DIGITAL TOOLS IN THE FOOTWEAR DESIGN PROCESS:

From traditional practices to artificial intelligence

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This thesis examines the challenges of introducing a digital approach into the footwear design process. There have been significant improvements in the quality of footwear design programs in recent years. Many companies have already adopted the new digital tools into their designs, while others are still preparing for them to be implemented. According to this thesis, the contribution of 3D software could be a useful tool in helping to solve the challenges inherent in traditional design and development workflows.

The main focus of this thesis is to explore the use of digital tools in the footwear design process. This thesis is the result of research concerning digital products' role in the footwear industry. The objective of the thesis is to determine the differences between the traditional way and the new digital way of designing footwear.

Research methods used in this study are primarily based on the review of online resources on digital footwear design and the review of professional literature. The study covers the main concepts and terms of the digital footwear design process, as well as the traditional footwear design process and its acceptance of digitalization.

In order to be able to build a conclusion on the main proposition of the study, the practical part of the study aims to test the theory introduced. The implementation part of the project involves conducting own research: interviews with professionals. This is designed to understand the strengths and weaknesses of each methodology in terms of its application and result. The practical part presents the case study as well where the digital tools were applied to the design process of a shoe. The main goal is to examine the possibility of creating the footwear concept fully digitally, and explain how digital tools affect the design process and the key benefits of using them within the design process through the case presented.

A study's final result is the conclusion based on the research, analysis, and case study carried out. The comparison of traditional and digital ways of designing footwear is made to show how digital tools can add value to the design process.

Keywords Digital tools, digital footwear, AI, design process.
Pages 59 pages and appendix 1 page

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1 Introduction

Footwear has been an essential part of human life since the dawn of civilization. From keeping feet warm in the cold months to providing support and protection in the heat of summer, footwear has been an important part of everyday life. Today, the industry continues to evolve, with innovations being introduced every year. The rise of 3D modeling in shoe design has made a significant impact on the industry. With the advent of new technologies, many new possibilities have opened up for designers and companies in the footwear industry.

The use of 3D Modelling and artificial intelligence (AI) has allowed for the creation of realistic models of shoes and has become a tool that has been increasingly used in the design process. With 3D modeling, designers can visualize the design of their shoes before creating them in the physical world. This enables them to make modifications as necessary before building the prototype and introducing it to the market By incorporating this new technology into the design process, designers can create much more realistic images of shoes. They also have much more freedom in their design process. But what is the potential impact of digital concepts on the footwear industry and what are the challenges and limitations that need to be overcome to fully realize its benefits?

There is still a lot of confusion regarding how digital footwear concepts work and how they can be utilized in the field, even though they are becoming more widely known. As a result, many businesses still prefer to design their products in the traditional way.

Footwear design has evolved significantly over the years, with advancements in technology paving the way for new techniques and tools. The traditional footwear design process has been used for decades, but with the emergence of digital tools such as modeling software and AI technologies, designers have the opportunity to enhance their creativity and streamline their work process. The purpose of this thesis is to compare the traditional footwear design process and the digital footwear design process, highlighting the advantages and disadvantages of each approach.

It is important to mention that this thesis examines the design process of only casual footwear and does not apply to any other types such as performance and safety footwear, etc.

The result of this thesis is a research and practical based conclusion on the possibilities of the use of digital tools in the footwear design process, their impact on the footwear field, and their comparison with the traditional footwear design process. The traditional way of designing footwear will be introduced and explained in order to show the main characteristics of the design process. The digital approach to designing footwear will be introduced as well and explained in order to introduce the new digital way of designing footwear and show the main characteristics of this new design process. Interviews with professionals will be held to get their opinion on a matter. Three interviewees will share their opinions on three open questions. The interview format is semi-structured, which involves the utilization of predetermined open-ended questions and an overarching framework, however, the conversation may flow organically in a direction that aligns with the research goals or caters to the specific characteristics of the respondent (George, 2022). The questions are responded to in written format, after which the analysis of the responses is done and presented. The case study will be presented as well on the process of designing a digital shoe concept, to examine the possibility of creating designing footwear concept with the use of digital tools only. AI and 3D modeling software are the main digital tools presented in the case study.

Based on the research carried out in the thesis as well as the case study the conclusions will be made by presenting the comparison of the traditional and digital ways of designing footwear and the main contribution of digital design tools in footwear design.

2 Background research

To be able to compare traditional and digital footwear design processes the basics of each should be introduced. All essential theories about the traditional footwear design process and digital footwear design process are gathered and introduced in detail. The theory part aims to provide the basics of the theories of the traditional footwear design process and

digital footwear design process based on a review of professional literature and other sources related to the research area. The method used is to conduct literature research to identify the key theories and assumptions in the field of footwear design and apply those theories to the identification of similarities and differences between the two processes to create the base for further research.

2.1 Traditional footwear design process

Footwear design is a complex and multifaceted process that involves the creation of footwear products for both functional and aesthetic purposes. Footwear designers must possess a unique blend of technical skills, creativity, and knowledge of consumer behavior, ergonomics, material science, as well as manufacturing processes. The traditional footwear design process entails a series of steps that require designers to go through research, concept development, design, material selection, prototyping, and testing in order to arrive at a final product that satisfies the needs and wants of the target market. In this research, a comprehensive description of the traditional footwear design process, along with references to relevant literature sources, is provided.

2.1.1 Research

The research process is the first step in the traditional footwear design process. It involves collecting information on market trends, consumer preferences, materials, and technologies that are relevant to the design. It is essential that designers conduct extensive research before they can develop a product that meets the needs and desires of the target market. As part of market research, fashion trends are studied, consumer behavior and preferences are examined, and market gaps are identified. As part of material research, it is important to examine the physical properties of various materials and evaluate whether they are suitable for the product's intended purpose.

It has been concluded that in order to design a successful product, designers have to be aware of current market trends and consumer preferences (McCann et al., 2009, pp. 7—9). Consumer research is a method of gathering information about consumer behavior,

preferences, and purchase patterns. There are a variety of ways in which this can be accomplished, including surveys, focus groups, and observational studies. Designing a product that meets the market's needs and preferences helps designers develop products that satisfy consumers' needs and preferences.

2.1.2 Concept development

The second step in the traditional footwear design process is concept development. Concept development involves generating ideas and developing a design concept. There are several techniques that designers utilize in order to develop a design concept, including sketching, brainstorming, and mood boards. Designers should create a clear design concept that sets the direction for the design process based on the research findings and the needs of the target audience.

It has been established that designers need to have a deep understanding of the problem they are trying to solve, in addition to the user they are designing for (Brubacher et al., 2021). Creating a design that meets the needs and preferences of a target market is the responsibility of the designer. Designers should be able to identify their target market, understand their needs, and create a design that meets their needs, including functionality, aesthetics, and ergonomics is essential.

2.1.3 Design

After the concept development phase, the designer moves on to the design phase. In this phase, the designer develops a detailed design specification that includes technical details such as dimensions, materials, and construction methods. When designing a shoe, the designer must take into account several factors, including the user's requirements, market trends, and footwear functionality. In traditional shoe design, sketches are drawn on paper, and then prototypes are constructed from simple materials such as cardboard, foam, and tape.

The design stage is a critical part of the traditional footwear design process. During this phase, the designer focuses on creating a detailed design specification that includes

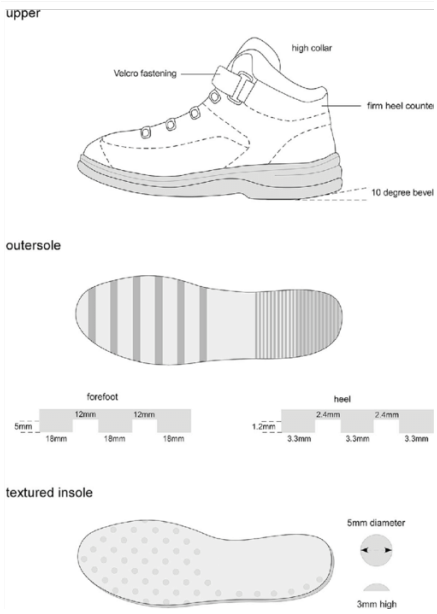
technical details such as dimensions, materials, and construction methods. In addition to meeting the user's requirements, the designer must ensure that the shoe stands out in the market as well. It is imperative that the designer considers several factors when designing shoes, including user requirements, market trends, and shoe functionality.

Designers should create sketches of the shoe from various angles and provide a detailed description of each element of the shoe (Chertenko & Tukalo, 2018, p. 2). A designer must create a design that not only looks good but also functions well (Menz et al., 2017, p. 2). The design should be aesthetically pleasing, comfortable to wear and meet the performance requirements. In addition, the designer should consider the sustainability aspect of the shoe, such as the use of eco-friendly materials, reducing waste, and improving the overall environmental impact.

During the design process, the designer starts by sketching the shoe on paper, which is then refined and developed further by the designer. During this process, the designer is able to explore several design possibilities and select the best one among them (figure 1).

When designing shoes, the traditional method involves creating patterns for each component of the shoe, such as the upper, etc. Once the design has been finalized, the designer creates a pattern that is then used to cut the prototype material.

Figure 1. Prototype footwear and insoles (Menz et al., 2017, p.4).



Some digital tools such as CAD software can be involved at this stage of the traditional design process. The software is widely used in the industry and can be included in traditional and digital designing processes.

2.1.4 Material selection

There is a fourth step in the traditional footwear design process which is material selection. Designers have to choose the right material for the shoe in order to achieve the desired result. A designer must take into account a variety of factors, such as durability, comfort, and aesthetics of the materials, along with the cost and availability of the materials. When designing a product, material selection is a crucial part of the process because it can have an impact on the product's functionality, aesthetics, and cost. In addition to the cost and complexity of using certain materials, some materials are more difficult to work with than others. It is extremely important for designers to select the appropriate material for their products in order to avoid making expensive mistakes or creating poorly designed products.

It is important for designers to choose materials that are durable, comfortable, aesthetically pleasing, and easy to source (Cho et al., 2009). As well as being cost-effective and easily accessible, the designer should also consider the environmental impact of the materials they select. In order to reduce waste, designers should pay attention to the types of materials which can be recycled.

2.1.5 Prototyping

As part of the traditional footwear design process, the prototype is a key component. By testing and refining the design, the designer is able to refine the design for the final product. First prototypes are often created by hand, utilizing basic materials such as cardboard, foam, and tape to create them. Despite taking some time to do this method, it gives the designer the opportunity to see and feel the prototype up close. It is important for the designer to ensure that the final product meets all the criteria they have outlined for the shoe design before manufacturing them in large quantities.

It has been shown that the process of developing a prototype is very similar to the process of developing a final product in terms of its design and functionality (Menz et al., 2017, p.5). The prototype be made from materials that are similar to those in use in the final product. Any necessary changes can be made before the final sample is created. This enables the designer to evaluate the fit, comfort, and overall aesthetics of the shoe. It is also possible to use the prototype for testing purposes, like testing its durability and functionality. After the prototype is evaluated and modified, a final sample is created, which is used for testing and market evaluation. By conducting a series of tests on the final product and its materials, the designer can ensure that the product is what they want and need to sell to their target customers.

2.1.6 Testing

A key part of the traditional footwear design process is testing, which is the process of evaluating the final sample in order to ensure that it complies with the user's requirements, safety standards, as well as manufacturing guidelines. As part of the testing process, the designer is also able to identify any flaws in the design so that any necessary modifications can be made before mass production.

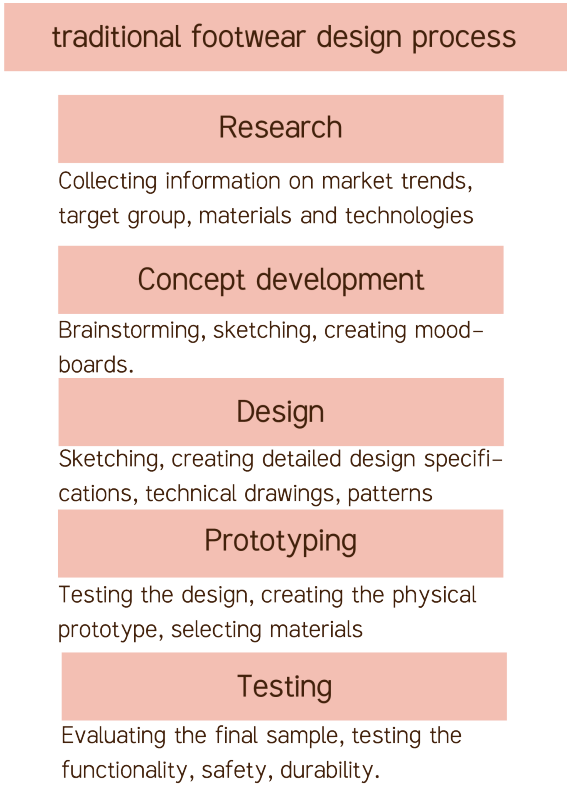
Designers need to conduct several tests, including wear tests, safety tests, and durability tests (MTS, 2018, pp. 3—6). As part of safety tests, the shoe is tested for slip resistance, impact resistance, and puncture resistance. Durability tests include evaluating the shoe's ability to withstand normal wear and tear as well as testing its durability.

