain near **real-time visibility** into and control over processes, enabling **proactive planning** and decision-making, reducing lead times, optimising inventory planning, and minimising disruptions to production due to changing demand.

[55] Yang, H., Aqlan, F., & Zhao, R. (2025). Toward smart manufacturing metaverse via digital twinning in extended reality. Journal of Computing and Information Science in Engineering, 25. https://doi.org/10.1115/1.4070437

[56] Mark Harrop. (2023). Why Digital Twins Will Be Essential To Building End-to-End Workflows. Retrieved from: https://www.theinterline.com/2023/08/15/why-digital-twins-will-be-essential-to-building-end-to-end-workflows/

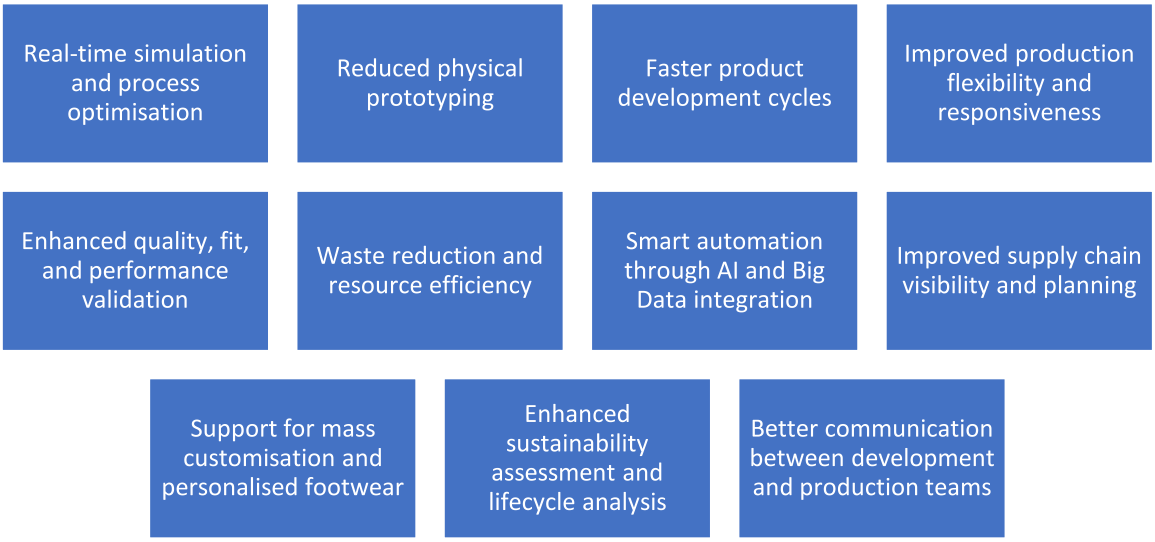


Fig. 30: Main impacts of Digital Twin technology on footwear technical development

Key players like Adidas, Nike, Prada, ASICS, and Crocs use Virtual Twins fo**r simulating design performance**, **optimising 3D-printed manufacturing**, and offering **personalised, on-demand customisation** (Transition Project, n.d[57]).

Finite Element Analysis (FEA) divides a component into a mesh of discrete elements, applies defined material properties and loading conditions, and computes the resulting stress distribution, deformation, and failure modes. In footwear technical development, FEA could be applied to **midsole cushioning optimisation** (mapping pressure distribution and energy return under different loading scenarios), **outsole tread design** (evaluating flex fatigue and grip under simulated wear conditions), **upper stress analysis** (identifying concentration points at lasting seams, eyelets, and flex lines), and **adhesive bond line performance** (modelling peel forces under different loading configurations).

The value of FEA in technical development is primarily in the decisions it enables before physical tooling: identifying a design geometry that will fail in flex testing before the mould is cut, eliminating weeks of rework and significant tooling costs. FEA results must be interpreted carefully; however, the accuracy of the simulation depends on the accuracy of the material property data used as inputs, and material properties of bio-based and recycled materials may be less well characterised than those of conventional materials.

5.6 Virtual and Augmented Reality

Virtual Reality (VR) and Augmented Reality (AR) technologies are reducing the time, cost, and carbon footprint of footwear product technical development by enabling meaningful decisions to be made without physical samples and by accelerating knowledge transfer to factory teams without requiring face-to-face travel.

