

The Role of FabLabs on Footwear and Metal Sectors: Prospects, Challenges, and Recent Applications

Maria G. Fernandes^{1*}, Pedro Duarte², Cristiano Figueiredo², Carla Florbela da Silva², Vânia Pacheco¹, Cristina Marques²

¹ Technological Center for the Metalworking Industry (CATIM), Portugal

² Portuguese Footwear Technological Centre (CTCP), Portugal

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ABSTRACT

This paper presents the role of FabLabs in the Portuguese footwear and metal industrial sectors, regarding the use of new and disruptive technologies and processes at industrial scale, aiming for the digitalization of the industry. MetalShoe FabLab Network is a project intending to provide a physical space and, at the same time, offering knowledge for experimentation, demonstration, validation, and human resources training regarding digital manufacturing technologies, with focus in the industrial implementation. For that, a survey was conducted among industrials from both sectors to understand the needs and expectations regarding these types of technologies. Digitalization, automation and robotics, additive manufacturing and digital marketing were the ones selected as the technologies not yet integrated and that would bring value to the companies, while the companies want to learn more about digitalization, additive manufacturing & 3D Printing and IoT, these being similarly chosen, and automation and robotics following closely behind. In this sense, the outputs of the projects were technical referential about each technology, guides for applications of the technologies, workshops, technical sessions and demonstration actions. In the end, it is expected that Portuguese companies from both sectors would recognize the potential of digital manufacturing technologies and incorporate those that provide the most value to each entity.

1. Introduction

In recent years, there has been increased interest in the diffusion and democratization of knowledge, innovation, and emerging technologies. The global challenges in our current generation such as climate change, the COVID-19 pandemic and overconsumption have reinforced the emergence of digital transformation and the digital economy. To face the future and handle these challenges, further efforts are required not only in applied research but also, and most importantly, in practical implementation (Vial, 2019). Hence, technological and

* Corresponding Author E-Mail Address: maria.fernandes@catim.pt

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collaborative innovation across societies, including governments, enterprises, and citizens, is crucial.

Collaborative spaces such as Makerspaces, Hackerspaces, Techshops, and Digital Fabrication Laboratories (FabLabs) play a crucial role in fostering innovation through the exchange and sharing of information, knowledge, and experience amongst their members (Blikstein, 2013). They leverage innovation by using technological resources available in those spaces, stimulating the creativity of its attendees and enabling the development of solutions, products and services based on customised projects derived from a concept, or the construction supported by knowledge developed by other players, thereby collaboratively enhancing the outcome (Gershenfeld, 2012).

In this paper, we focus on the role of FabLabs in the industrial context, in particular, the footwear and metal sectors. The purpose of this study was to analyse the main prospects, challenges, and characteristics of FabLabs, as well as how these places might adapt to the needs of the footwear and metal industries. In light of this, this paper summarises the findings of a survey that attempted to evaluate the level of knowledge and industrial integration of the digital technologies supplied by our FabLab (MetalShoe FabLab) in both sectors. Based on this, MetalShoe FabLab was able to provide a better support strategy that meets the requirements of footwear and metal enterprises.

2. FabLabs spaces in industrial context

The increasing digitalization of industrial processes and their automation will inevitably lead to an increase in the number of experts in these fields. However, most companies, mainly small and medium enterprises (SMEs), are unprepared for this new reality and need to seek external support. FabLabs, sometimes also referred as fabulous laboratories, are collaborative and innovative spaces fitted with open-source tools and technologies such as three-dimensional (3D) printers and scanners, computer numerical control (CNC) milling machines, laser cutters and engravers, electronic components and programming tools, high-speed microcontrollers, among others. These spaces aim to promote new technological skills at a time when access to these technologies may still be costly, and not widely available. Beyond the technical capacities, FabLabs also foster skills such as creative thinking, resource management, planning, self-efficacy, and teamwork. These spaces facilitate interdisciplinarity by bringing together individuals from diverse backgrounds. As a result, the companies have the opportunity to effectively explore, digitalize and materialize their ideas based on available and affordable technology (Gershenfeld, 2012; Mortara & Parisot, 2016; Schmidt *et al.*, 2011). It provides significant value to companies, allowing them to stand out in a competitive industry.

