International Journal for Quality Research 12(4) 957–974
ISSN 1800-6450

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Article info:
Received 10.08.2018
Accepted 30.10.2018

UDC – 65.016.2
DOI – 10.18421/IJQR12.04-11

MANUFACTURING LABS: WHERE NEW DIGITAL TECHNOLOGIES HELP IMPROVE LIFE QUALITY

Abstract: *The aim of this paper is to analyze where Do It Yourself (DIY) comes to life, investigating the economic reality of Italian Fabrication Laboratories, an international network of digital laboratories which provide a space with new technologies tools for digital manufacturing, identifying their role both towards consumers and businesses in the Industry 4.0 era, with the purpose of helping to improve the quality of life. Data from Italian Fab Labs were collected using a questionnaire survey; 27 Fab Labs participated to the survey. The results show that, while some laboratories are still in an embryonic phase, with no or very few registered users, others are in full activity reaching over 100 users. Italian laboratories are characterized by ample space available, but limited capacity for investment in machinery and technology. The role of Fab Labs in the Italian economic panorama could be double, and affect the consumer side, transforming consumers in "co-designers" of products, and on the other side, helping businesses designing and building prototypes to improve products 'quality.*

Keywords: *Fabrication Laboratories, Industry 4.0, Digital technologies, Additive Manufacturing*

1. Introduction

The need for reduced development time together with the growing demand for more customer-oriented product variants have led to the next generation of Information Technology (IT) systems in manufacturing (Chryssolouris et al., 2009) The possibility of controlling through a computer the equipment for the Manufacturing production, that helped to improve the quality of the production process, was a reality as early as the 80s, when the first numerical control equipment for milling, turning, drilling, etc. were introduced, according to the logic of "subtraction from full ", typical of traditional manufacturing (Beltrametti & Gasparre, 2015; Santos & Barbosa, 2006; Santos, Mendes & Barbosa, 2011). Another example of the introduction of IT, in the manufacturing world, is the concept of computer-integrated manufacturing (CIM). This concept was introduced in the late 1980s, favoring the enhancement of performance, efficiency, operational flexibility, product quality, responsive behavior to market differentiations, and time to market (Cagliano & Spina, 2003). Almost simultaneously the first 3D printers, which were used to realize plastic prototypes, developed. Unlike numerical control machines, for a few decades this technology had important applications in the process of development of new products but its diffusion was relatively

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limited and it started to be used into the final production only about ten years later. As in the case of numeric control machines and robot, 3D printers manufacturing can be called "digital" since the designer must be able to use a software - the computer Aided Design (CAD)- which gives a virtual representation of the object that has to be produced starting from its geometric parameters that are transmitted from a computer to a machine that realizes it (Beltrametti & Gasparre, 2015). The CAD systems have become indispensable to today's manufacturing firms, because of their strong integration with advanced manufacturing techniques such as 3D printing. CAD models are often considered sufficient for the production of the parts, since they can be used for generating the code required to drive the machines for the production of the part. Rapid prototyping is just an example of such a technology (Chryssolouris et al., 2009).

Over the past few decades, the extensive use of IT in manufacturing has allowed these technologies to reach the stage of maturity, and to be now used as high quality tools to process and production quality management (Doiro et al., 2017; Rebelo et al., 2016; Stefanovic et al., 2009).

In this context, Digital Manufacturing represents the natural evolution of the manufacture: 3D Printing, Generative Manufacturing, e-Manufacturing, Constructive Manufacturing, Additive Layer Manufacturing, Direct Digital Manufacture, Freeform Fabrication, Rapid Manufacturing are just some of the terms that are used to describe "features" or "impacts" of digital technologies and the technologies of 3D printing on the production systems. Thus it was born the need to arrive at a clear definition of business models that exploit this set of new technologies. In this sense, the definition of *Digital Manufacturing* is justified by the need to describe an already extensive system, not necessarily tied to a specific technology, which in the next few years promises to evolve further in its qualitative and quantitative meaning. In this sense, Digital Manufacturing expresses well the renewal of the manufacturing system using digital technologies and 3D printing technologies, that are used in an integrated way in order to reach product innovation, testing, prototyping and the production of goods, allowing also the optimization of the manufacturing, marketing and distribution processes in a virtual environment (Pricewaterhouse & Confartigianato imprese, 2015). It should be stressed that the 3D printing is just one of the technologies related to Digital Manufacturing; numerical control machines (CNC) and laser cutter technologies are digital technologies as equals, although already widely used and no longer directly related to the concept of innovativeness and renewal that it wanted to be described. The word "Digital" connotes a wide range of Information Technologies and phenomena caused or affected by these technologies. The list can be shorter or longer, but experts, universities and consulting firms tend to converge in considering in it Mobile, Social Media Collaboration, Cloud Computing, Big Data and Internet of Things (IoT), along with the innovative 3D technology of AM (Pwc & Confartigianato imprese, 2015).