VR-based sample review allows technical developers and design teams to **evaluate digital samples at a life-size scale** and in a realistic product context — on a virtual last, in a virtual retail environment, or in a virtual athletic performance context. This enables colour, material, proportion, and construction decisions to be made with greater confidence than flat-screen 2D

[57] Transitions Project. (n.d.). Digital twin. Retrieved from: https://transitionsproject.eu/digitalisation-2/digital-twin/

review allows, thereby reducing the number of physical sample rounds required to reach a sealing sample and the material and logistics costs associated with physical sampling.

VR environments can also be used to conduct **virtual factory trials** — simulating the assembly sequence of a new construction before the factory team has built the physical tooling and jigs. This identifies process sequence issues, ergonomic challenges, and component-handling problems before they arise in physical production, reducing the time and cost of production ramp-up.

Fig. 31: High-tech innovations that will change the footwear industry. Source: https://www.worldfootwear.com/news/2-high-tech-innovations-that-will-change-the-footwear-industry/2454.html

AR systems overlay technical specifications — construction notes, dimensional tolerances, colour standards, assembly sequence instructions — directly onto the physical work environment. This has two specific applications in the technical development of footwear.

AR-guided assembly instructions can accelerate the learning curve by providing real-time, step-by-step visual guidance directly at the workstation, reducing the need for experienced technical staff to be physically present during qualification.

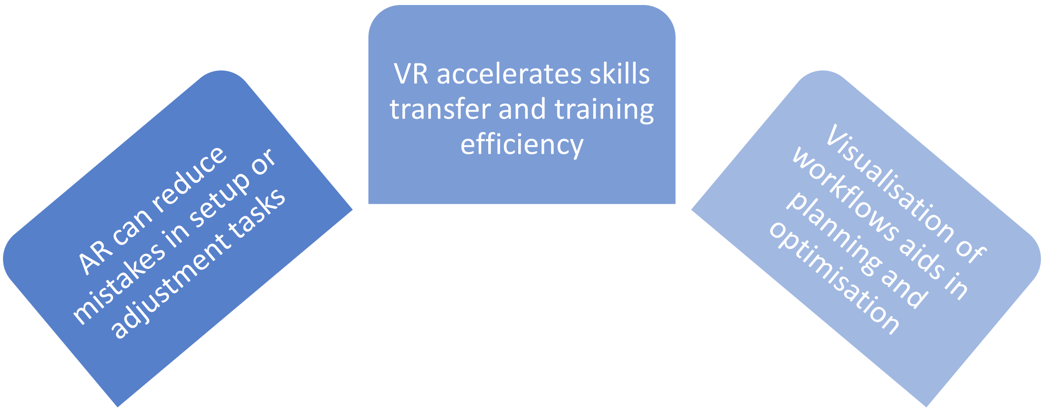


Fig. 32: Main benefits of VR and AR in the footwear technical development phase

6 Case Study and Project Work

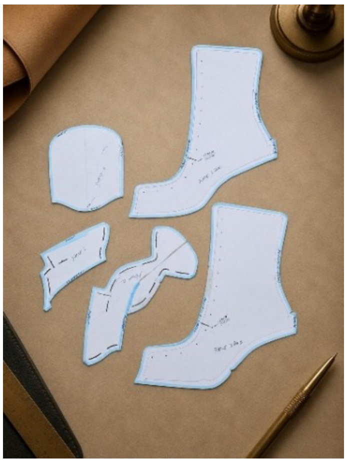
6.1 Case study – CONDUR by alexandru

ANGELINA MAGIC BLUE - *Product Data Sheet*

1. PRODUCT IDENTIFICATION

Product name	**Angelina Magic Blue**	**Line / Collection**	Angelina — Limited Edition
Category	Women's high-heeled ankle boots	**Season / Year**	AW2025–2026
Internal reference	AMB-AW-2025-2026	**Size range**	35 – 40 (EU / Continental)
Colour / Print	Magic Blue — exclusive UV digital print with an expressionist brushstroke effect; predominantly cobalt blue, lime green, multicoloured	**Country of manufacture**	Romania (handmade, artisanal production)
Reference	MAGIC-BLUE Collection	**Genuine leather and accessories**	Imported from Italy