The first FabLab, created in 2001, was funded by the National Science Foundation (NSF) from the United States of America (USA) and started based on the success of the course taught by Gershenfeld himself titled “How to Make (Almost) Anything” (Gershenfeld, 2012). The success of this class was so remarkable and the resulting projects so interesting that the concept quickly spread and FabLabs started to appear all over the world. Currently, FabLabs can be found in a variety of environments, whether public (*e.g.* universities or polytechnics, schools, etc.) or private (*e.g.* technology centers, companies, private organizations, etc.). According to the most recent data, there are approximately 2.000 FabLabs in over 149 countries (*FabLabNetwork*, June 2022). Whatever the type of FabLab, these spaces share the objective of democratising access to technical invention tools, promoting equality of race and gender, all in a horizontal relationship, without titles or awards, just competence and mutual respect, working and learning from each other in a common space. The FabLabs can be supported by the Fab Charter of the Fab Foundation, which is responsible to facilitate and support the growth

of the international FabLab network as well as the development of regional capacity-building organizations (*Fab Foundation, June 2022*).

With no specific purpose or project, FabLabs offer an array of distinct activities. Nevertheless, according to the results of the FabLab Global Survey, which sought to understand the characteristics of FabLabs through the visions of their managers, the main interests are activities related to technology (50% of the participating laboratories) and design (30%), although there is a growing interest in developing activities relating to education (9.6%) and medical/biological activities (2.24%) (Francisco Javier Lena-Acebo; María Elena García-Ruiz, 2022; García-Ruiz & Lena-Acebo, 2022). García-Ruiz and Lena-Acebo (García-Ruiz & Lena-Acebo, 2022) concluded that FabLab activities allow economic and industrial growth through innovative projects, since they boost creativity and innovation, increase self-efficacy and promote knowledge sharing. Collaborative innovation is the key to success for any industry process seeking to develop creative and competitive products and services (Caner & Tyler, 2015; Fleischmann *et al.*, 2016; Fonda & Canessa, 2016; Roma *et al.*, 2017). In this way, FabLabs enable the establishment of a bridge between qualified employees and the manufacturer of high-tech goods, as well as other individuals who are typically more averse to manufacturing transformation and digitalization, thereby enhancing the capabilities of all involved players (Chesbrough, 2011; Pacheco, 2022; Stacey, 2014). Using these facilities, companies may create low-cost prototypes and undertake rapid market research to establish the viability of a product. Moreover, the entrepreneurs can adapt easily and economically their ideas based on the community suggestions, leveraging crowdsourcing and the collective knowledge of the public (Caner & Tyler, 2015).

2.1 Evolution and role of FabLabs in Portugal

The concept of FabLab emerged in Portugal at the end of 2010, as a result of a conference, whose main purpose was to promote technologies that encourage creative entrepreneurship in Portugal. Since then, the interest in FabLabs was growing, and there are currently 22 FabLabs in Portugal, although only 13 are active (Table 1) (*Labs | FabLabs, June 2022*). These FabLabs range from public to private organizations, or even a combination of two. Some are fully open (generally those located in public spaces), others are members only, or even - in the case of corporate makerspaces - fully closed to the outside. In Portugal, FabLabs generally struggle with the financing aspect, and they must constantly demonstrate a sustainable business model to maintain their activity and get funds. According to Matos *et al.* (2020) there are significant differences between the FabLabs. Those that received private investment are companies with a larger structure, more demand and higher turnover. On the other hand, the ones that are mostly financed by public funds have lower demand. Private FabLabs have a greater focus on organizations that finance them, while public investment-based FabLabs are more concerned about the mission of providing tools to the community, and helping to educate the population. Based on a questionnaire aimed to the FabLab managers in Portugal, Matos *et al.* (Matos *et al.*, 2020) concluded, that FabLabs are not profitable on their own. Profitability requires a shift in the mindsets of people, a heightened level of collaboration between organisations, and the encouragement of curiosity for its use in generating innovation and progress. Bernardo Gaeiras, the former director of FabLab Lisboa, mentioned two major challenges associated with FabLabs. The first is the collection of information on developed projects, which is still limited, and the second is the search for new sources of funding (Gaeiras, 2017). Redlich *et al.* (Redlich *et al.*, 2016) presented the findings of a study conducted on 75 FabLabs from developed countries and 19 from developing countries, which revealed that:

- an overwhelming majority of those polled FabLabs prioritise community building (70%) and education (85%) over Research and Development (R&D) (56%);
- 30% of the FabLabs reported that they have not collaborated with other FabLabs, or have not yet. Those who cooperated and still cooperate indicated that these interactions were extremely beneficial to all sides involved;
- 25% of the polled FabLabs identify the lack of a communication and collaboration platform as the greatest barrier to cooperation enhancement;
- 67% of FabLabs are supported by external funds and grants. 40% of FabLabs acquire funds through membership fees, while 33% by external project resources. Other sources of funding include sales revenues, donations, machine usage fees, etc;
- 45% of the FabLabs in developed countries are financed by membership fees, but in developing countries, only 21% use that source of funding. However, FabLabs in developing countries are much more successful in acquiring external project funding (74% versus 65%). When it comes to collecting donations, developed countries are more successful (23% versus 5%);
- FabLabs in developing countries focus a bit more on R&D than on community building and education. Additionally, they usually lack supply of 3D printers but they are in the lead with cutting and milling machines.