2.1.7 Summary

Traditional footwear design involves several stages, including research, concept development, design, material selection, prototyping, and testing, all of which are complex, multifaceted processes (figure 2). For the process to work effectively, designers need to combine technical skills, creativity, and a thorough understanding of consumer behavior, ergonomics, materials science, and manufacturing processes with a unique blend of technical skills and creativity. Shoes are traditionally designed by sketching out a design on

paper, creating a pattern for each component of the shoe, and then constructing a prototype of the shoe using basic materials to make a working prototype. After the prototype is evaluated, it is modified, and then a final sample is created, which is used for testing and market testing. It is essential to include testing in the traditional process of developing footwear since this ensures that the final product will meet the requirements of users, safety regulations, as well as manufacturing requirements. Some digital tools (such as footwear CAD software) can be used in a traditional design process, as they are widely used in the field and considered by many as a part of a traditional process as well.

Figure 2. Traditional footwear design process: Summary.



2.2 Digital footwear design process

As a result of digital technology, the design process has been revolutionized, resulting in new opportunities and possibilities for designers. Footwear design is a complex process involving creativity, technology, and innovation. In this research, various stages and technologies used in the digital footwear design process are introduced. A detailed description of each part of the process is provided along with references to relevant literature sources. The digital

footwear design process can be broken down into several stages, such as concept development, 3D modeling, virtual prototyping, physical prototyping, and testing, each of which involves different tools and technologies. The following is an overview of these stages.

2.2.1 Concept development

Initial concepts and ideas for footwear design are developed during this phase. This step is usually similar to the traditional concept development process. Despite the widespread use of sketching, mood boards, and other traditional methods, digital tools such as Adobe Illustrator, Sketchbook Pro, and Procreate are also commonly used to create digital sketches and drawings. With these digital tools, designers can modify and refine their ideas more easily, providing greater flexibility. There is also a variety of 3D sketching software that can be used to create digital footwear concepts, In this case, there is no need to switch between 2D and 3D and the process of 3D modeling can start already in the development stage.

The incorporation of AI or Artificial Intelligence in concept development through digital tools is worth mentioning. Although not yet a common practice, its application in the field has become more widespread and provides designers with potent resources to develop innovative concepts and designs. Presently, various free AI tools are available for shoe designers enabling them to produce new designs by generating them from scratch using basic prompts as well as simulating human movement while walking on shoes that assist the design process.

The utilization of artificial intelligence (AI) has commenced in the production of personalized footwear. Notably, Adidas and Nike have established AI-based platforms that scrutinize customers' foot scans to generate bespoke shoes that fit precisely (Galer S., 2019). This technological innovation is significantly transformative for the footwear sector as it empowers consumers to procure shoes customized according to their unique requirements and inclinations (Thomas, 2019).

2.2.2 3D modeling

Digital footwear design requires the use of 3D modeling as an essential part of the design process. Virtual models of designs can be created to enable designers to create accurate and detailed prototypes and simulate different manufacturing processes, which are then used to create physical prototypes. As footwear design involves complex shapes and geometries, 3D modeling is particularly useful (Davial-Aracil et al., 2017).

There are several types of software available for 3D modeling in footwear design, each with its strengths and weaknesses. Rhino, SolidWorks, and AutoCAD are some popular software programs (Davial-Aracil et al., 2017). All of these software programs are designed to allow users to create 3D models of their designs but have different user interfaces and features.

The ability to create accurate and detailed models of footwear designs is a major advantage of using 3D modeling software for footwear design (Choi, 2022). By using this level of precision, designers can create intricate and complex geometries that are otherwise impossible or difficult to produce using traditional methods. In addition, 3D modeling allows designers to experiment with different design concepts quickly and easily, as changes can be made to the virtual model by simply clicking on a few buttons.

3D modeling in footwear design also provides the capability of creating digital prototypes (Choi, 2022). The purpose of digital prototypes is to test the functionality, aesthetics, and usability of the final product. By using 3D modeling software, digital prototypes can be constructed quickly and easily, and they can then be modified and refined as necessary until the final design is ready to be produced.

Using 3D modeling in footwear design provides numerous advantages, including the ability to simulate a variety of manufacturing processes c). Injection molding, for example, can be challenging to create using traditional methods, and this includes simulating the process of creating shoe soles. By simulating the manufacturing process in 3D modeling software, potential design issues or manufacturing issues can be identified before production begins, saving time and money in the long run.

Although 3D modeling software can be used in footwear design, there are also some limitations. There are several challenges associated with using this software, including the steep learning curve. To effectively use 3D modeling software, significant amounts of training and experience are required. Additionally, the software requires high-quality data, including accurate foot measurements, to create accurate models of footwear designs.

The benefits of using 3D modeling in footwear design, despite these limitations, outweigh these drawbacks for many designers. As well as the benefits previously mentioned, 3D modeling can also facilitate the design process by allowing designers to collaborate with others remotely and easily share their designs. As a global industry such as footwear design, this can be particularly valuable.

2.2.3 Virtual prototyping

Virtual prototyping is the process of using simulation software to test the design virtually. This stage allows designers to identify potential issues and optimize the design before physical prototyping. Visual prototyping is usually closely connected to 3D modeling.

The designer can use computer-aided design (CAD) software to create digital designs, which can be viewed in 3D and manipulated to make modifications quickly.

CAD software allows designers to create complex designs, experiment with various materials, and view the shoe from all angles, which saves time and resources (Davial-Aracil et al., 2017). Using computer-aided design software, designers can create digital designs, which can be viewed in 3D and manipulated quickly to make changes. With the help of software such as virtual fit technology, a virtual prototype can be created based on a digital design that can be tested for fit and comfort (Goonetilleke, 2012, pp. 213—261).

The use of finite element analysis (FEA) software in footwear design is common as well. This software allows designers to simulate the performance of footwear designs under different circumstances, such as impact and stress (figure 3). As an example, Ansys is a popular FEA software for footwear design, which allows designers to simulate and optimize the design before physical prototyping (Goonetilleke, 2012, pp. 321—341).

Figure 3. Finite element modeling of sports shoes (Cho et al., 2009, p.4).

Overall digital prototyping is saving a lot of time and reduces the material waste that would be used for creating the same prototypes by hand. It allows people to see the result right away, change materials, and even the text of the virtual prototype.

2.2.4 Physical prototyping

A physical prototype of the footwear design is created during physical prototyping. An array of materials and methods can be used to manufacture the prototype, including 3D printing, CNC machining, and traditional handcrafting techniques. This stage enables designers to test and evaluate the design in the real world. The use of 3D printing in footwear design is becoming increasingly popular as it enables designers to create accurate and detailed prototypes rapidly (Davial-Aracil et al., 2017).

As a result of virtual prototyping, physical prototyping might not be necessary for some situations. A virtual prototype can be generated in minutes, whereas a physical prototype requires several days to produce. Therefore, a virtual prototype can be more cost-effective

than a physical prototype for prototyping designs that are tested on a smaller scale (Goonetilleke, 2012, pp. 339—341).

2.2.5 Testing

Testing is the process of evaluating the performance, comfort, and usability of the footwear design. Biomechanical testing, wear testing, and user testing are commonly used to evaluate footwear design. Biomechanical testing involves analyzing the movements and forces associated with walking, running, and other activities. Wear testing involves wearing the footwear design under different conditions to evaluate its durability and comfort (MTS, 2018, pp.3—6). User testing involves gathering feedback from users to evaluate the usability and design of the footwear. For example, Nike uses a range of testing methods, including biomechanical testing, wear testing, and user testing, to evaluate its footwear designs (Green Chemistry & Commerce Council, n.d.).

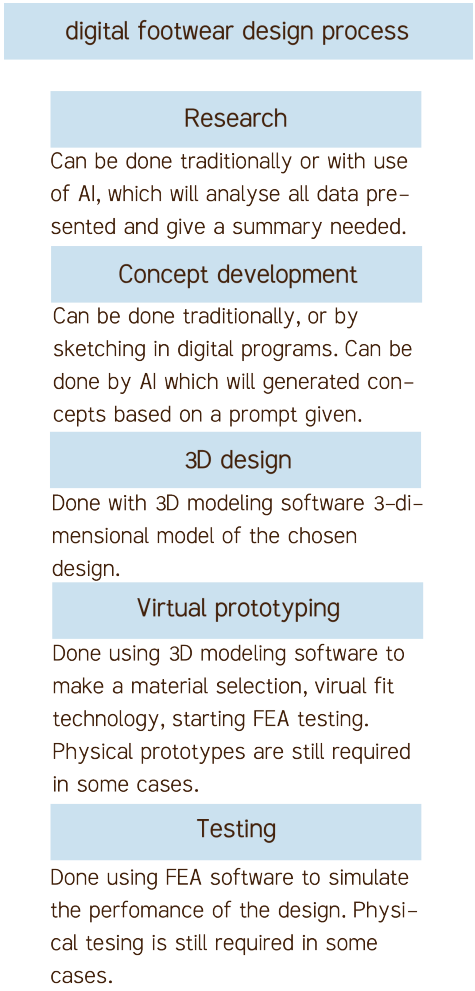
As mentioned before, some of the testing practices can be done on a stage of virtual prototyping already with FEA, and although it might not be enough for many cases, will definitely save some time and reduce unnecessary material waste. To help designers to spend less time and money testing their designs, designers can integrate product testing on a stage of virtual prototyping into the design process to get closer to their real purpose (Azariadis et al., 2019, pp. 60—65).

2.2.6 Summary

In conclusion, the digital footwear design process involves several stages, from concept development to production. Each stage involves different tools and techniques, from digital sketching and 3D modeling to virtual prototyping and testing (figure 4). In contrast to traditional methods, designers can create detailed and accurate designs more quickly and easily by using digital tools and technologies. The noteworthy integration of digital tools utilizing Artificial Intelligence (AI) in concept development is a topic of interest. Despite not yet being widely adopted, this technology has gained popularity within the field and offers designers powerful resources to create inventive designs and concepts. Nevertheless, the

learning curve associated with digital tools, the need for high-quality data, and the cost of digital technologies can also serve as barriers for smaller or independent designers. The examples of digital footwear design demonstrated, however, the potential for innovation and creativity in footwear design. Additionally, digital tools can help designers make their ideas easier to create and test, which can benefit the design process and increase the chances of success of their designs. The digital footwear design process also allows skipping some of the traditional footwear design stages, although it is not applicable to all cases.

Figure 4. Digital footwear design process: Summary.



3 Interviews

In recent years, the incorporation of digital tools has substantially increased in the footwear design process. This advancement provides designers with various opportunities to create

unique, tailor-made, and eco-friendly shoes. Although depending excessively on these technological gadgets might have its pros and cons, it is highly probable that they will significantly influence the future direction of footwear design in diverse aspects.

In order to explore the complete capabilities of digital tools in footwear design, a series of interviews were conducted with professionals from the fashion and footwear industry. These experts hailed from various countries across the globe and shared their perspectives on how digital tools are influencing the overall process of creating shoes. The insights gleaned from these conversations have been thoroughly analyzed and are presented herein for academic consideration.

The interview format has a semi-structured nature, which involves the utilization of predetermined open-ended questions and an overarching framework (George, 2022). However, the conversation may flow organically in a direction that aligns with the research goals or caters to the specific characteristics of the respondent. The questions posed are responded to in written format, after which a thorough examination of the responses is conducted and subsequently presented.

3.1 Interviewees

Three experienced individuals from the fashion industry were selected to partake in the interview, each possessing unique backgrounds and varying levels of expertise garnered over numerous years.

1. Svetlana Abdulova – freelance fashion buyer (former “Prada”, “Mercury”).
2. Pavlo Pecheniuk – former senior buyer in “THE ICON” and “SPAZIO”.
3. Daniele Radi – entrepreneur and owner of DR concept sas fashion agency specializing in fashion distribution in eastern countries.

The individuals interviewed predominantly operate in the retail sector. Their perspectives hold significant academic merit and offer insight into how digital design tools affect this industry as a whole, including their impact on post-design processes.