The aim of this paper is to analyze where DIY comes to life, investigating the economic reality of Italian Fab Labs. These laboratories work with the typical mechanisms of the sharing economy: they provide a space with tools and equipment for digital manufacturing, making them available to individual users, small businesses and schools. In detail the aim is to analyze the Italian economic reality of Fab Labs identifying their role both towards consumers and businesses in the Industry 4.0 era with the purpose of helping to improve the quality of life. The work tries to cover a literary gap, since only few and specific qualitative works have been done on Fab Labs. The novelty resides in the experimental techniques used, in fact while some qualitative case studies have been developed in the field, no previous quantitative analysis have been developed on a sample of Fab Labs.

The research questions, which the paper investigates are the following:

RQ1: How is the structure and organization of an Italian Fab Lab?

RQ2: Which are Italian Fab Labs' main customers and which kind of services they deliver to them?

RQ3: Which are the main Italian Fab Labs skills?

The paper is divided as follows: section two defines the theoretical framework, section three presents the research methodology used. Subsequently section four describes the results of the empirical research and discusses them. Finally section five draws the conclusions of the work, explaining the main implications and the limitations of it.

2. Theoretical Framework.

2.1. Digital Manufacturing and the International Maker Movement

Digital Manufacturing represents for large-scale manufacturing the opportunity to approach the customer's specificity and product uniqueness, while maintaining the dimensional characteristics that are typical of industrial production (Doiro et al., 2017; Marques et al., 2018). Digital, artisan or industrial manufactures offer the ability to design and produce new product solutions by following innovative manufacturing processes that are developed through market dynamics stimulated by a constantly changing demand. In this way, the world of handicrafts and manufacturing is also approaching consumers who are not usually involved because of cultural, economic and/or logistical barriers (Pricewaterhouse & Confartigianato Imprese Varese, 2015). In this context lies the definition of Maker Movement which consists of a growing culture of hands-on making, creating, designing, and innovating. It has been with the launch of MAKE Magazine in 2005, that Dale Dougherty and his team provided the catalyst for a tech-influenced Do-It-Yourself (DIY) community that has come to be identified as the Maker Movement (Dougherty, 2012). The maker movement refers broadly to the growing number of people who are engaged in the creative production of artefacts in their daily lives and who find physical and digital forums to share their processes and products with others (Halverson & Sheridan, 2014).

According to Manzo & Ramella (2015), makers might be called the new craftsmen of the digital era. Many of them are hobbyists and amateurs. Werner Sombart (1916) would have classified them as «Sunday inventors». Others, however, are proto-entrepreneurs who use their creative and professional skills to launch new products and activities. These would have been defined by Sombart (1916) as "weekday inventors" or "inventors of anything".

Makers are often young people with a passion for personal fabrication: they combine DIY with the use of digital technologies, thus giving rise to new economic phenomena. In some cases, these are activities that are not primarily motivated by reasons of acquisitiveness and are not aimed at producing goods for the market: they follow a different logic, based on cooperation, the dissemination and sharing of knowledge and the application of open source principles to the manufacture of material objects. In other cases, these are activities that do not exclude commercial purposes, generating productive and entrepreneurial phenomena that collocate them partly in the context of the sharing economy and partly in that of the market economy (Manzo & Ramella, 2015).

It is believed that the maker movement has the potential to transform how and what people learn in Science, Technology, Engineering, and Mathematics (STEM) and arts disciplines (Peppler & Bender, 2013).

President Obama spoke about it in his remarks on the Educate to Innovate campaign, saying *"see the promise of being the makers of things, and not just the* *consumers of things"* (www.washingtonpost.com). This orientation toward personal fabrication rather than blind consumerism is also seen as the foundation for a new, more prosperous economy.

Always president Obama, at the first ever White House Maker Faire in 2014, declared *"I am calling on people across the country to join us in sparking creativity and encouraging invention in their communities"* (www.obamawhitehouse.archives.gov).

Chris Anderson (2012), former editor-in-chief of *Wired* magazine, defines the movement as "a new industrial revolution." He distinguishes between the maker movement and tinkerers, inventors, and entrepreneurs of prior eras by referencing three key characteristics: the use of digital desktop tools, a cultural norm of sharing designs and collaborating online, and the use of common design standards to facilitate sharing and fast iteration.