Based on that, it is evident that there are differences among FabLabs. In developed countries, FabLabs may typically rely on the financial support of individuals, whereas in developing countries, FabLabs predominantly need to rely on project funding from non-governmental organizations (NGOs) and institutions.

Table 1.

List of FabLabs registered on Fab Foundation (Labs | FabLabs, June 2022).

FabLab Name	Lab Location	Activity Status
FabLab EDP	Sacavém - Lisboa	Active
FabLab Porto – OPO LAB	Porto	Active
FabLab Lisboa	Lisboa	Active
FabLab Aldeias do Xisto	Fundão	Active
Weproductise FabLab	Viana do Castelo	unknown
FabLab Alto Minho	Arcos de Valdevez	unknown
FabLab Penela	Coimbra	unknown
FabLab Santarém	Santarém	unknown
FabLab ÉvoraTech	Évora	Active
FabLab IPB	Bragança	Active
Algarve FabFarm	Lagos	Active
FabLab Castelo Branco	Castelo Branco	unknown
MILL - Makers In Little Lisbon	Lisboa	Active
FabLab Caldas da Rainha	Caldas da Rainha	Closed
Buinho FabLab	Aljustrel	Active
FabLab Guarda	Guarda	unknown
FabLab Coimbra	Loreto	unknown
FCT FabLab	Almada	Active
FabLab Benfica	Lisboa	Active
VIVA Lab	Porto	Active
FabLab Porto de Mós	Porto de Mós	Active
Lab Aberto FabLab	Torres Vedras	Active
MetalShoe FabLab Network	Porto	Under evaluation

Hopefully, more funds are becoming available from international organisations - the European Union, the World Bank, *etc.* – as well as from municipalities that recognize the impact of these spaces on citizens, and on the Portuguese economy to be able to face future challenges: instead of outsourcing, they must invest to improve their in-house facilities and produce better services. Moreover, FabLabs can encourage university-industry collaboration by providing a space where culture, ethics of experimentation, trial/error logic, and mutual support are dominant.

2.2 FabLabs in footwear and metal industries

The Fourth Industrial Revolution or Industry 4.0 and the COVID-19 pandemic situation brought to light the importance of FabLabs, which are already viewed in Portugal as a mean to gain access to technology based on computer-controlled manufacturing to realize ideas, acquire knowledge and methods of innovation. In the particular case of COVID-19, the FabLabs had a great contribution by producing by 3D printing PPE and accessories/adaptors such as face shields, face masks straps/ear savers, door openers, respirator connectors among many other items (Coronell *et al.*, 2020). Besides, in a world where climate change is regarded as the greatest global health challenge of the 21st century due to its impact, sustainable and cleaner manufacturing systems are essential in industrial processes, particularly aerospace, automotive, and power generation (Perera *et al.*, 2020; Romanello *et al.*, 2021). Some conventional manufacturing methods are highly unsustainable regarding carbon emissions, energy consumption, material wastage, costly shipment, and complex supply management. Common spaces, such as FabLabs, where companies may access digital technologies and alternatives to conventional processes are crucial for innovation, creativity, learning, and implementing sustainable strategies in their organizations. Meanwhile, where conventional manufacturing techniques were hampered by lockdowns and restricted transportation, FabLabs spaces and digital adaptability enabled the rapid mobilization of technology as an effective emergency response.

In the metal sector, FabLabs have emerged as promising spaces, challenging the internal culture of industry innovation. The sector recognizes that such spaces can provide an effective alternative to the rigidity of the dominant and standardized processes, which were unfit for the maturation of ambitious ideas. Frequently, within corporations, employees have ideas that are either too exploratory or not technological enough to be incorporated into the standard processes. However, FabLabs can be a useful platform for assisting individuals to introduce more flexibility and versatility into long-standing processes. A good example is the implementation of a FabLab by Renault, Creative Lab, which was created by two employees who decided to challenge the existing paradigm and provide an alternative space for innovation. Employees at Creative Lab can engage in new (exploratory) activities without the approval of their managers (Lô & Fatien Diochon, 2019). Lô and Diochon (Lô & Fatien Diochon, 2019) conducted a two-year study of participant observation and 42 interviews on the Creative Lab. Based on their research, they proposed that FabLabs should be defined as a hybrid and inclusive workspace dedicated to exploration activities that support the empowerment of low-power actors within an organization. By offering employees the opportunity to carry out exploratory activities, they concluded that the in-house FabLab serves as a valuable tool and support for emerging employee ambidexterity. It takes the form of a safe space for exploratory activities and allows each employee to manage their own work, between production and exploration, and thus becoming ambidextrous.