3.2 List of questions

The interviews comprised a series of three open-ended inquiries that aimed to gather insights from experts and practitioners in the domains of footwear and fashion concerning the potential applications of digital technologies in shoe design. The questions were deliberately kept broad, affording participants the flexibility to share their perspectives based on their specific areas of expertise within these industries.

1. What are the advantages of the usage of digital tools in the footwear design process compared to the traditional design process in your opinion?
2. What are the disadvantages of the usage of digital tools in the footwear design process compared to the traditional design process in your opinion?
3. Are there any future opportunities for the footwear concepts designed with help of digital tools/fully digitally in your opinion?

Through soliciting responses from industry experts, this thesis will benefit academically by gaining insights into the matter at hand to reach a conclusive outcome.

3.3 Interview analysis

Drawing on the insights gained from conducting interviews, a comprehensive analysis was undertaken to examine the viewpoints of participants with regard to three primary themes pertaining to digital tool usage in footwear design. These include an examination of the benefits that can be derived from incorporating such tools into design workflows, identification of potential drawbacks associated with their use, as well as exploration of future prospects for integrating these technologies more effectively within footwear design processes.

According to all interviewees, the use of digital tools in the realm of footwear design presents a multitude of academic benefits, particularly concerning the acceleration and optimization of design iterations. With access to these advanced technological resources, designers are able to produce numerous versions of their designs within compressed

timeframes, thereby enabling them to explore a more extensive range of creative possibilities while simultaneously refining their concepts with greater efficiency.

Pavlo Pecheniuk says: “I have recently faced the artificial intelligence (AI) application that can be used in a design process. It gives you way more freedom to develop your own ideas and it can save a lot of time compared to traditional sketching”.

This increased facility for experimentation can lead to heightened levels of innovation that would be unachievable through traditional methods alone. Additionally, digital tools facilitate precision and accuracy during the designing process which leads to producing more consistent and dependable products as well.

Another benefit mentioned by two out of three interviewees is that the utilization of digital tools offers the added benefit of enabling collaboration among designers and stakeholders, regardless of geographical barriers or scheduling constraints (figure 5). The incorporation of such technology enables designers to share and evaluate designs remotely, which enhances communication efficacy and facilitates constructive feedback exchange. Ultimately, this can help expedite design development while improving the quality standards for final products by reducing time consumption and resource expenditure.

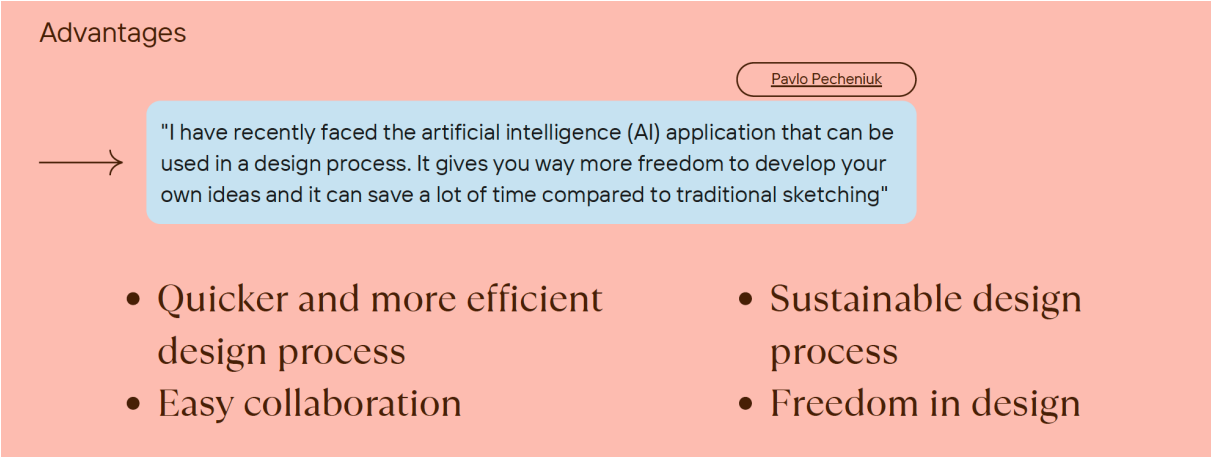
Digital tools play a significant role in facilitating designers to optimize their designs suitable for various manufacturing methods (figure 5). According to Daniele Radi, the use of digital tools empowers designers to develop designs customized according to the specific requirements of each production technique, resulting in reduced production expenses and superior product quality. A prime example would be that digital simulation can evaluate the effect of diverse materials and construction approaches, assisting designers in selecting optimal techniques for creating their design with maximum efficiency and effectiveness.

Some of the interviewees also mention, that digital tools not only enhance the productivity and proficiency of design methodology, but they also widen designers' horizons with regard to their access to a plethora of materials and colors (figure 5). The utilization of digital tools facilitates experimentation with diverse shades and substances sans the requirement for physical prototypes. As such, it contributes significantly towards minimizing waste

production while conserving valuable resources. Moreover, it enables designers to produce more distinctively original designs that capture attention effortlessly.

The sustainability aspect was mentioned by all the interviewees (figure 5). The utilization of digital tools can significantly contribute to enhancing sustainability and eco-friendliness in the design industry. These digital tools enable designers to simulate various materials and production techniques, enabling them to make informed decisions regarding the environmental impact of their designs. This is particularly relevant for the footwear sector known for generating excessive waste and pollution; hence this approach could considerably mitigate these adverse effects on our environment.

Figure 5. Interviewees' view: Advantages.

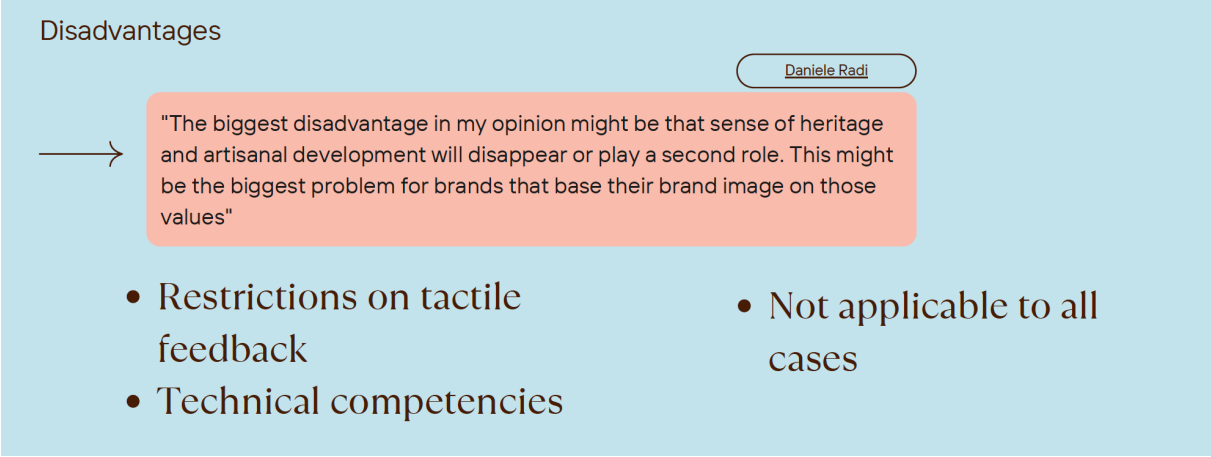


Answering the second question of the interview, professionals made a point, that than utilizing digital tools for footwear design, there are numerous benefits that can be gained, however, it is crucial to also consider the possible drawbacks. One of the most significant disadvantages is that digital technology has the potential to restrict designers' capacity to explore different materials and construction techniques in a more practical manner (figure 6). As a result, this may lead to designs lacking creativity and innovation as designers may not have access to comparable tactile feedback provided by traditional methods of designing footwear. Daniele Radi says: "The biggest disadvantage in my opinion might be that sense of heritage and artisanal development will disappear or play a second role. This might be the biggest problem for brands that base their brand image on those values".

The use of digital tools in design also processes presents a plausible drawback, whereby designers are required to possess certain technical competencies (figure 6). This could potentially act as an obstacle for some individuals who lack the necessary expertise and resources to effectively incorporate these tools into their work. In addition, inaccuracies or misinterpretations may occur between designers and manufacturers due to the limitations of digital representations that fail to accurately depict final product outcomes.

As per the respondents of the interview, it has been highlighted that digital tools cannot be deemed efficacious in every scenario (figure 6). According to Svetlana Abdulova, this implies that there is a possibility of encountering quality concerns during a phase of physical production if preliminary physical testing was not carried out.

Figure 6. Interviewees' view: Disadvantages.

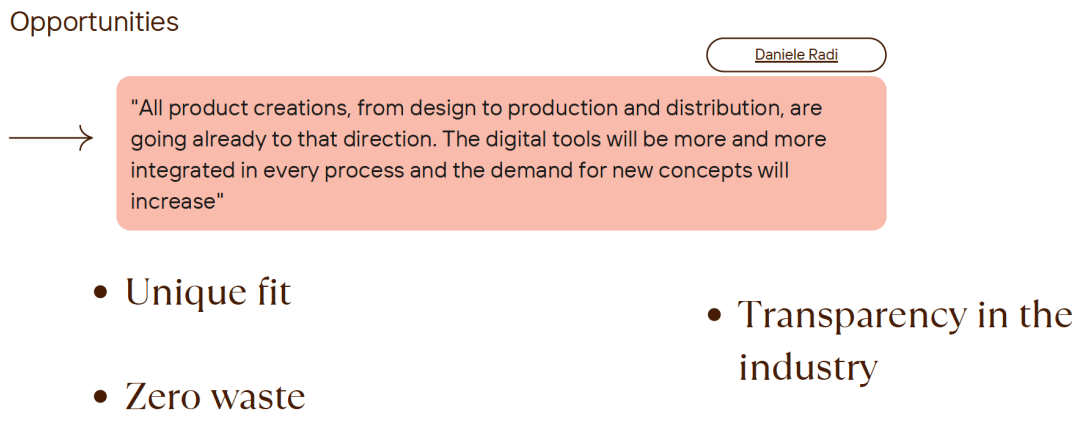


Despite the possible drawbacks, there exist numerous compelling prospects for leveraging digital tools in footwear design. During a recent interview with experts in this field, they largely agreed on one such prospect: designers could potentially develop customized 3D-printed footwear tailored to each individual's unique foot shape and requirements. Through scanning and analyzing customers' feet and gaits using digital technologies, designers can craft personalized footwear that surpasses the comfort and efficacy of mass-produced options. Such an approach may ultimately promote sustainability and ethics within the industry as consumers are less likely to dispose of ill-fitting shoes while retaining them for prolonged periods instead (figure 7).

According to interviewees, digital tools can have a significant impact on the footwear design industry by utilizing augmented reality (AR), virtual reality (VR), and artificial intelligence (AI) technologies. By enabling customers to virtually try on and customize their shoes before making purchases, these technologies create an immersive shopping environment that is highly interactive. Such an innovative approach would not only improve customer satisfaction levels but also contribute towards reducing return rates while helping designers better comprehend client preferences and requirements effectively (figure 7).

The interviewees also unanimously emphasize that the integration of digital tools in footwear design has the potential to pave the way for innovative and sustainable materials and manufacturing techniques (figure 7). This, in turn, could reduce the ecological footprint of the footwear industry and foster a more ecologically responsible future. According to interviewees, the use of digital tools enables designers to explore an extensive array of material choices and production methods leading to novel products that prioritize sustainability.

Figure 7. Interviewees' view: Opportunities.



After conducting thorough interviews and analyzing all gathered information, it can be concluded that the use of digital tools in footwear design presents both advantages and disadvantages. Nonetheless, the latest tools, such as AI, VR, and AR, are likely to shape the future of the industry in various ways. Specifically, they allow for quicker and more efficient design iterations while also promoting collaboration among designers and stakeholders by facilitating communication. Furthermore, such technology grants access to a broader

selection of materials and colors resulting in innovative designs with sustainability at their core.

Despite these benefits, potential drawbacks must be carefully considered when implementing digital tools including their limited opportunities for hands-on experimentation which could limit creativity. Consequently, continued development is necessary towards producing new technologies that address such challenges to ensure long-term success within this field.

4 Case study

As previously noted, certain digital tools have been utilized in the footwear design process for an extensive period (such as CAD, among others). Nonetheless, many phases of this particular design procedure are still performed through conventional means on a global scale. This prompts us to question whether it is possible to execute all stages of the design process without resorting to traditional methods. This case study aims to answer this question. This will build the base for the conclusion of the thesis work.