Mark Hatch (2014), Chief Executive Officer (CEO) and cofounder of TechShop, one of the first and most successful makerspaces, has also proposed a "Maker Movement Manifesto" that describes makers' activities and mind-sets organized around nine key ideas: make, share, give, learn, tool up (i.e., secure access to necessary tools), play, participate, support, and change. Anderson (2012) and Hatch (2014) highlights the importance of the construction of physical objects as a feature of the maker movement that makes it distinct from the earlier computational and Internet revolutions.

Hatch (2014) said that *"The real power of this revolution is its democratizing effects. Now, almost anyone can innovate. Now almost anyone can make. Now, with the tools available at a makerspace, anyone can change the world"* (Hatch, 2014).

The celebration of the Maker Movement is a large scale event called Maker Faire. It defines itself as *"part science fair, part county fair, and part something entirely new, Maker Faire is an all-ages gathering of tech enthusiasts, crafters, educators, tinkerers, hobbyists, engineers, science clubs, authors, artists, students, and commercial exhibitors."* All of these "makers" come to Maker Faire to show what they have made and to share what they have learned.

The launch of Maker Faire in the Bay Area in 2006 demonstrated the popularity of making and interest among legions of aspiring makers to participate in hands-on activities and learn new skills at the event. 200,000 people annually attend the Maker Faires in the Bay Area and New York. It is a family-friendly event, in fact 50% of people attend the event with children. In 2017, over 190 independently-produced "Mini Maker Faires" plus over 30 larger-scale Featured Maker Faires will have taken place around the world, including Tokyo, Rome, Shenzhen, Taipei, Seoul, Paris, Berlin, Barcelona, Detroit, San Diego, Milwaukee, and Kansas City. Maker Faire is primarily designed to be forward-looking, showcasing makers who are exploring new forms and new technologies. But it's not just for the novel in technical fields; Maker Faire features innovation and experimentation across the spectrum of science, engineering, art, performance and craft (Peppler & Bender, 2013; http://makerfaire.com/makerfairehistory/).

According to Dougherty (2012) at Maker Faire, *"we see innovation "in the wild." It hasn't been "domesticated" or controlled, you have to look for it, and to turn a corner at any of our Faires is to see something you haven't seen before."*

2.2. The Italian Economic Reality of Fab Labs

The Fab Foundation defines a Fabrication Laboratory (Fab Lab) as an *"educational outreach component of Massachussetts Institute of Technology's (MIT) Center for Bits and Atoms (CBA), an extension of its research into digital fabrication and computation. A Fab Lab is a technical prototyping platform for innovation and invention, providing stimulus for local entrepreneurship. A Fab Lab is also a* *platform for learning and innovation: a place to play, to create, to learn, to mentor, to invent. To be a Fab Lab means connecting to a global community of learners, educators, technologists, researchers, makers and innovators - a knowledge sharing network that spans 30 countries and 24 time zones. Because all Fab Labs share common tools and processes, the program is building a global network, a distributed laboratory for research and invention."* (http://fabfoundation.org).

This international network was founded by MIT professor Neil Gershenfeld, who opened the CBA in 2001. The Fab Lab project builds on the success with MIT students of an experimental course launched by Gershenfeld in 1998 called "How to Make (Almost) Anything", the intention of which was to bring together personal and digital fabrication, individual creativity and group collaboration (Manzo & Ramella, 2015).

The rapid proliferation of Fab Labs in many countries over the past decade must be understood against this background. The actual number of Fab Labs present all over the world is at present (September 2018) of 1176 laboratories.

These laboratories work with the typical mechanisms of the sharing economy: they provide a space with tools and equipment for digital manufacturing, making them available to individual users, small businesses and schools. There are three main objectives (Manzo & Ramella, 2015): training; the promotion of digital fabrication and the development of open-innovation, improving the quality of products (Rebelo, Santos & Silva, 2017; Ribeiro et al., 2017), as well as, the well-being of workers (Santos et al., 2014; Santos, Bravi & Murmura, 2018a), collecting their best ideas to promote business excellence (Santos et al., 2018c).

The short history of the Italian Fab Lab is characterised by two important stages: a first stage that could be called *embryonic* and a second that could be labelled *explosion*. The diffusion process, was very quick, with the first Fab Lab born in 2012 in Turin (http://fablabtorino.org) and the *explosion* phase developed in the first half of 2014. The phenomenon has spread first in the North of Italy, via Reggio-Emilia, Trento and Milan, and then it reached the South (Aliazzo, 2014).