Concerning the footwear industry, the scenario is slightly different from the metal industry. It can be said that there are almost no FabLabs dedicated to this sector. There are, however, a few spaces for innovation, demonstration, and training of technologies, without being classified as

FabLab per se. The CTC from France is an example of that, which features a “platform” for footwear and leather goods (“CTC - Compagnons Du Devoir - Un Partenariat de Formation Inédit,” 2020). In addition to that, some FabLabs with general purpose promotes activities that are related to footwear materials and prototyping as is the case of Barcelona FabLab (*FabLab Barcelona, Innovative Wearable Technology*, 2022) and FabLab Leon (*FabLab León, Biomaterials*, 2022).



Figure 1. Left: 3D printed shoe made at Barcelona FabLab. Right: Biomaterials developed at Leon FabLab

In Portugal, the Technology Centre of Footwear features an experimental learning space, created in 2018 for training, innovation, demonstration and acceleration of new ideas, the CTCP FabLab (*CTCP FabLab*, 2022), formerly referred as Shoe FabLab. This space aims for a professional network of footwear and leather goods manufactures, small enterprises, and craftsmen. It allows the production of prototypes, production of samples or even low-volume series/orders. It is also often used for workshops dedicated to either professionals or students from high school and university. The CTCP FabLab is equipped with CAD systems dedicated to footwear 2D and 3D modelling, cutting tools and sewing machines, and assembly and finishing equipment. In addition to the services and activities described before, the FabLab users also have access to a full range of other services, such as laboratory, footwear and leather goods materials, search for possible materials and component suppliers and specialized support from the CTCP technical team.

Overall, FabLab offer to the industry, particularly, footwear and metal industries, an opportunity for companies to use digital technologies to influence the production process towards sustainable design and adapt to the ever-changing environment of markets and innovative practices.

3. MetalShoe FabLab Network

The MetalShoe FabLab Network (*MetalShoe FabLab*, August 2022) project focus on the technical and technological support to the Portuguese companies of the metal and footwear sectors, regarding the recent developments in technologies such as computation, sensorization, digitalization, digital manufacturing, among others. The project enabled the establishment of two physical spaces as FabLabs fitted with these technologies, allowing the co-creation, training, learning by doing, innovation and acceleration of ideas, products and new business models, all while being supported by digital technologies in conjunction with traditional methods. It thus acts in 4 pillars: entrepreneurship, training, testing and promoting.

In addition, technical human resources are working in both FabLabs aiming to the knowledge transfer for the companies, at the same time they support the test of new materials, technologies, products and services. The group of technologies comprehend Additive Manufacturing, CAD

Modelling, Digitalization of Industrial Processes, Automation and Robotics, Digital Marketing and e-Commerce, Laser Cutting and Engraving, Virtual Reality and Augmented Reality, Internet of Things, Big Data, Cybersecurity, among others.

3.1. Current prospects and challenges

A FabLab role is also to be useful for the industry where it is integrated and to serve as an experimentation and dissemination channel for new or upcoming technologies. Companies were asked to answer a survey helping the MetalShoe FabLab to understand how these technologies are known and the level of integration in the industry and, at the same time, to shape the direction of the FabLab and how it will respond to the needs of the companies. This response is being taken on two levels, a direct reply to the identified needs of the industry and an introduction of new technologies that companies are not aware, and that the FabLab understands could be useful to the industry.

The questionnaire put the companies focused mainly on 4 limited answer questions and one open answer question:

1. Among the technologies/tools available in the MetalShoe FabLab, please indicate, on a scale of 0 (not familiar) to 5 (very familiar), how familiar are you with them?
 - a. Additive Manufacturing & 3D Printing
 - b. Digitalization of manufacturing and management/processes
 - c. 3D CAD Systems
 - d. Automation & Robotics
 - e. E-Commerce
 - f. Digital Marketing
 - g. Laser Cutting
 - h. Augmented Reality
 - i. Virtual Reality
 - j. IoT (Internet of Things)
 - k. Big Data
2. Among the technologies/tools identified, please indicate which ones are available or have already been integrated in your company?
3. Following the answer to the previous question and taking into consideration the technologies/tools identified as not being available or integrated in your company, please point out which one or more you think would add value to the activity of your company?
4. Of the technologies/tools identified, please tick which one or ones you would be interested in obtaining additional information or in more detail?
5. In addition to the technologies/tools available at MetalShoe FabLab, please indicate other technologies/tools for which you would like additional information or more detail?