The case study expounded in this thesis centers on the creation of footwear designs by utilizing AI, and 3D modeling software. The research delves into how these digital resources to aid in conceptualizing footwear from its nascent stage to the ultimate phase of design completion. Furthermore, the basics of each tool are accessed along with their influence over the design process as well as their impact upon resulting shoe concepts.

The primary objective of this case study is to showcase the prospective usage of digital tools in footwear designing while simultaneously detecting scopes for refining and extending them and to examine the possibility of designing the footwear concept fully digitally, without the use of conventional design methods. Additionally, we will scrutinize the significance of human creativity and intuition during the design process along with exploring how these digital tools can be leveraged to amplify rather than substitute these vital human characteristics. The final aim of the case study is to explore how digital tools can ease the footwear design process, this will help to make a comparison between digital and traditional design processes in the conclusion of this thesis work.

4.1 Aims and methods

The primary objective of the case study is to generate a footwear concept by comprehending the design procedure and implementing appropriate design methodologies entirely through digital tools. The purpose of this exercise is to demonstrate that it is feasible to perform the entire process of footwear designing digitally, without resorting to traditional methods. While not intending to establish superiority or inferiority between conventional and digital techniques, the investigation aims at highlighting their contrasts, merits, and demerits regarding shoe design.

The study aims to go through all the steps of the footwear design process that are possible to achieve with the aid of digital tools. The stages demonstrated in the study are the following: research and concept development, design, prototyping, and material selection. All stages will be considered as a part of footwear concept creation through the use of digital tools which are going to be studied in detail.

1. Research and concept development will be done with help of AI (ChatGPT, Midjourney) tools instead of the traditional way of manual research.
2. The design will be done with AI as well instead of creating sketches manually. Midjourney AI will create concepts and sketches based on a prompt given.
3. Prototyping and material selection will be done with 3D modeling software (Blender). The concept will be modeled in 3D, and realistic concept pictures with materials applied will be rendered.

Going through all these stages with the usage of only digital tools will result in a unique footwear concept, done with zero waste, that can be used for manufacturing the physical prototype in the future perspective.

4.2 Design process

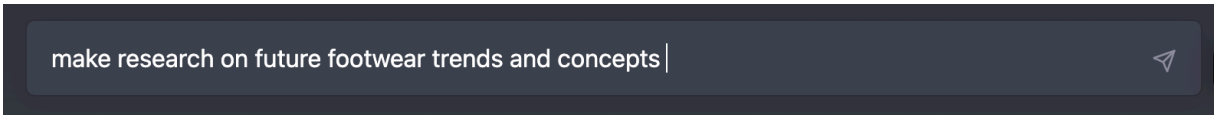
The development of the footwear concepts will involve a comprehensive three-stage design process, which shall be entirely digitalized and elaborately explicated.

4.2.1 Research and concept development

The research study was conducted with the assistance of ChatGPT AI, an advanced model that is programmed to comply with directives and offers comprehensive feedback (OpenAI, 2022). An efficient artificial intelligence-powered search engine collates and organizes a vast array of research findings from numerous libraries, presenting relevant data in a user-friendly format for optimal ease of use.

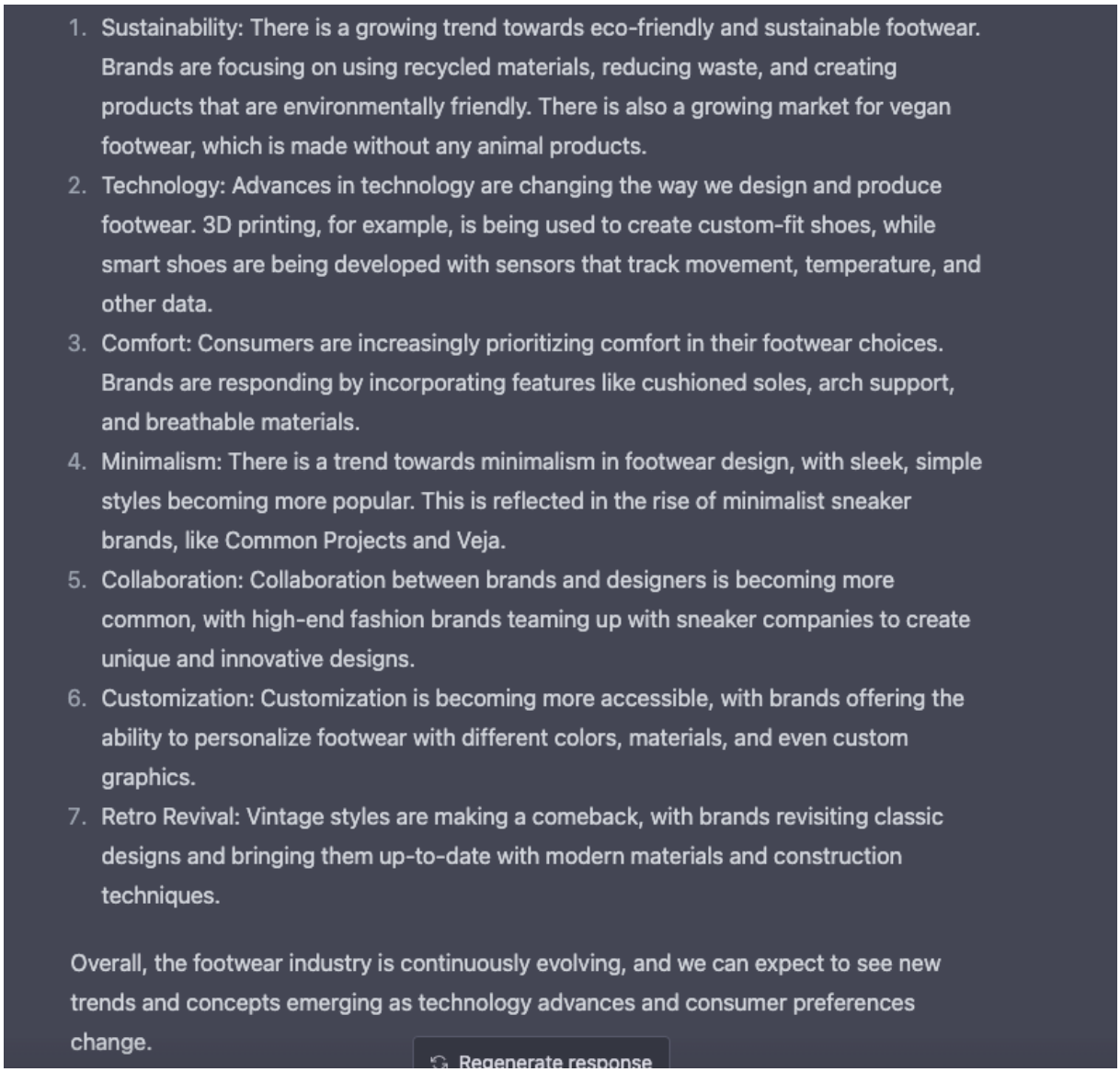
ChatGPT received a task to conduct an academic inquiry into the ongoing footwear trends and technologies implemented globally, alongside future predictions concerning them (figure 5).

Figure 8. Prompt for ChatGPT.



The analysis conducted on ChatGPT's response revealed that there are seven primary patterns in the realm of footwear design (figure 6). These trends encompass sustainability, technology integration, comfort-driven designs, minimalistic aesthetics, collaboration-oriented approaches to shoe production, personalized customization options for customers, and a resurgence in retro styles. Each one of these emerging directions is accompanied by its own set of standards regarding brand identity and expectations which contribute to their distinctive definitions within the field.

Figure 9. Response of ChatGPT.



According to the analysis of ChatGPT's feedback, several trends were identified as significant for generating a new concept in footwear design. The proposed idea should prioritize sustainability and innovation while ensuring optimum comfort and customization options are available. Additionally, it is recommended that the product be designed with a minimalist approach by incorporating one-piece construction techniques.

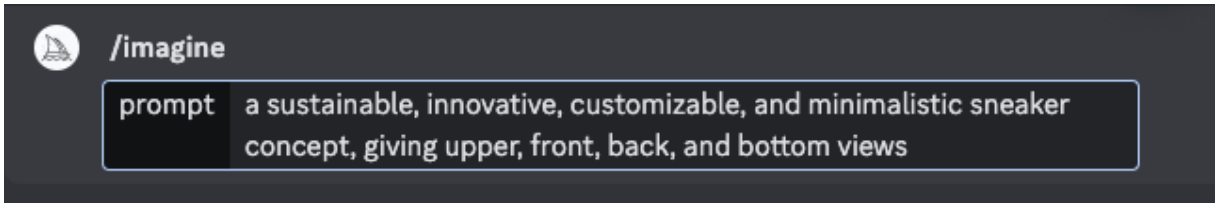
The decision to develop a concept for a sneaker stemmed from its high global demand and popularity as an exceptionally comfortable footwear option. In addition, the versatility of this product offers ample opportunity to integrate all crucial design elements while catering to various activities such as hiking or running. The adaptability of sneakers caters explicitly to

diverse customer preferences and requirements in terms of usability, making it an ideal choice for conceptualization purposes.

Once all the fundamental aspects of the prospective concept had been established, it paved the way for ideation. To carry out this phase of creating a concept, yet another advanced AI technology developed by Midjourney - an autonomous research facility dedicated to discovering novel modes of thinking and augmenting humanity's creativity (Midjourney, n.d.) - was employed. Its chief objective is to generate visual representations based on a specific prompt.

The prompt given to Midjourney AI included all the key points mentioned above (figure 7).

Figure 10. Prompt for Midjourney AI.



During the course of its operation, Midjourney utilized artificial intelligence to create a series of four unique conceptual images in response to a given prompt (figure 8). These initial designs were then subjected to further regeneration, resulting in an expanded selection of potential options (figures 9, 10). It is noteworthy to state that Midjourney AI fails to provide any information concerning the components and intricacies of the produced design, whereby text-like symbols depicted in concept images merely constitute an indecipherable sequence.

Figure 11. The first response by Midjourney AI.

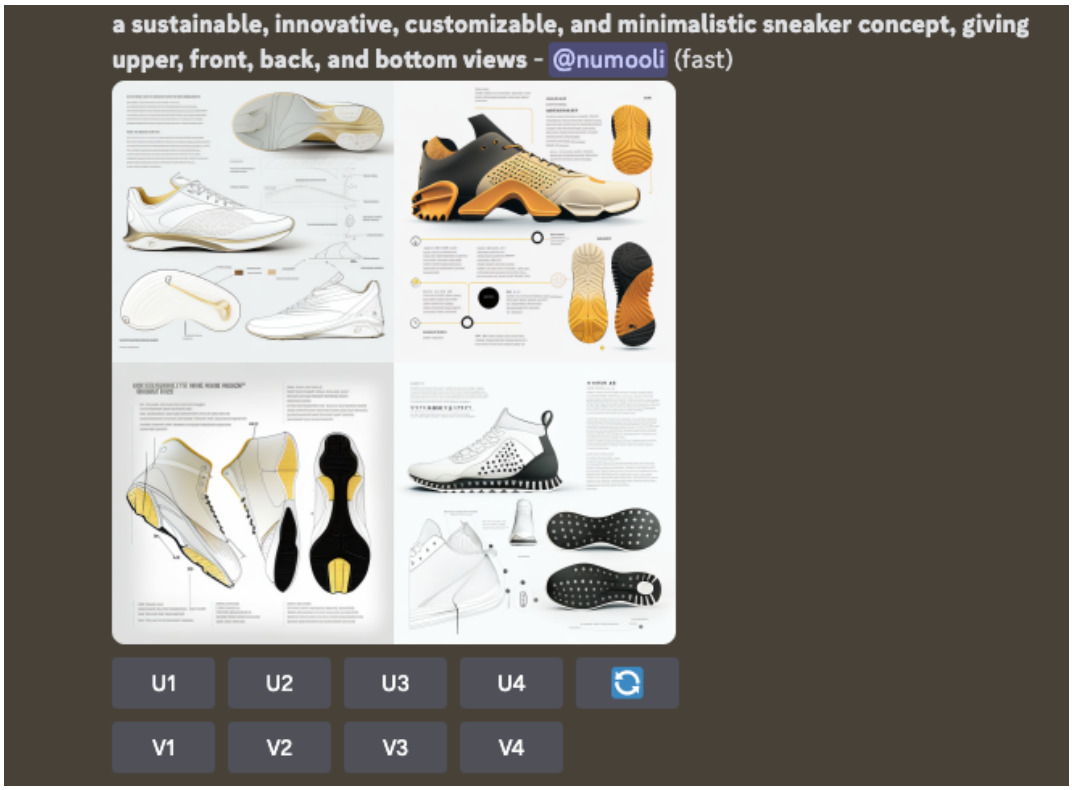


Figure 12. The second response by Midjourney AI.