If the spread of Italian Fab Labs was very fast, it was still late taking off compared to the rest of Europe: the European *embryonic phase* occurred in 2008 (four years before the "Fab Lab Torino"), when two laboratories were opened in Barcelona and Amsterdam that are still a reference point for the global network (Manzo & Ramella, 2015).

In the years preceding the explosion phase, two major events involving the digital fabrication and maker world took place. The first took place in Turin in 2011, when, as part of the "Future Station" exhibition, "Fab Lab Italia" was created, a temporary digital fabrication laboratory. The theme of digital fabrication found fertile terrain in the city and, a few months after the exhibition closed, exactly February 14, 2012, the first Italian laboratory, the "Fab Lab Torino", was founded in former industrial buildings which housed the co-working *Toolbox* and *Officine Arduino*. The second major event occurred in 2013, when Rome hosted the first *Maker Faire*, *the European edition*, an exhibition connected to Make magazine, a point of reference for the Maker community.

According to the work of Manzo & Ramella (2015) the founders of Italian Fab Labs, in most cases, are men (11% being women) and are between 30 and 40 years of age (the average age being 35). Aliazzo (2014) found that about 80% of the tested realities were born on the initiative of individuals. Engineers, Architects, Industrial Designers and Informatics (these are the founders' profiles in all the cases analyzed) gathered to start an association in 44% of cases or to a private enterprise in 27%. Fab Lab is located in private premises rented in 50% of the sample, but a high percentage is hosted by public premises (23%). Three different types of founders were defined (Manzo & Ramella, 2015):

1) ***the sharing-entrepreneurs***: for the sharing-entrepreneur, opening the laboratory is all about their passion to lead the way. Before opening the Fab Lab, they have had other professional experiences related to information technology, electronics and design, but these have not completely satisfied their know-how and need for professional independence. The sharing-entrepreneur believes that the Fab Lab, thanks to its particular features and potential, can become a real R&D laboratory external to companies.
2) ***The designer***: The Fab Lab represents an evolution of one part of the designer's professionalism: not a "new" starting point, as in the previous case, but something in a line of continuity with their work. It is not a private investment made exclusively to bring growth to their own studio: "collective" and pro-social objectives also exist, since the space is open to everyone.
3) ***The patchworker***: these are founders for whom the laboratory has become a (patch-like) "piece" of their professionalism. All have one or more jobs and, having always been passionate about electronics and new technologies, they decide to make a professional investment in a Fab Lab. In these cases, the opening hours are influenced by the availability of free time of the founder and the other partners: they are usually open in the late afternoon and/or evening and at weekends.

With regard to machine equipment, the main tool used in the Fab Labs is 3D printer: about 95% of respondents claim to own and use 3D printers, there are on average 2.6 of them per laboratory. Along with 3D market printers, the amount of self-assembled and built-in Arduino technology increases, accounting for about 30% of 3D printers in Fab Lab. Just Arduino circuits are the second technology in the Fab Lab, with 13.1 units present on average in over 83% of the interviewed realities. The high spread of Arduino control cards is a symptom of one of the pillars behind Fab Lab's philosophy: knowledge-based culture based on the spread of open source technologies that are subject to continuous evolution. In addition to highly innovative machineries and technologies (from 3D printers to Arduino, from Internet of Things (IoT) platforms to 3D scanners), Fab Lab's equipment also features traditional machines typical of craftsmanship (numerical milling machines, lathes, pantographs, instrumentation for carpenters) to prove how the Fab Labs are structuring to become laboratories in which the "new" craftsman experiments and adopts digital technologies to face the challenges imposed by innovation. Open Source technologies have a predominant presence in these realities (Aliazzo, 2014). The services offered by Fab Labs can be categorized into three main areas (Aliazzo, 2014):

1) the first concerns services closely related to the design, prototyping, and production (in a low-scale) of products through 3D printers and the universe of corollary modelling software. 88% of Fab Labs deliver product printing services (mainly for the consumer world), and supports the user in product design and in designing new concepts.
2) The second is due to consultancy activities. It increases the use of skills of Fab Labs for choosing the right 3D printer for specific demand requirements (75% of Fab Labs outsourced this service); but also for the advice in terms of support in redefining production processes rather than material consulting (over 60% of sample Fab Labs have been involved in decisions in such areas).
3) Finally, always connected to the material theme, Fab Lab is often

used as a reference operator for the supply of printable materials.

Often, the success of a Fab Lab is closely related to the competences within it: first of all, Arduino's programming skills on the platforms, but equally significant and widespread are the expertise in materials, hardware and self-assembled machines, software programming, knowledge of company processes and design software. Important, but not so widespread, the expertise of the companies or products in the field of IoT (Aliazzo, 2014).