At the time of the writing of this document, the questionnaire was still open, and answers being collected. Therefore, the data here presented represents a snapshot for July 2022, with 52 companies having replied.

Considering the first question referred above, where the degree of familiarity was evaluated, most of the companies appear to not be so well familiar with technologies related to virtual and augmented reality, IoT and Big Data. E-commerce appears to be the most common familiar technology with 3D CAD systems, laser cutting and digitalization following closely. Companies also appear to be familiar with the digitalization of management and processes

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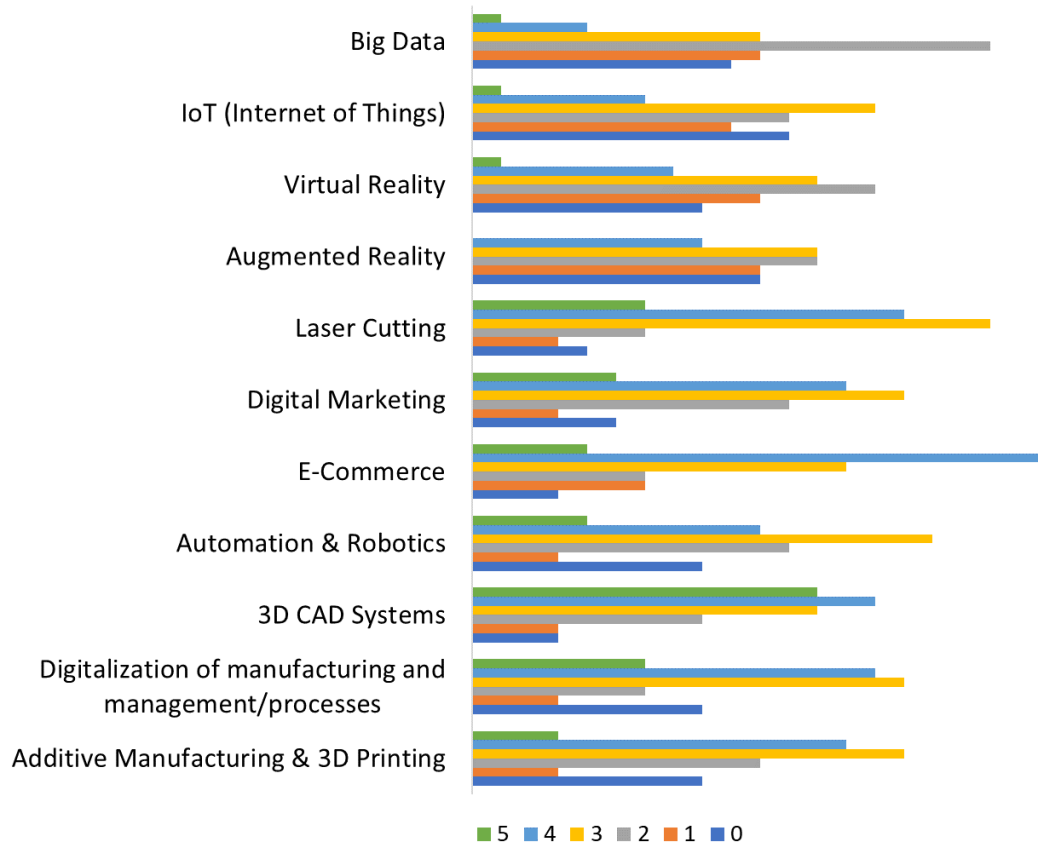


Figure 2. Question 1 - “Among the technologies/tools available in the MetalShoe FabLab, please indicate, on a scale of 0 (not familiar) to 5 (very familiar), how familiar are you with them?”

Considering the degree of integration of these technologies by the companies, 3D CAD systems were the most referenced, as can be seen in **Error! Reference source not found.**. This is related to the nature of both sectors where 3D CAD design and visualization are crucial. The trend of the replies appears to be related to the previously discussed question, where the knowledge of the technologies is somehow related to the degree of integration. Here, again, the least integrated technologies are augmented and virtual reality, IoT and Big Data. This can be due to a lack of interest and usefulness in these tools or a lack of the potentialities. At the same time, and considering question number 4, the companies seem to want to learn about these.