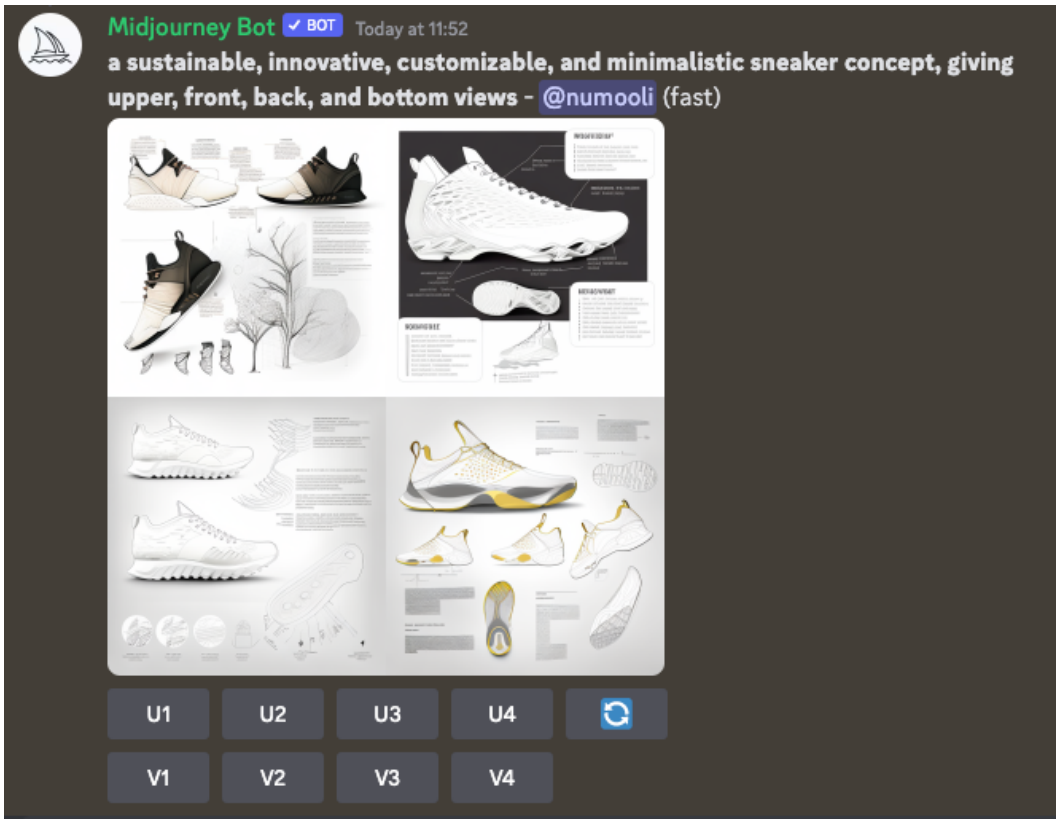
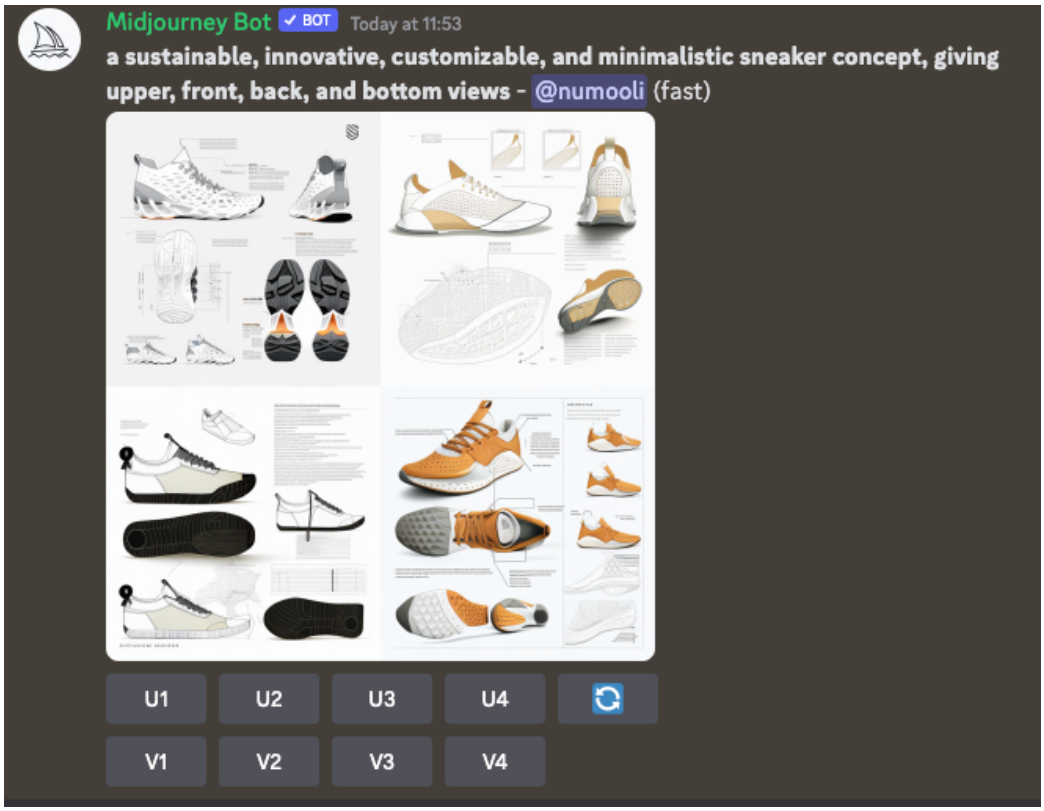


Figure 13. The third response by Midjourney AI.



After careful consideration, the concept deemed most suitable for further exploration and development is the second one presented in the initial response (figure 11).

Figure 14. The concept generated by Midjourney AI to continue working with.

4.2.2 Design

During the conventional process of designing footwear, the design stage typically involves producing multiple sketches and generating a range of ideas to advance the concept. Nevertheless, one major area for debate is centered on the absence of an entirely automated system that can generate new concepts for footwear designs. As a result, during our design phase, the work with Midjourney AI continued in order to expand upon our chosen shoe concepts by requesting it to create various additional variations as part of its ongoing efforts toward achieving different perspectives on sneaker design (figure 12).

Figure 15. Making variations of the chosen design generated by Midjourney AI.

Several concept variations were made (figures 13-16).

Figure 16. The first variation of the chosen design generated by Midjourney AI.

Figure 17. The second variation of the chosen design generated by Midjourney AI.

Figure 18. The third variation of the chosen design generated by Midjourney AI.

Figure 19. The fourth variation of the chosen design generated by Midjourney AI.

After considering all the concepts that were generated, one was chosen to proceed with further development (figure 17). The next step in this process involves moving towards prototyping to transform the concept into a tangible 3D representation.

Figure 20. The final design generated by Midjourney AI.

4.2.3 Prototyping and material selection

Upon selection of the final design, the project proceeded to its prototyping stage. The process involved digital modeling in Blender which is a 3D creation suite that operates on an open-source and cost-free platform. It encompasses all facets of the 3D pipeline ranging from modeling, rigging, animation, and simulation to rendering as well as motion tracking with added capabilities for video editing and game development (Blender, n.d.).

The initial stage in the process of prototype modeling entailed importing the reference design to the software (figure 18). The Midjourney AI concept was subsequently brought into Blender for further development and refinement (figure 19).

Figure 21. Blender interface: inserting a reference.

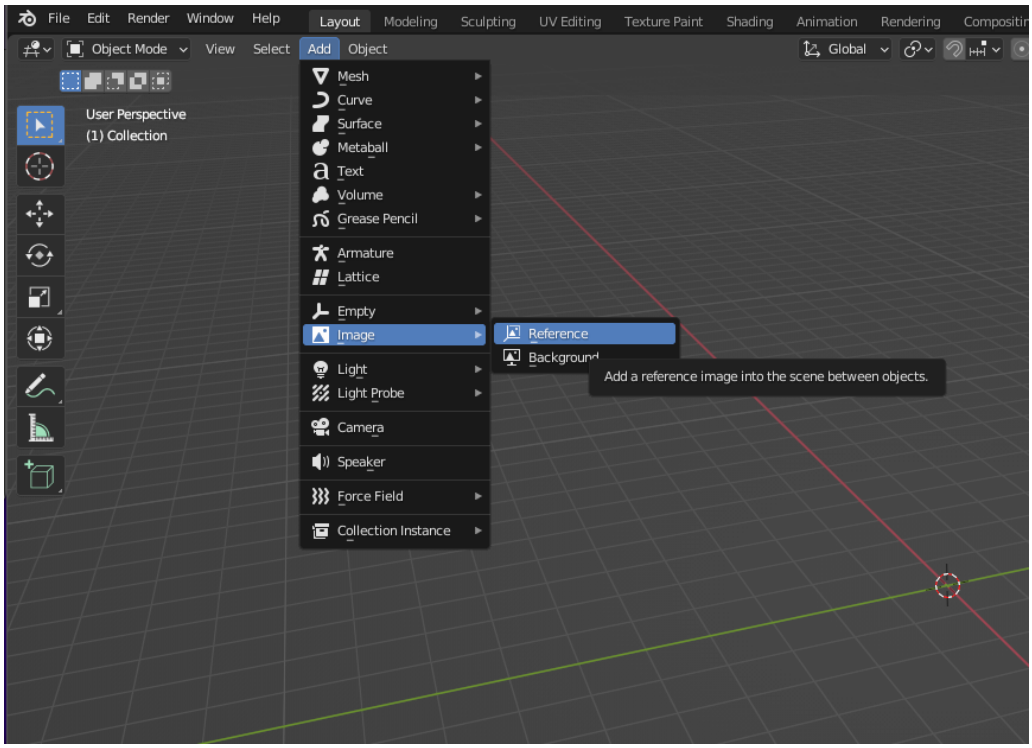
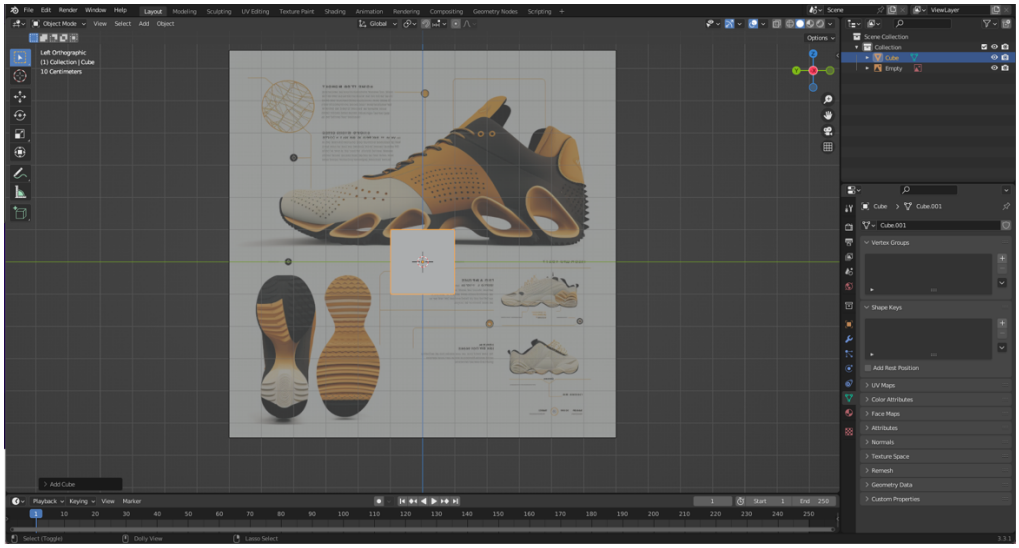
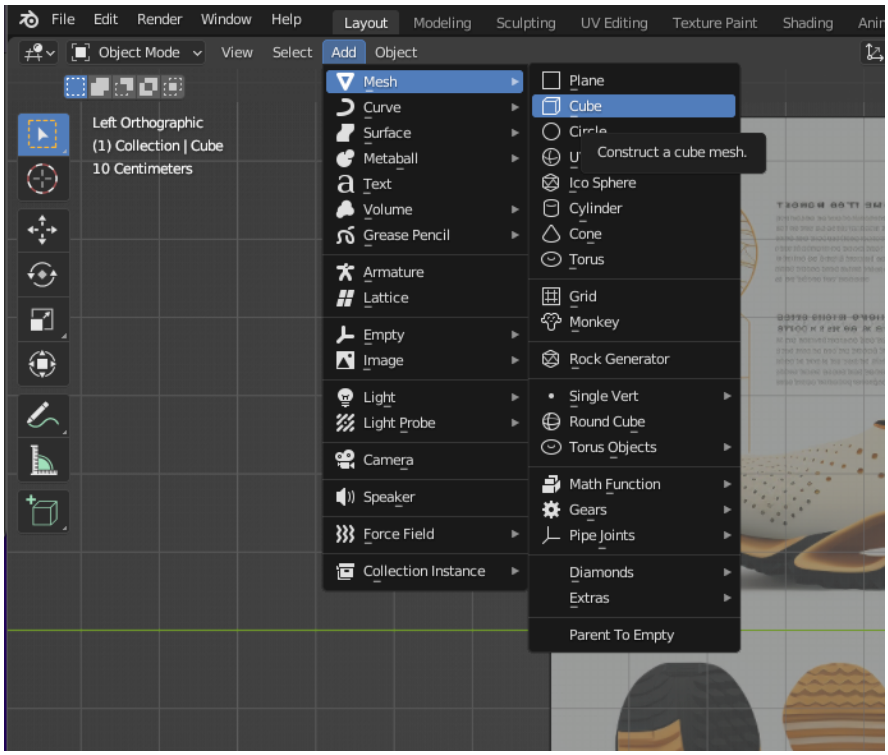


Figure 22. Blender interface: reference picture.