2. MANUAL PATTERN MAKING – PIECES OVERVIEW

Upper pieces	Lining Pieces	Reinforcements
		

3. CONSTRUCTION PARAMETERS AND SHAPE

Parameter	Description
Toe cap shape	Square toe cap— straight front edge at 90°; toe box width: 38–40 mm for EU size 38; ergonomic, allows for natural transverse spreading of the toes. Increment: +1 mm per size.
Quarter height	Ankle boot: 13–15 cm from the ground to the top edge of the boot. Straight, horizontal top edge, without cut-outs. Increment: +3 mm per size, starting from EU 35 at 13.0 cm.
Heel profile and height	Flared sculpted heel (sculptural flared heel): zinc core, painted satin gold. The inner curve at the middle of the heel flares out at the base to a diameter of ~35 mm. H = 9 cm. Heel angle: ~22°. No front platform.
Construction method	Sole: Tunit glued with two-component PU adhesive under cold pressing (20 min). Heel secured with a central M6 stainless steel screw + epoxy adhesive.
Internal reinforcements	Thermoplastic toe-puff at the toe (activated at 70–80°C, inserted between the upper and the lining); thermoplastic back counter at the heel — both contribute to shape retention and impact resistance.
Closure system	Double: (1) Back zip — spiral type 5, centred in the back seam, L ~15 cm, starting 20 mm from the hem, gold-coloured alloy stopper, edges turned in 5 mm and stitched all round; (2) Front lacing — 13 pairs of gold D-ring eyelets spaced 18 mm apart, 10 mm royal blue satin ribbon, laced in an X or straight pattern.
Pull loop	10×30 mm natural leather strap, glossy cobalt blue box- , stitched to the upper rear edge of the buckle. Tensile strength ≥50 N.
Stitching specification	50/3 polyester thread, colour-matched to the print; stitch density 5–6 stitches/cm; double stitching at all stress points (base of the carambol, heel stitching, zip ends). Tensile strength of main stitching ≥40 N/cm.
Sizing and size increments	EU 35–40; last length increases by +5 mm per size; last width by +1 mm per size; heel height by +3 mm per size; toe box width by +1 mm per size. Reference last: EU 38 (internal length 250 mm, width 76 mm).
Cutting efficiency	Pattern tracing on printed leather: target utilisation ≥75%. Critical: pattern pieces must be oriented to align the print direction uniformly for all components of each pair.

4. SIZE RANGE

EU size	Internal length (mm)	Last width (mm)	Quarter height (cm)	Distribution %	Pcs. / 12-pack
35	225	73	13.0	8%	1
36	230	74	13.5	14%	2
37	235	75	14.0	22%	3
38	240	76	14.5	28%	3
39	245	77	15.0	20%	2
40	250	78	15.5	8%	1

Note: Reference shoe size EU 38. Minimum boutique production: 6 pairs per colourway. Maximum production: 20 pairs per colourway per season (limited edition).

5. ANATOMY OF THE HEEL

Structure and function of the components

A	**Upper fixing plate** The surface in contact with the sole of the shoe. The area where the heel is fitted, and it is secured by screw, pin, insert or adhesive.
B	**Upper connection / Transition area** The curved section between the fixing plate and the heel collar. Aesthetic and structural role: distributes stresses and prevents the concentration of pressure.
C	**Heel neck — Load-bearing body** The central, narrower area. It takes up and transmits the weight from the fixing point to the support base.
D	**Support base** The lower part that touches the ground and ensures stability.

FUNCTIONAL ORDER

A attachment to footwear **B** transition + resistance **C** support / load-bearing **D** ground contact + stability