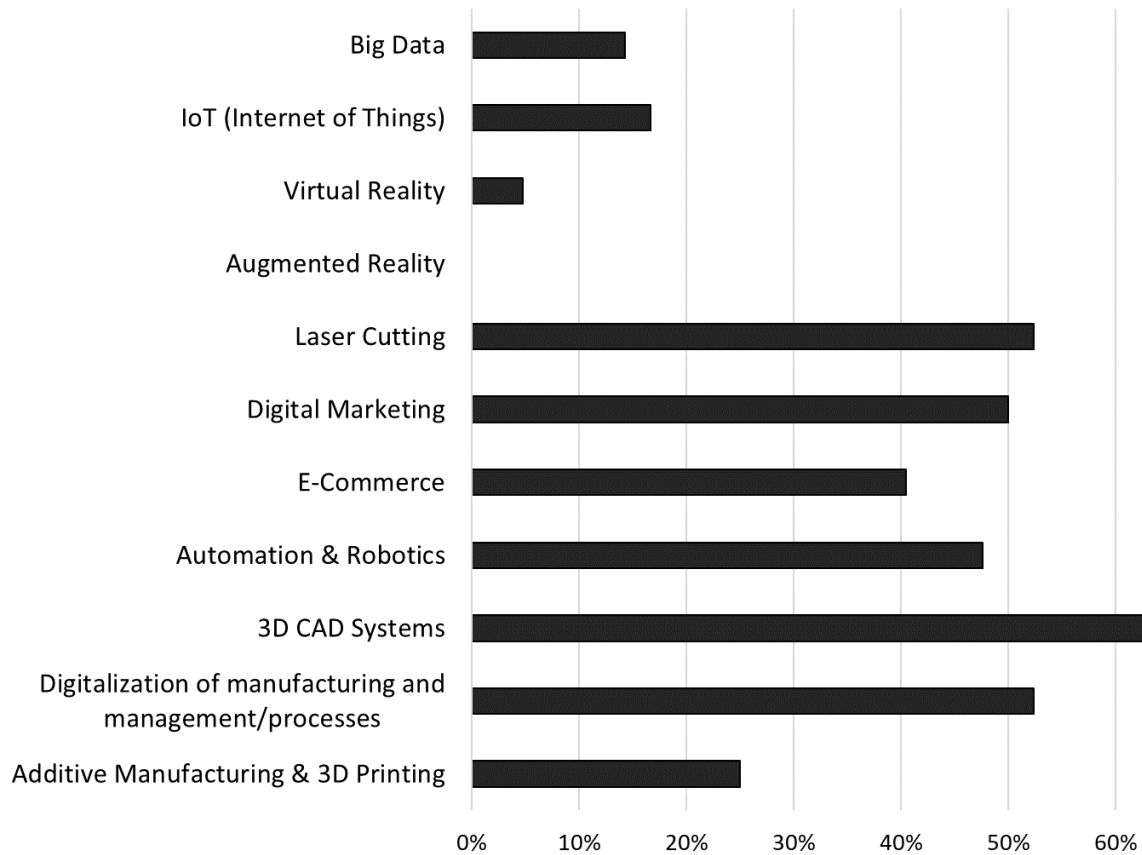


Figure 3. Question 2 - “Among the technologies/tools identified, please indicate which ones are available or have already been integrated in your company?”

Digitalization, automation and robotics, additive manufacturing and digital marketing were the ones selected as the technologies not yet integrated and that would bring value to the companies. Related to this, companies want to learn more about digitalization, additive manufacturing & 3D Printing and IoT, these being similarly chosen, and automation and robotics following closely behind (**Error! Reference source not found.** and **Error! Reference source not found.**).