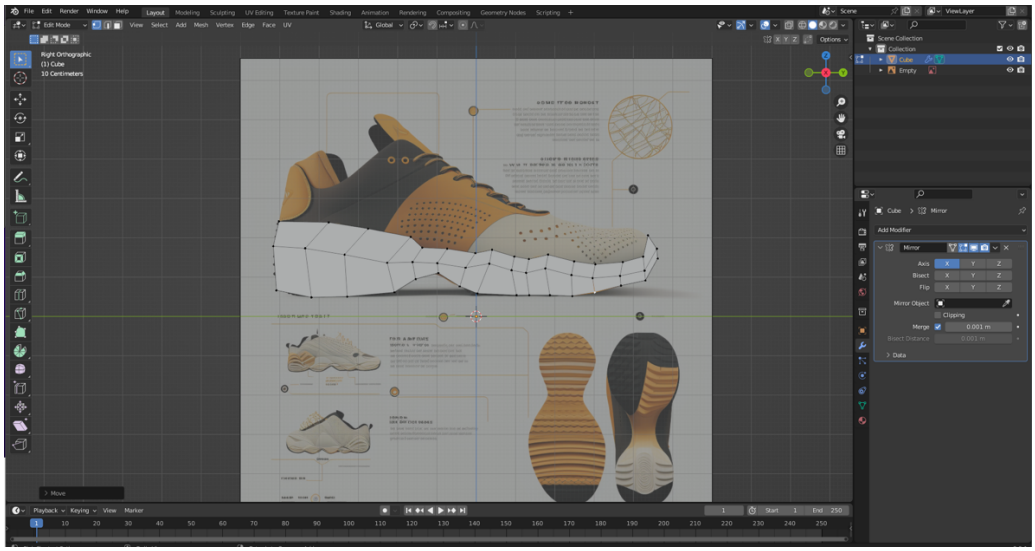
Following the import of the reference, the modeling phase was initiated wherein basic shapes such as cubes and spheres were utilized (figure 20). The first step involved creating a model of only the sole component of the shoe.

Figure 23. Blender interface: adding the cube to the scene.



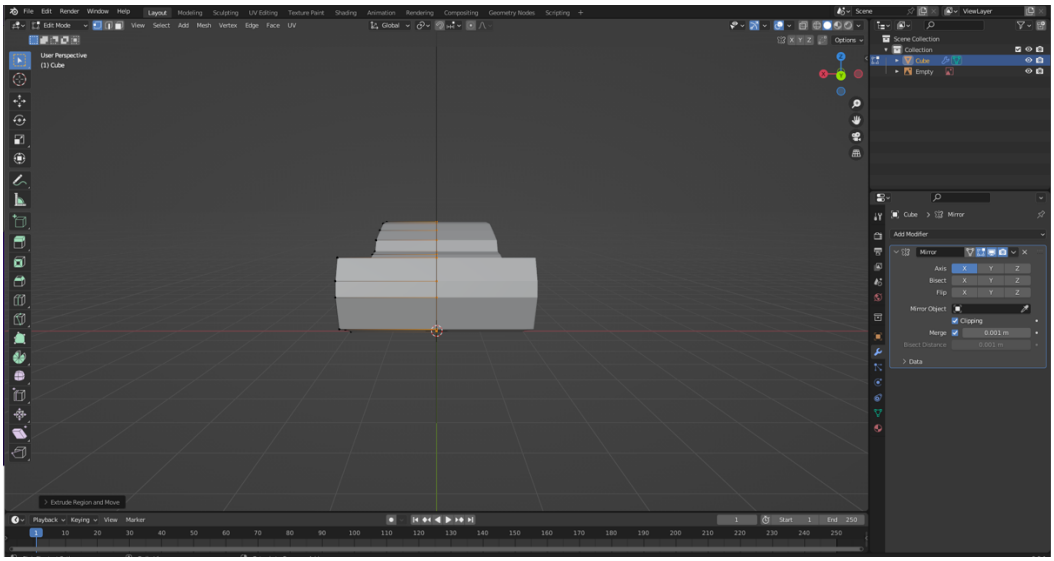
The process of creating the sole shape involved utilizing fundamental commands in Blender such as extruding, moving, intersecting, and rotating while tracing a reference image. This approach was employed to ensure an academic expansion toward achieving the intended outcome (figure 21).

Figure 24. Blender interface: Tracing the reference.



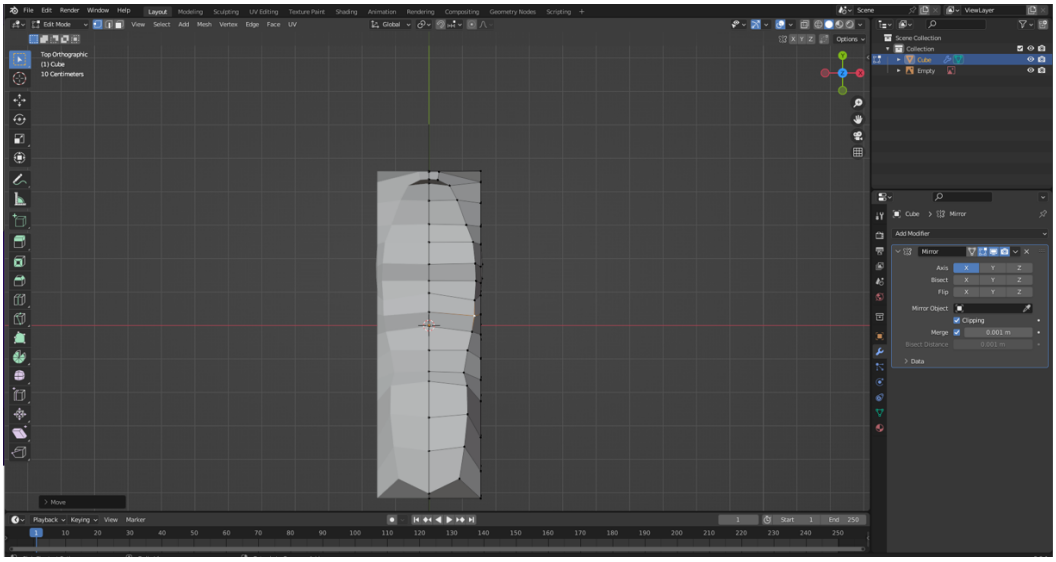
Following the completion of tracing, the shape underwent extrusion to impart a three-dimensional appearance through extension in depth (figure 22). This technique enhanced its academic perspective by lending greater visual depth and substance to the object.

Figure 25. Blender interface: Extruding.



After completing that phase, further efforts were dedicated to refining and enhancing the realism of the sole part. This involved incorporating intricate details from the original design while simultaneously modifying it to achieve a more pragmatic appearance (figure 23).

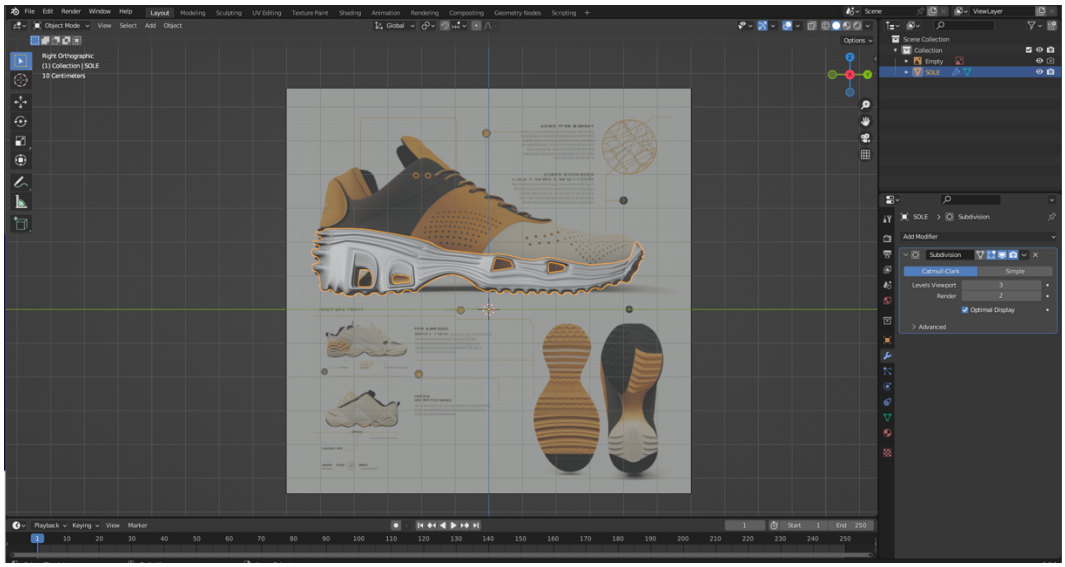
Figure 26. Blender interface: Shaping the sole.



As a result, significant alterations were made during modeling which led to an ultimate transformation in its overall look and feel. A subdivision surface modifier was used on a model to give it a smoother and more realistic look (figures 24, 25).

Figure 27. Blender interface: Subdivision modifier.

Figure 28. Blender interface: Sole part completed.



After completing the construction of the sole, identical procedures were performed to produce the upper portion of the sneaker (figures 26, 27).

Figure 29. Blender interface: Upper part tracing.

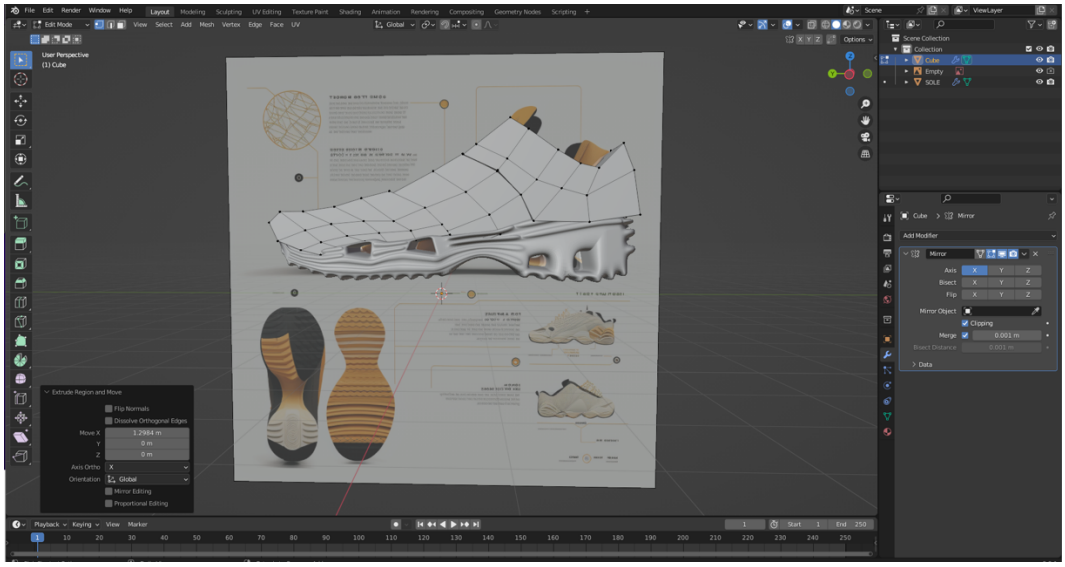


Figure 30. Blender interface: Upper part with subdivision modifier applied.