6. MATERIAL SPECIFICATIONS

Component	Material	Origin	Standard	Technical Notes
Uppers	Box calf leather, UV digital print, matt PU lacquer	Italy	SR EN ISO 17131; ISO 11644	1.2–1.3 mm; flex. ≥50,000 cycles; colour fastness ≥3
Vamp lining	Goatskin nappa leather	Italy	SR EN ISO 11644; pH ≥3.5	0.6–0.8 mm; vapour permeability ≥0.8 mg/cm²/h
Quarter lining	Natural, breathable leather	Italy	SR EN ISO 20344:2011	Direct skin contact; moisture absorption ≥65%
Insole cover	Split cowhide, printed CONDUR by Alexandru	Romania	SR EN ISO 20344	1.8–2.0 mm; moisture content ≥70%; CONDUR by alexandru logo
Heel core	Cast zinc alloy, satin gold finish	Italy	SR EN ISO 19953; EN 1811	H=9 cm; base ø35 mm; compression ≥1,200 N; Ni-free
Outer sole	Tunit — vulcanised thermoplastic rubber, black	Romania	SR EN ISO 20344 ; EN 13287	CoF ≥0.32 (wet); abrasion loss ≤150 mm³; 3–4 mm
Insole	1.5 mm cardboard insole + 5 mm PU foam	Romania	SR EN ISO 20344:2011	Impact absorption ≥10, , kN/m; stable at 24-hour humidity
Rear zip	Spiral zip type 5, gold slider (equivalent to YKK)	Italy	EN ISO 5591; EN ISO 2062	L≈15 cm; ≥2,000 cycles; gold alloy stopper
Eyelets	Brass/zinc D-ring, matt gold finish, 13×2 pcs.	Italy	EN 71-3; EN 1811	Internal Ø 5 mm; tensile strength ≥80 N/eye; Ni-free
Lanyard	Polyester satin, royal blue, L=10 mm	Italy	EN ISO 105-C06	L≈80 cm; heat-sealed ends; Pantone 2727 C
Pull loop	Natural leather, cobalt blue	Romania	SR EN ISO 11644	10×30 mm; tensile strength ≥50 N; glossy finish

Note: All materials comply with the EU REACH Regulation (EC) No 1907/2006. Natural leather sourced from LWG-certified tanneries or equivalent. Nickel-free metal fittings (EN 1811). Tests are carried out on a minimum of three pairs per production batch or when changing suppliers.

7. TECHNICAL QUALITY AND TESTING REQUIREMENTS

Test	Standard	Minimum Acceptable Value
Flexibility strength — uppers	SR EN ISO 20344:2011 §8.4	≥50,000 cycles without visible cracks
Sole-to-surface adhesion	SR EN ISO 17708:2003	≥4.5 N/mm (split test)
Axial pull-out strength of heel	SR EN ISO 19953:2016	≥1,200 N
Slip resistance of sole (wet ground)	SR EN 13287:2012	Coefficient of friction ≥0.32
Colour fastness to rubbing (print)	SR EN ISO 11640:2012	≥Grade 3 (wet and dry)
Dye migration onto the lining	SR EN ISO 15700:1999	≥Grade 3
pH of aqueous extract — natural leather	SR EN ISO 4045:2018	pH 4.0–5.5
Zipper durability (cycles)	EN ISO 5591	≥2,000 open/close cycles
Unalloyed nickel — metal fittings	EN 1811:2011	<0.5 μg/cm²/week
SVHC substances (REACH)	EU Reg. (EC) 1907/2006	<0.1% per substance in any component
Tensile strength of D-ring	In-house test — axial tensile strength	≥80 N per eye
Moisture absorption — insole	SR EN ISO 20344:2011 §6.6	≥70% absorption capacity

8. MANUFACTURING PROCESS (ARTISANAL / MANUAL PROCESS)

No.	Phase	Main operations	Quality control point
1	**Cutting**	Manual pattern marking on printed calfskin; cutting press or knife. Print direction alignment checked per component. Target yield ≥75%.	Visual inspection for defects (print consistency, leather surface); check left-right symmetry.
2	**Preparation**	Thinning of edges 0.4–0.6 mm; folding of the upper edge; activation of thermoplastic adhesive at 70–80°C, insertion between the face and lining.	Uniformity of edge thickness; adhesion test for reinforcements (manual peeling).
3	**Eyelet application**	Template-guided perforation; D-ring eyelet pressing; 13 pairs on the front of the carabiner, centre-to-centre distance 18 mm; check for matt gold finish.	Uniformity of spacing (±1 mm); eye stability (tensile test 80 N/eye).
4	**Sewing**	Zip sewn into the rear centre seam (centred ±1 mm; sewn pull tab; stitch density 5–6 stitches/cm; double stitching at stress points.	Seam tensile strength ≥40 N/cm; zip centred; pull tab secure; no puckering.
5	**Lasting**	Lightly moisten the surface; stretch and secure to the last using pliers; thermoform at 60–70°C for 5 minutes; allow to cool on the last for at least 20 minutes before removing.	Uniform shape; correctly formed square toe; no creases or tension marks; symmetry between the pair.
6	**Sole assembly**	Abrasion and priming of bonding surfaces; application of two-component PU adhesive; cold pressing for 20 minutes; heel secured with M6 stainless steel screw + epoxy adhesive; insole insertion.	Shear strength ≥4.5 N/mm; heel perpendicularity; no adhesive leakage on the upper.
7	**Finishing**	Trimming and dyeing of sole edge; conditioning of leather with colourless cream; threading of blue satin ribbon through eyelets; application of water-repellent treatment (silicone/wax) to the upper.	360° visual inspection; symmetrical threading; no adhesive residue; uniform surface finish.
8	**Final inspection and packaging**	Full compliance check against technical data sheet; photographic record per pair; ISO 19952:2005 labelling (composition, size, country of origin pictograms); acid-free paper; individual branded box.	Signed and stamped by the craftsman; internal inspection sheet attached; zero-defect delivery.