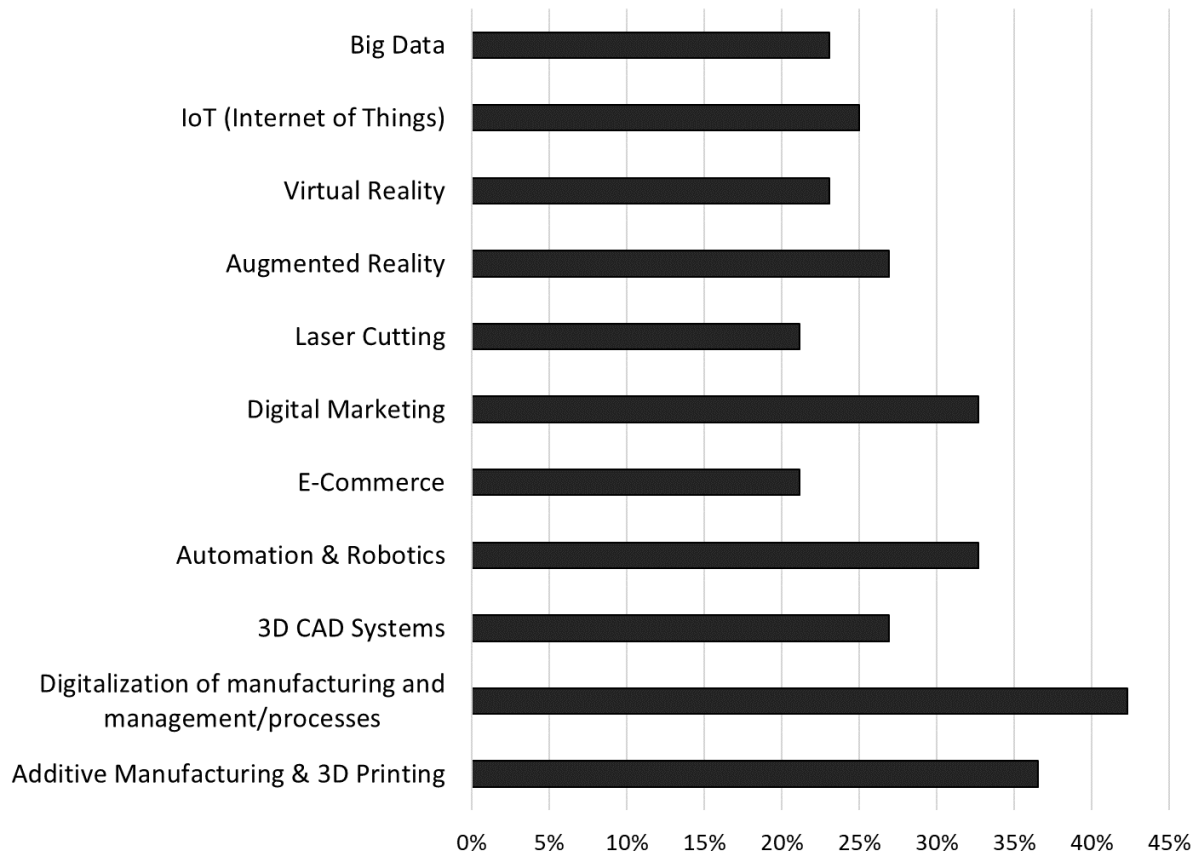


Figure 4. Question 3 - “Following the answer to the previous question and taking into consideration the technologies/tools identified as not being available or integrated in your company, please point out which one or more you think would add value to your company's activity.”