Upon completion of the upper design, modifications were made to enhance its distinctiveness and innovation. The same techniques employed in the creation of other upper pieces were utilized for producing both lacing and tongue elements (figure 28).

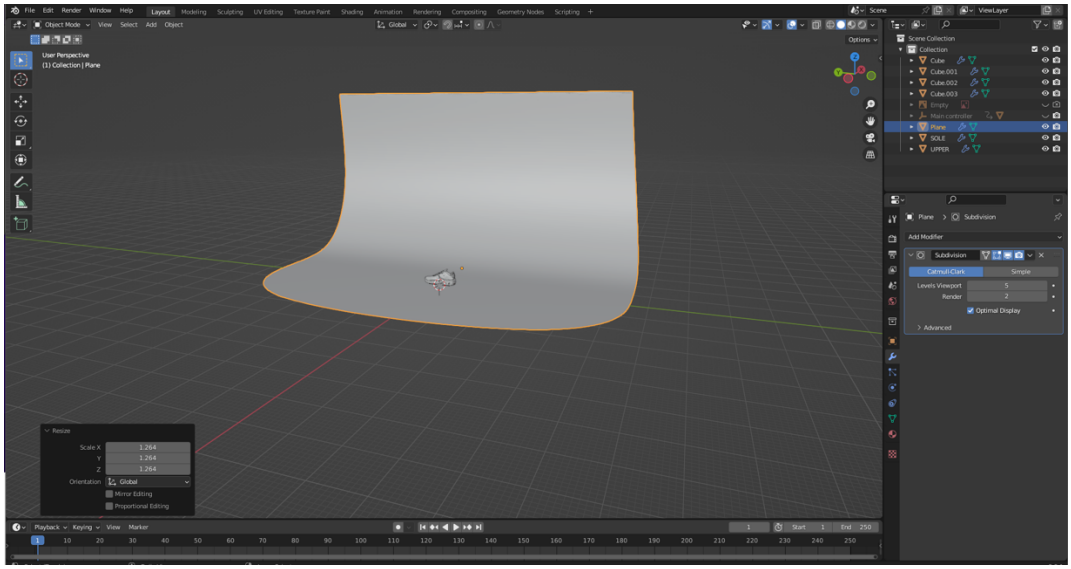
Figure 31. Blender interface: Upper part, lacing, and tongue added.

Following the application of identical methods, heel components were produced (figure 29).

Figure 32. Blender interface: Heel pieces added.

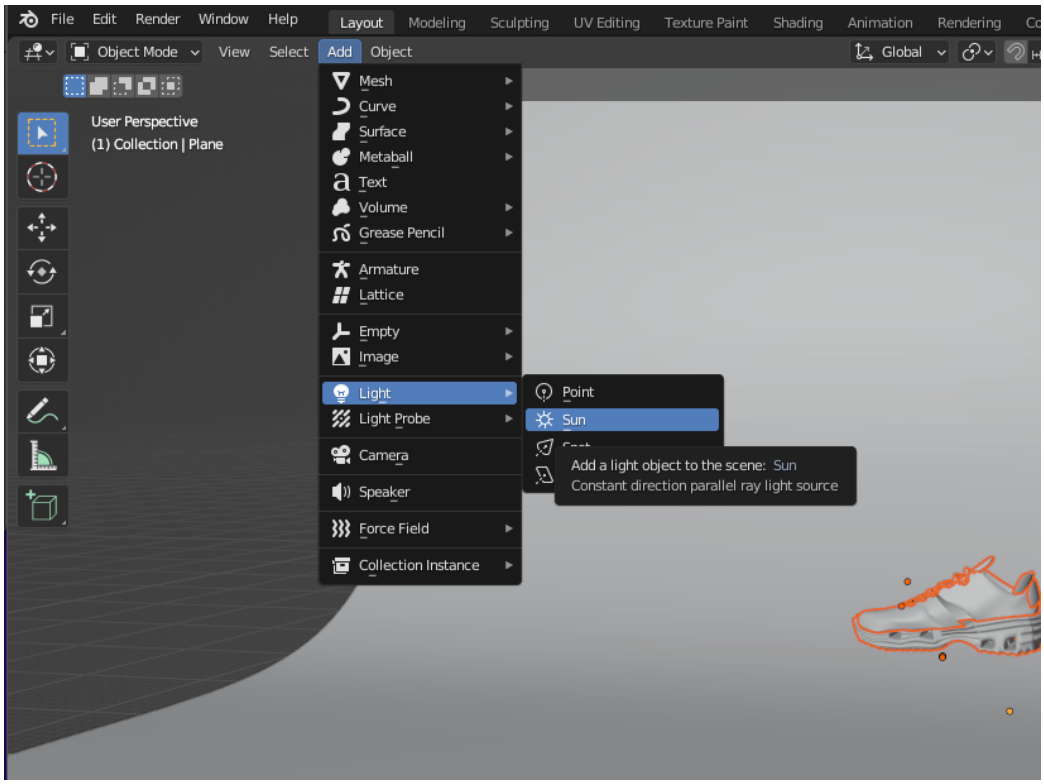
The sneaker design had progressed to the material selection phase, but before proceeding with this step, it was necessary to establish an appropriate setting. A plane object was incorporated and adjusted in order to impart a suitable ambiance and serve as a background for the scene (figure 30). The objective was to construct an augmented 3D environment that would showcase the shoe model as its principal element.

Figure 33. Blender interface: Adding a plane for a background.



In order to accurately display the selected materials' true colors and textures, the source of light had to be incorporated into the scene as well (figure 31).

Figure 34. Blender interface: Adding light to the scene.



Following the establishment of the setting, materials were allocated to different components of the sneaker with a view to creating an enhanced visual effect consistent with its original design (figure 32). Diverse materials were employed for both the sole and upper portions in order to achieve this objective. Commencing with identifying a fitting color paint was integral as it had a significant bearing on achieving realism and display efficacy. Thus, identical colors utilized in the initial design were incorporated by duplicating their respective HEX codes onto distinct segments of the sneaker (figure 33).

Figure 35. Blender interface: Adding a material.

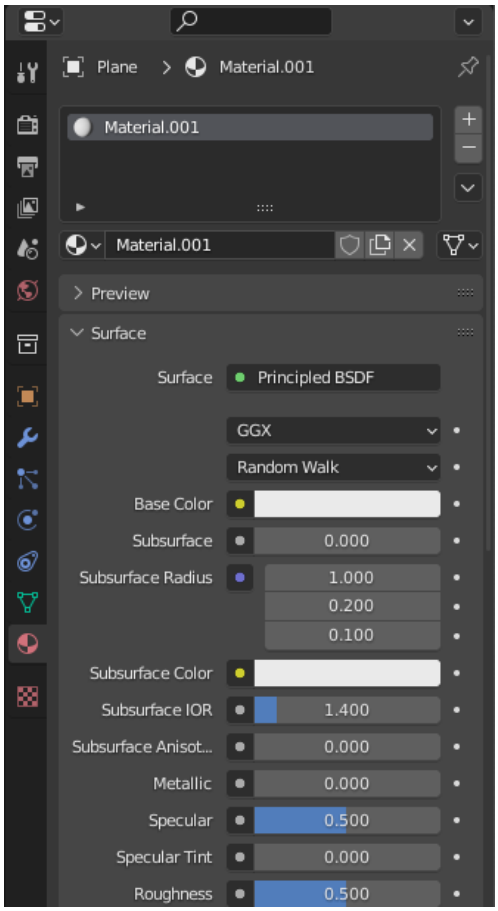


Figure 36. Blender interface: Color applied to the sole.

After applying the fundamental colors, it became essential to create certain textures that could effectively convey the material. According to previous remarks, the concepts generated by Midjourney AI do not provide any details on materials. Consequently, it remains within the designer's purview to select appropriate materials. To accomplish this task, a material map was generated using Blender software which facilitated the inclusion of distinctive texture for each color (figure 34); enabling differentiation of every part of the upper covering based on its individual uniqueness and design pattern. In order to replicate the tangible feel associated with vegan leather, it was determined appropriate to use such texture for making uppers as it is sustainable and ethically appealing, while golden metallic eyelets were used in combination with synthetic fiber laces and rubber soles. All maps pertaining to materials were manually created through Blender without employing any pre-made substances thereby allowing adjustment according to model requirements thus yielding an unparalleled look (figure 35).

Figure 37. Blender interface: Applying textures.

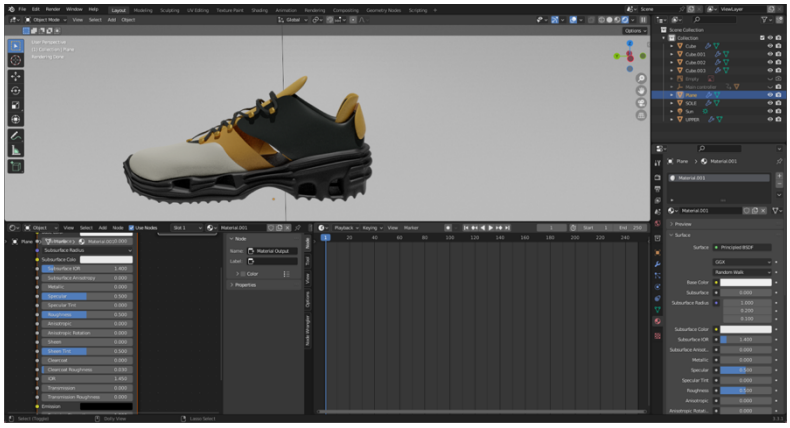
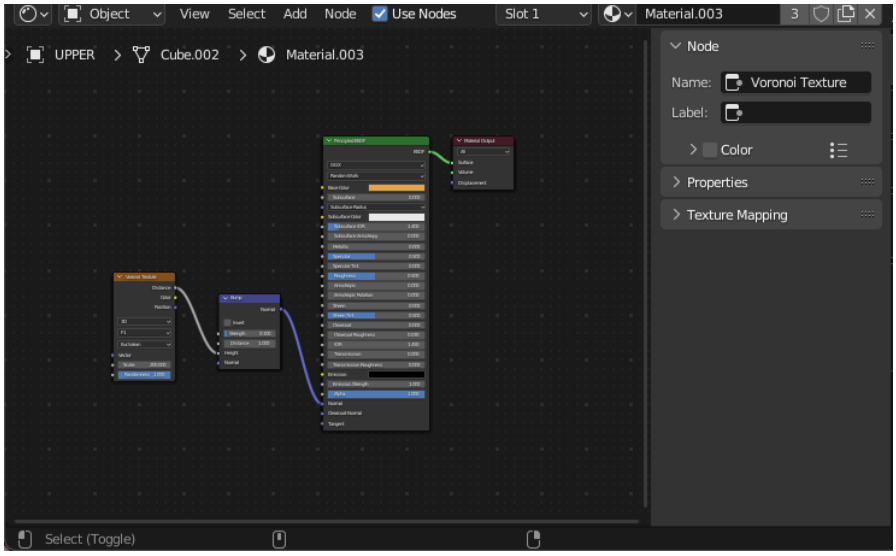
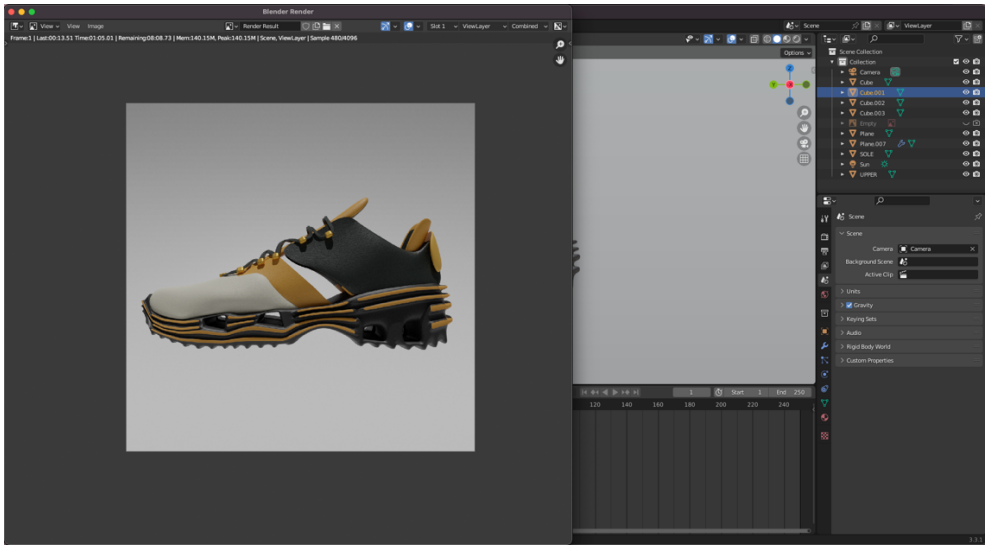


Figure 38. Blender interface: Material mapping.