9. LABELLING AND MARKING (SR EN ISO 19952:2005)

Mandatory element	Content / Format (SR EN ISO 19952:2005)
Material composition	ISO 19952 pictograms + text: Upper 100% Natural Leather | Lining 100% Natural Leather | Outsole: Thermoplastic Rubber (moulded)
Size marking	EU / Continental system: 35 / 36 / 37 / 38 / 39 / 40 — stamped on the insole and printed on the box
Trademark	CONDUR by alexandru — printed on the insole; label sewn inside the lining on the heel; printed on the box lid
Country of origin	Made in Romania — insole, inner label, box
Origin of accessories	Genuine leather and accessories imported from Italy — stated on the inner label of the shoe
Care instructions	Clean using products specifically designed for dyed/printed natural leather; avoid prolonged exposure to moisture or direct sunlight; store in an anti-static bag; periodically lubricate the zip with zip wax; the satin ribbon is replaceable

10. DESIGN NOTES, COLLECTION CONTEXT AND RELEVANCE

Printing technology and design identity

The face of the Angelina Magic Blue model is crafted from box calf leather that has undergone a UV digital transfer printing process, producing an exclusive expressionist brushstroke pattern in cobalt blue, lime green, yellow, magenta and white on a deep blue background. A matt PU protective lacquer is applied post-print to ensure colour fastness (ISO 11640 ≥ Grade 3) and resistance to surface abrasion. The nature of digital printing means that no two pairs are visually identical — a deliberate design choice that reinforces the limited-edition positioning and artisanal character of the CONDUR by alexandru brand.

Square toe cap — ergonomic and aesthetic design

The square toe acp is preferred to the pointed toe cap for two complementary reasons. Ergonomically, the wider, orthogonal toe cap allows for the natural lateral spread of the forefoot when bearing body weight, reducing compressive forces on the first and fifth metatarsophalangeal joints. Aesthetically, the square profile creates a voluminous, architectural silhouette that anchors the fluid brushstroke print above and offers a contemporary counterpoint to the classic heel shape. The width of the toe cap increases by +1 mm per size, consistent with foot morphology data for the European female population.

The sculptural flared heel — structural and biomechanical considerations

The sculptural flared heel, featuring a metal core and a satin gold finish, is the signature feature of the Angelina range. The geometry of the flared base (base diameter ~35 mm compared to ~12 mm for a standard stiletto of the same height) increases the contact area with the ground and reduces localised pressure on the outer sole by an estimated 30–35%. The inward curve at the mid-heel provides an aesthetic contrast between the narrow shaft and the flared base. The die-cast zinc core meets the compressive strength requirement of SR EN ISO 19953 (≥1,200 N axial), whilst the secondary fastening with an M6 stainless steel screw + epoxy eliminates modes of failure under torsion.

The dual locking system — functional and semiotic dimensions

The combination of a rear zip and a front D-ring lacing system with a satin ribbon meets both functional and aesthetic requirements. The zip allows for quick putting on and taking off — essential for a 13–15 cm heel height — whilst the lacing system allows for circumferential adjustment of the heel, accommodating variations in calf width across the EU size range. Stylistically, the satin ribbon lacing references the traditions of Victorian ankle boots, placing the Angelina Magic Blue model within a lineage of decorative footwear that celebrates craftsmanship and ceremony. The unified gold metallic finish across all hardware (zipper pull, D-ring) creates visual coherence between the fastening system and the heel.