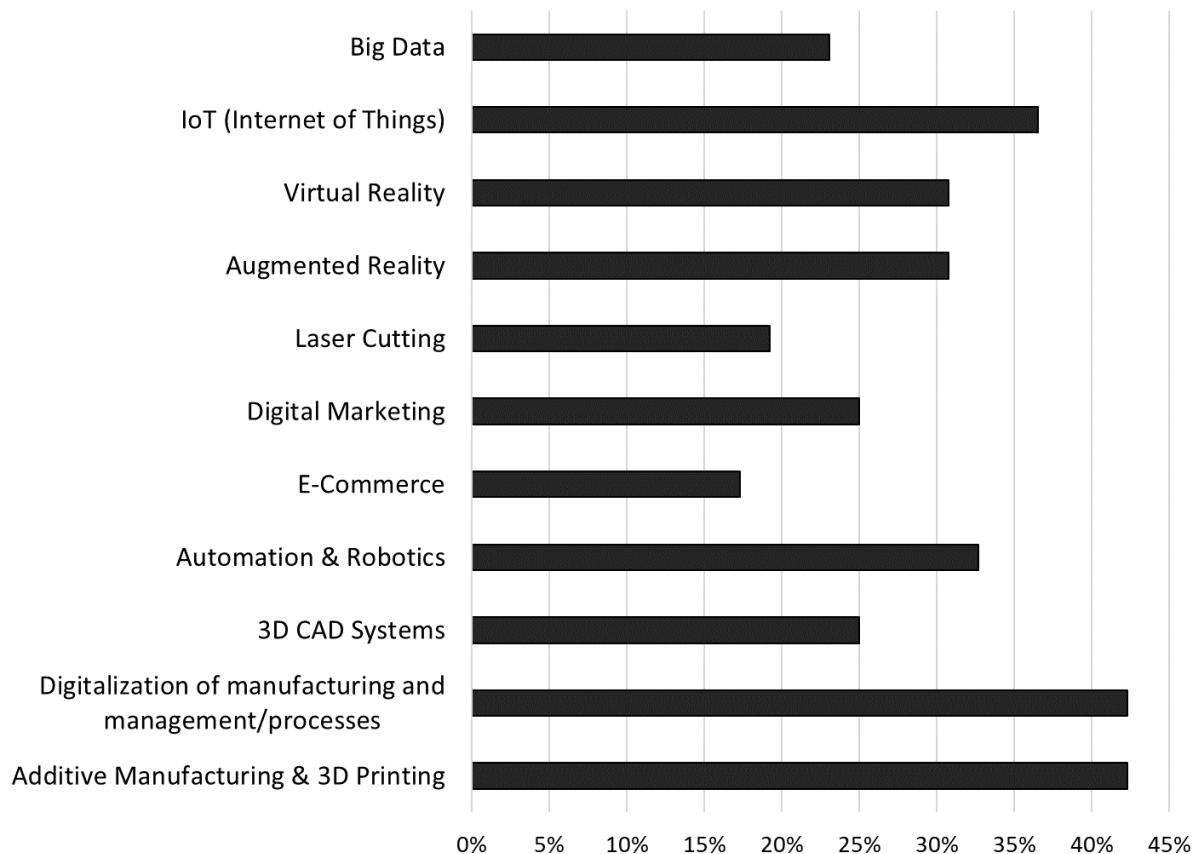


Figure 5. Question 4 - “Of the technologies/tools identified, please tick which one or ones you would be interested in obtaining additional information or in more detail?”

From the data presented and collected until the moment, even considering that it is just a snapshot of an ongoing process, it appears that companies are interested in the digitalization of their management and manufacturing processes, augmenting their level of automation and the degree of connectivity using IoT technology. The commercial part of the business is also relevant as it can be seen for the importance given to e-commerce and digital marketing. Laser cutting and 3D CAD systems are well integrated and known technologies. However, when related to additive manufacturing some 3D CAD processes need to be adapted and these are intimately connected. Considering the last question, the few answers received indicate that these companies search for general information about the metal industry and the computer numerical control for components and tools manufacturing.

As any FabLab, one of the challenges for the MetalShoe FabLab is to keep updated with the state of the art of digital technologies which may help the productivity and competitiveness of the companies that belong to the metal and footwear Portuguese sectors. It is important to identify the needs of the industry and guide them to the best technological solutions. In the scope of the MetalShoe FabLab Network project, a series of technical documents focused on various technologies were published, as follows:

- 1) Additive Manufacturing
- 2) Digitalization of Industrial Processes
- 3) CAD Systems
- 4) Automation and Robotics
- 5) Laser Cutting and Engraving
- 6) Digital Marketing and e-Commerce

- 7) Virtual Reality and Augmented Reality
- 8) Big Data
- 9) Internet of Things
- 10) Cybersecurity

The objective of these technical documents was to allow the entrepreneurs and their technical teams from both sectors to understand the potential of the technologies, their state of the art and have access to practical examples of those technologies from their related industries. With this, the companies can compare these cases with their reality and conclude if that is what meets their needs or not.

Another challenge of the MetalShoe FabLab Network is to support human resources training. Companies that adopt new technologies must prepare their employees for those technologies, which is not always the case in traditional sectors, such as the footwear industry. In addition to that, the implementation and use of new technologies in the companies will attract young human resources, which typically choose to work in companies which adopt innovation.

Finally, the MetalShoe FabLab Network aims to create European channels to improve the access to market and innovation technologies for the sector-specific and niche cluster entities. In addition, it is a challenge to create synergies between different industrial sectors, companies, entities and even consortia.

4. Conclusions

FabLabs play an important role in the implementation of innovation not only in companies but also in start-ups and other entities, acting as a space where they may analyse, test and validate the potential of new technologies and materials.

One of the objectives of the MetalShoe FabLab Network project was the creation of two spaces for the metal and footwear Portuguese sectors, filling a gap regarding this kind of structures.

It is noticeable that Portuguese companies have an increasing interest in digital tools and technologies, to help improve their level of digitalization and organizational efficiency. The technologies that got more interest were IoT, digitalization of industrial processes, additive manufacturing and automation and robotics. The MetalShoe FabLab Network supports the industrial entities not only in validation and technology testing but also in the technological demonstration and technical guidance.

The importance of the MetalShoe FabLab Network for the Portuguese metal and footwear sectors is perceived by the companies and the future holds for the FabLabs an important role in the identification and knowledge transfer of new and disruptive technologies.

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