Upon the completion of assigning materials and textures, and ensuring that they were fully set, a camera was incorporated into the scene. After making all necessary adjustments, concept shots depicting the final prototype were rendered (figure 36).

Figure 39. Blender interface: Rendering.



4.3 Results

The case study culminates in studio photographs of the sneaker design developed entirely through digital means. Employing artificial intelligence and 3D modeling software for research, ideation, sketching and prototyping enabled the designer to achieve a distinctive aesthetic while avoiding the superfluous expenditure of resources and time. Utilizing AI dramatically streamlined both idea generation and data analysis; these processes that would typically require hours are completed within seconds. The virtual prototyping not only minimized material waste but also facilitated exploring various combinations of materials or colors with just a few clicks on a computer mouse (figures 37-39).

Figure 40. Final product first shot.

Figure 41. Final product second shot.

Figure 42. Final product third shot, different colorway.

Through the examination of this case study, it is evident that a fully digital footwear design process can be achieved (figure 40). In addition to its feasibility, such an approach significantly reduces both time and material costs when compared to traditional methods. Nonetheless, it should be noted that while these techniques hold promise for certain applications at present they may not always prove equally efficient. Therefore, it is too early to discuss a complete shift toward the exclusive use of digital tools in all aspects of the footwear design process worldwide.

Figure 43. Final product collage: Initial design and virtual prototype.

5 Conclusions

Upon conducting background research, interviews, and case studies within the thesis work, it is imperative to academically analyze all information gathered to draw well-supported conclusions.

In order to provide a more comprehensive analysis, it is imperative to establish certain parameters pertaining to the conclusions outlined in previous sections of this study. Specifically, it should be noted that this investigation exclusively scrutinizes the casual footwear design process; therefore, any findings or recommendations are not necessarily applicable to other types of footwear design processes (e.g., safety or performance footwear). It is critical that readers recognize and respect these limitations so as not to overgeneralize the results presented herein

Another limitation of the conclusions presented in this study pertains to how traditional and digital footwear design processes are defined. Specifically, the analysis considers the former as a process that primarily employs physical tools and techniques for research (conducted manually through analyzing web resources and professional literature), concept development (achieved by creating sketches manually), design (undertaken through manual sketching and technical drawings), physical prototyping (carried out using materials and tools to create physical models of designs) as well as testing procedures which are performed with specialized machinery. However, it should be noted that certain digital technologies such as CAD software have been integrated into conventional footwear design practices over an extended period, thereby blurring boundaries between these two types of processes.

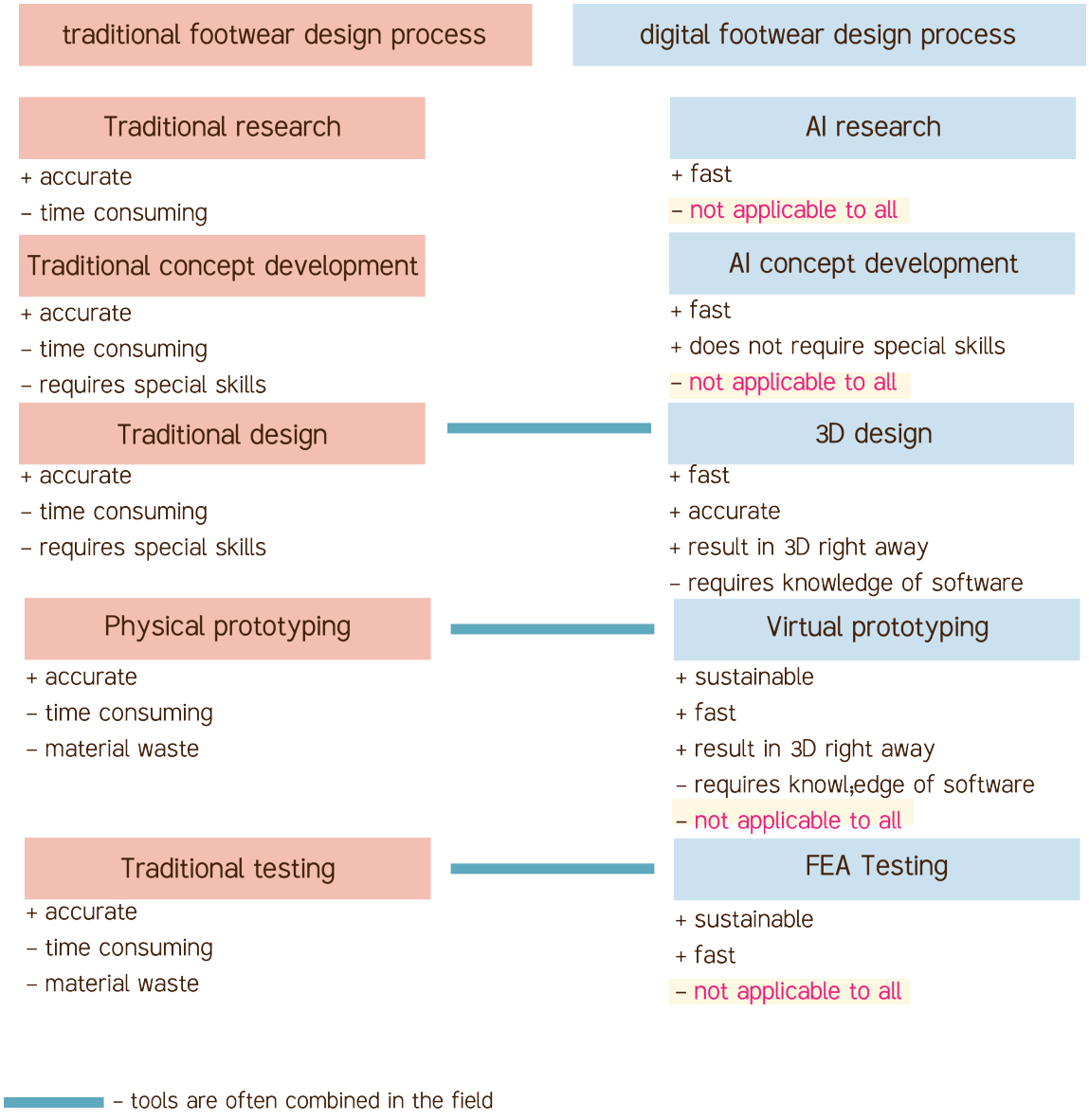
The definition of the digital footwear design process being examined in this comparison pertains to a method that relies solely on digital technology and does not involve any traditional processes or physical prototypes. Through our case study, we have demonstrated that it is feasible to execute an entire footwear design process digitally, thereby warranting the inclusion of such processes within the scope of this definition. This encompasses several stages, including research conducted by artificial intelligence (AI), AI-generated concept development, 3D modeling software utilized for fully digital designing and virtual prototyping as well as Finite Element Analysis (FEA) performed via simulation software to evaluate performance and durability characteristics.

In order to provide a comprehensive understanding and facilitate the comparison between traditional and digital footwear design processes analyzed in this research, it is essential to

establish clear definitions. These definitions have been formulated through an extensive background study as well as by conducting a case study analysis.

The diagram presents a detailed comparison of the defined processes, encompassing all their stages along with an analysis of advantages and drawbacks (figure 41). This comprehensive assessment is grounded in extensive background research, interview analysis, and case study review. Additionally, the diagram's interpretation is provided alongside a written conclusion summarizing final observations on the topic at hand.

Figure 44. The comparison between traditional and digital footwear design processes.



From the diagram, it is evident that both traditional and digital footwear design processes entail a number of distinct steps. Despite sharing an identical count in this regard, there exist considerable differences between them with regard to the nature and implementation of each step.

Based on the findings of this study, it has been observed that conventional research methods in design consume a greater amount of time as opposed to utilizing AI tools which enable a swift analysis of available information. However, AI-based research may not be entirely precise unless adequately programmed and trained for specific applications.

The traditional approach is deemed more accurate during the concept development phase as well, due to its ability to encompass creative and artistic aspects beyond the scope of AI capabilities. However, it should also be noted that unlike traditional concept development techniques requiring technical expertise, prompt-driven AI development does not necessitate any special skills or knowledge.

In terms of the design phase, 3D modeling offers several benefits. Its ability to create concepts in a three-dimensional view expedites the design process and facilitates real-time modifications, resulting in faster completion times than traditional methods. Additionally, 3D modeling's precision and accuracy in specifications reduce errors during manufacturing and minimize time spent on rectifying designs. However, proficiency with such software demands specialized knowledge that may necessitate supplementary training or expertise.

Transitioning to the prototyping phase, it was discovered that conventional techniques afford greater flexibility and precision in the visual look of designs. Nonetheless, tangible prototyping demands materials which are unlikely to be repurposed or recycled particularly if numerous attempts are necessary for optimal fit and materials. In contrast, virtual prototyping enables designers to visualize their concepts with diverse materials without generating any waste and within a shorter timeframe. Nevertheless, virtual prototypes may not be suitable for all scenarios as physical models may still be required due to software constraints.

In regards to the final phase of the design process, it bears resemblance to prototyping. While physical testing generates material waste, Finite Element Analysis (FEA) offers a method of assessing footwear without actual production. Nonetheless, as with prototyping, certain situations mandate physical testing and thus render FEA unsuitable for all circumstances.

As also can be seen from the diagram, contemporary footwear design practices utilize both traditional and 3D design, virtual and physical prototyping, FEA, as well as conventional testing. Large corporations have recognized how these digital tools can be integrated to streamline production processes while reducing material wastage. It is therefore imperative for designers to comprehend the strengths and limitations of each technique in order to synergize them efficiently toward creating a sustainable design process.

Conversely, AI tools are not yet widely adopted by companies that still rely heavily on traditional approaches without considering integrating AI into their workflows. Nevertheless, some individual designers have already begun utilizing AI in their designs with demonstrated success cases such as those presented within this thesis focusing on footwear design. This means that there is potential for wider implementation of AI in the design process, but it requires companies to embrace new technologies and adapt their workflows accordingly.

In summary, the thesis underscores the significance of utilizing digital tools in footwear design. These tools not only enhance visualization capabilities for designers but also foster sustainability by decreasing material waste during production. Nevertheless, it is premature to advocate for a fully digitized footwear design process on a global scale since there is limited adoption and implementation of digital technologies and artificial intelligence (AI) in this field; furthermore, physical testing remains necessary under certain circumstances. Despite this, the possibility of a sustainable design process using digital tools and AI integration shows promise. Further technological advancements may lead to a complete transition towards an entirely digital and eco-friendly footwear design process in the coming years. In summary, it is essential for designers and companies alike to welcome digital technology while contemplating incorporating AI into their workflows with the objective of enhancing their design processes' efficiency and sustainability.

The objectives of the thesis were accomplished proficiently. The literature review facilitated comprehension of traditional and digital methods for designing footwear, while semi-structured interviews with experts provided their insights on the matter. Furthermore, a case study demonstrated that creating a completely digital concept for footwear design is feasible. This array of techniques employed established an ideal foundation upon which conclusions could be drawn from this thesis. The research provides a noteworthy addition to the domain of footwear design and promotes further investigation into employing digital instruments and AI incorporation for eco-conscious design methods. Hence, it is vital for designers and enterprises to persistently assess the capabilities as well as constraints of each approach in order to combine them effectively towards formulating inventive yet sustainable shoe designs that fulfill consumers' requirements whilst lessening ecological repercussions.

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Data management plan: Interviews

Data collected: In the present study, semi-structured interviews were conducted to gather data. The participants provided written responses during private online chats with the author of this thesis work. These chat logs contain all interview answers and have been exclusively used for the purpose of this research project without any disclosure or utilization elsewhere.

Processing of personal data: Furthermore, the interview process adhered to ethical standards for research by safeguarding participant confidentiality and obtaining informed consent. Prior to conducting interviews, each interviewee provided their informed consent. The personal information incorporated in this thesis was obtained with explicit permission from participants for its use in academic work.

Ownership and further use of data collected: The complete transcripts of the interviews are stored privately between the author of this thesis and individual interviewees, ensuring that no full answers will be published or utilized beyond the scope of this project. After the completion of thesis work, comprehensive responses are retained within a confidential conversation. The author of the thesis keeps the material securely for one year from the date of acceptance of the thesis, so that the results of the thesis can be confirmed if necessary and the material is then disposed.