Sustainability and traceability

All materials comply with EU REACH Regulation (EC) No 1907/2006. Natural leather is sourced from LWG-certified tanneries or equivalent, ensuring responsible management of water and chemicals throughout the tanning process. Metal fittings (eyelets, zip pullers) are free from free nickel in accordance with EN 1811:2011, eliminating the main risk of contact allergens associated with footwear hardware. The construction method is also chosen for its compatibility with low-VOC adhesive systems; the two-component PU adhesives used comply with current VOC restrictions. As a limited-edition boutique product (max. 20 pairs per colourway per season), the model generates minimal production waste and does not contribute to the overproduction of stock — in line with the principles of the circular economy set out in the manual.

DECLARATION OF CONFORMITY

This product complies with: EU REACH Regulation (EC) No 1907/2006 · SR EN ISO 20344:2011 · SR EN ISO 19952:2005 · EN 1811:2011 (nickel-free) · General Product Safety Regulation (EU) 2023/988

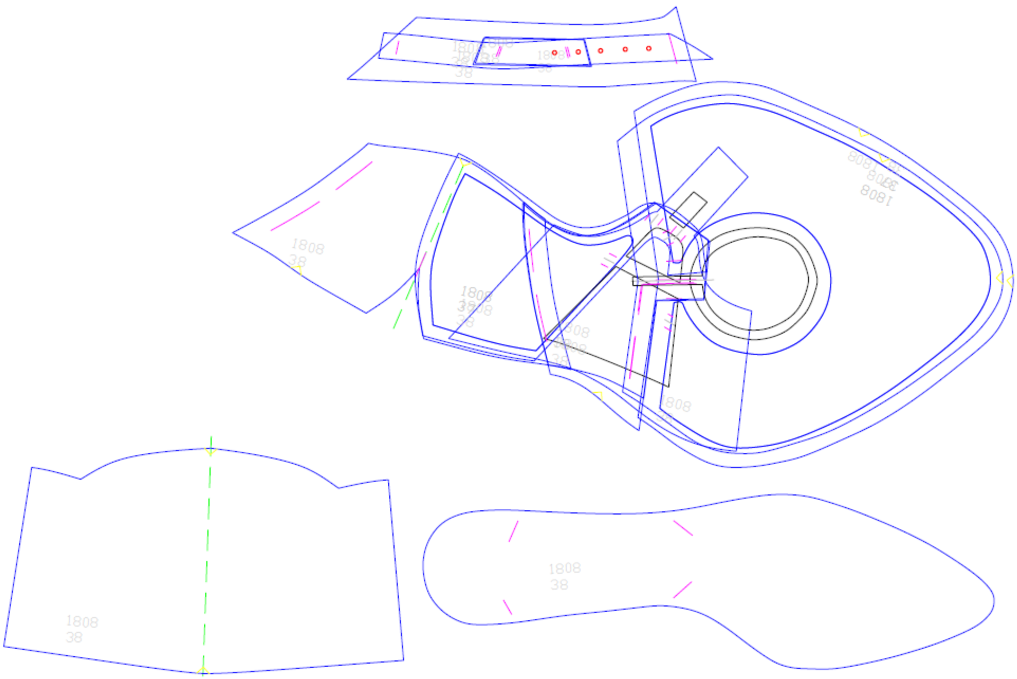
FANTASY BLUE MAGIC - *Product Data Sheet*



1. PRODUCT IDENTIFICATION

Product Name	**Fantasy Blue Magic**	**Collection Line**	Heavy Heel
Season / Year	SS 2026	**Size range**	35 – 40 (FR/Continental)
Internal reference	FBM-HH-2026	**Colour code**	Blue Magic Print
Category	Women's block-heel shoes with adjustable strap	**Manufactured**	Romania (handmade)

2. FANTASY BLUE MAGIC - MASTER PATTERN (*designed with Elitron CAD)*



3. CONSTRUCTION PARAMETERS AND SHAPE

Parameter	Description
Toe cap shape	Short pointed toe — front angle ~25°; design that visually elongates the foot without compromising toe cap comfort
Heel height	9 cm — cobalt blue lacquered block heel (Heavy Heel)
Heel type	Heavy Heel — solid, sculptural heel with a geometric visual effect; base ≥ 3.5 cm wide; superior stability compared to a stiletto heel of the same height (35% forefoot pressure)
Reference last	Women's last EU 38 (internal length 250 mm); series increment: +5 mm/size
Assembly system	Assembled (thermally bonded + perimeter stitching to the upper); sole cold-glued with polyurethane adhesive
Construction type	Slip-lasted with internal thermoplastic reinforcement (toe-puff + back counter)
Strap / Fastening	Double transverse ankle strap adjustable via 2 buckle straps, 3 positions each
Front graphic design	Exclusive digital print on leather featuring a unique expressionist brushstroke motif in blue and lime green with red accents; UV transfer technique, certified for durability; exclusively on natural nappa leather

4. SIZE RANGE

EU Size	Internal length (mm)	Last width (mm)	Distribution %	Pcs. / 12-pack	Note
35	225	73	8%	1	Small series
36	230	74	14%	2	—
37	235	75	22%	3	Frequent
38	240	76	28%	3	Reference
39	245	77	20%	2	—
40	250	78	8%	1	Small series

5. MATERIAL SPECIFICATIONS

Component	Material	Standard	Technical notes
Upper	Genuine leather — calf nappa, UV digital print	SR EN ISO 17131:2012 SR EN ISO 11644:2009	Thickness 1.2–1.4 mm; front-side dyeing; flex resistance ≥ 50,000 cycles; UV print certified for abrasion resistance
Lining	Genuine leather — goatskin/nappa	SR EN ISO 11644:2009; pH ≥ 3.5	Vapour permeability ≥ 0.8 $mg/cm^2 \cdot h$; certified thermal comfort
Insole	Genuine leather (pig/cow split)	SR EN ISO 20344:2011, clause 6.6	Moisture absorption ≥ 70%; thickness 1.8–2.2 mm
Heel	ABS/metal core covered with cobalt blue patent leather	SR EN ISO 19953:2016	Height 9 cm; base diameter ≥ 35 mm; compression 100 kgf
Outer sole	Tunite (vulcanised thermoplastic rubber)	SR EN ISO 20344:2011, clause 8.2 SR EN 13287:2012	Coefficient of friction ≥ 0.3; abrasion resistance ≥ 150 mm^3
Insole	Cardboard insole + 5 mm PU foam	SR EN ISO 20344:2011	Heel impact absorption ≥ 10 kN/m; moisture resistance 24h
Fastening system	Double strap with adjustable metal buckles	EN 71-3; nickel < 0.5 $\mu g/cm^2$/week	Finish: matt gold; corrosion resistance ≥ 96h brine

All materials comply with the REACH Regulation (EC) No 1907/2006 and are tested in accordance with the applicable EN ISO standards.

6. TECHNICAL QUALITY AND TESTING CONDITIONS

Test	Standard	Minimum permissible value
Flexural strength (front)	SR EN ISO 20344 clause 8.4	≥ 50,000 cycles without cracks
Sole-to-upper adhesion	SR EN ISO 17708:2003	≥ 4.5 N/mm
Heel tear resistance	SR EN ISO 19953:2016	≥ 1000 N (axial force)
Sole slip (wet ground)	SR EN 13287:2012	Coefficient of friction ≥ 0.30
Colour fastness to rubbing	SR EN ISO 11640:2012	≥ grade 3 (wet/dry grey)
UV print abrasion resistance	SR EN ISO 11640:2012 adapted	≥ grade 4
Dye migration onto the backing	SR EN ISO 15700:1999	≥ grade 3
pH of aqueous leather extract	SR EN ISO 4045:2018	pH ≥ 3.5 (preferably 4.0–5.5)
SVHC content (REACH)	Reg. EC 1907/2006	< 0.1% per substance

Tests are carried out on samples from each production batch or when changing material suppliers. UV digital printing is subject to an additional colour fastness testing protocol.

7. MANUFACTURING FLOW (ARTISANAL / MANUAL PROCESS)

No.	Phase	Main operations	Quality control
1	**Cutting**	Manual pattern marking on printed nappa leather; cutting with a cutting knife or press; optimisation of usable area ≥ 75%; particular attention to the continuity of the graphic pattern at the seams	Check for visual defects in the leather; align the print with the template
2	**Component preparation**	Thinning of front edges 0.4–0.6 mm; double-folding of the welt; application of reinforcements (toe-puff, back counter) using thermosetting adhesive	Uniform thickness; left-right symmetry
3	**Sewing (top assembly)**	Front stitching on lining, double-bar stitching and application of 2 buckles; decorative perimeter stitching	Stitch strength ≥ 40 N/cm; stitch density 5–6 stitches/cm
4	**Shaping on the last**	Light dampening of the front; pulling and fixing to the last with pliers; thermoforming at 60–70°C for 5 min.	Uniform shape; no creases or uneven pressure
5	**Sole + heel assembly**	Surface abrasion; primer; sole bonding using two-component PU adhesive; cold pressing for 20 mins; bonding of lacquered cylindrical heel (screw + adhesive)	Shear test ≥ 4.5 N/mm; heel verticality
6	**Finishing**	Cleaning of sole edges; polishing of front; waterproofing treatment (wax/silicone); insertion of insole	Final visual inspection; symmetry of pairs
7	**Final check & packaging**	Check for compliance with technical specifications; photograph each pair; labelling (composition, size, origin); packing in acid-free paper box	Each pair signed by the craftsman; internal inspection certificate

8. LABELLING AND MARKING (IN ACCORDANCE WITH SR EN ISO 19952:2005)

Mandatory element	Content / Form
Material composition	ISO 19952 symbols + percentages: Upper: 100% genuine leather | Lining: 100% genuine leather | Outsole: thermoplastic rubber | Heel: leather + ABS/metal core
Size	Sizes: 35 / 36 / 37 / 38 / 39 / 40 (European/continental sizing)
Trademark	CONDUR by alexandru® — logo embossed on the insole and printed on the box
Country of origin	Made in Romania
Care instructions	Clean with products specifically designed for natural leather; do not expose to extreme humidity or direct sunlight; store in an anti-static bag; the UV print requires no special care — protected against normal wear and tear

9. DESIGN NOTES, COLLECTION CONTEXT AND RELEVANCE

Design & Ergonomics

The Heavy Heel block heel offers superior stability compared to a stiletto heel of the same height, reducing pressure on the forefoot by ~35% (force distribution over a larger surface area). The short, pointed toe visually elongates the line of the foot without compromising comfort in the toe box. The combination of a high heel and an adjustable double strap ensures ankle support — a critical factor for active wear and prolonged comfort.

Digital Print & Sustainability Materials

The exclusive digital print on leather is created using UV transfer technology — compatible with vegetable-tanned natural leather. The technology allows for the optimisation of the usable leather surface (reducing waste through digital pattern layout), contributing to sustainability and circular economy objectives.

Relevance

Fantasy Blue Magic illustrates the convergence of several key themes in the manual:

1. the digitisation of the design process through UV printing and CAD;
2. sustainability through optimised cutting and the selection of REACH-certified materials;
3. globalisation through a boutique-artisan identity as a response to industrial standardisation;
4. traceability through comprehensive supply chain documentation. The limited-edition production supports the CONDUR by alexandru boutique model and promotes the value of Romanian artisanal authenticity.

Niche product · Boutique limited edition (max. 30 pairs/season per colourway)

6.2 Structure of the project work

Topic/Theme: Develop a footwear technical development project focused on 2D pattern making, technical data sheets, and material consumptions, while integrating the impact of globalisation, digitalisation, and sustainability.

Research & analysis

- Analyse the design brief and sketches.
- Identify product particularities in terms of footwear construction methods, materials, pattern engineering techniques, and industrial development workflows.
- Investigate digitalisation tools used in footwear technical development (e.g., CAD systems).
- Assess sustainability challenges linked to material waste, overconsumption and inefficient cutting processes.

Digital technical development

- Develop digital 2D patterns using CAD software.
- Produce complete technical data sheets.
- Create digital consumption markers and material nesting layouts.

Prototype preparation & industrial validation

- Prepare the technical package for prototype manufacturing in a footwear company or/and in a Fablab.

Physical prototyping

- Manufacture the physical prototype in a footwear company or/and in a Fablab.
- Validate pattern accuracy, fitting consistency, and assembly feasibility.

Presentation & evaluation

- Compile a visual and written report documenting all project stages.

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