3. Methodology

The aim of the research was to develop an exploratory analysis (Malhotra & Grover, 1998) using an inductive research approach Eisenhardt (1989).

Data from Italian Fab Labs were collected using a questionnaire survey. The total number of Italian Fab Labs was at the moment of the survey (September, 2017) n= 134 and of these, the e-mail address of 112 Fab Labs was found on the web. The list and contacts needed to contact Fab Labs have been found in the official website of the Fab Foundation (http://fabfoundation.org/), an organization formed in 2009 to facilitate and support the growth of the international Fab Lab network. The survey began September 18th, 2017 and answers were accepted until November 8th, 2017. The administration of the survey took place by e-mail; 27 Fab Labs participated to the survey reaching a total response rate of 24.11%. A structured questionnaire was distributed via Computer Assisted Web Interviewing (CAWI) consisting of three sections, following the structure of Menichelli & Ranellucci (2015) and Aliazzo (2014). The first section investigates the sample profile of the respondent Fab Labs, considering the location, the number of workers, the size of the structure, the annual revenue, the average number of users and their investments for machinery and technology. The second section depicts Fab Labs' skills and competences; in detail which are their main customers, which kind of products they realize and for which sector, which kind of new digital machines they use most, their main skills and the services they deliver most to their customers have been investigated.

Finally section three takes into consideration the use of digital technologies and their impact on the environment considering which percentage of Fab Labs' production is reserved to the creation of eco-sustainable products and if they think that the use of digital technologies, such as 3D printers, can affect the environment, in detail the air quality of the work environment. At the end of the section it has been asked if they think that 3D printers and other digital technologies can represent the turning point that will allow industries to enter a new industrial revolution.

Descriptive analysis was performed to describe the sample profile of respondent Fab Labs. A five-point Likert scale was used to evaluate Fab Labs' skills, competences and services delivered to their customers.

Moreover, to verify the reliability of the Likert analysis, Cronbach's alpha values were computed, taking into account only alpha values greater than 0.60 as suggested by Nunnally & Bernstein (1994). In data processing, the SPSS 23.0 program (Statistical Package for Social Science) was used.

Non-response bias was assessed by verifying that early and late respondents were not significantly different (Armstrong & Overton, 1977). A set of tests compared respondents who answered to the questionnaire during the first administration and those who answered when the survey was submitted for the second time. All possible t-test comparisons between the means of the two groups showed insignificant differences ($p<0.1$ level).

4. Results and Discussion

4.1. Italian Fab Labs' profile

Depicting the profile of respondent Italian Fab Labs (Table 1), it can be seen that volunteer workers are usual, and in the 73.3% of cases there are among 1 and 10 volunteers working on these laboratories, while more than 1 Fab Lab in 2 (55.6%) does not have paid staff. The size of these Italian laboratories is in majority between 25 and 74 (33.3%) and between 75 and 200 square meters (44.4%). As for the number of associated or registered users, this is very varied, with some laboratories (probably of recent birth) that do not have registered users (14.8%), while others that have more than 100 users registered (22.2%).

In average the annual income of Italian Fab Labs is about 31,875.00 € and therefore their relative investments for machinery and technology are relatively slow, with 51.9% of them investing less than 10,000 € per year and a 25.9% arriving at most not more than 50,000 € per year. There are two singular cases of big laboratories which invest between 100,001 and 300,000 € and between 300,001 and 500,000 € per year, but these are exceptions in the Italian reality. Finally considering the acquisition of State of European incentives 11 out of 27 laboratories (40.7%) claimed to have received this kind of economic aid.

Table 1. Profile of respondent Fab Labs

	Italy (27)	
	n	*%*
Volunteers workers		
0 volunteers	5	18.5%
1-5 volunteers	14	51.1%
6-10 volunteers	6	22.2%
11-20 volunteers	2	7.4%
more than 20 volunteers	0	0.0%
Paid staff		
0 employees	15	55.6%
1-5 employees	10	37.0%
6-10 employees	1	3.7%
11-20 employees	1	3.7%
more than 20 employees	0	0.0%
Size of Fab Lab		
5-24 SQM	1	3.7%
25-74 SQM	9	33.3%
75-200 SQM	12	44.4%
>200 SQM	5	18.5%
Associated or registered users		
0 users	4	14.8%
1-20 users	6	22.2%
21-50 users	6	22.2%
51-100 users	5	18.5%
More than 100 users	6	22.2%

Table 1. Profile of respondent Fab Labs (continued)

Annual Income in avarage	31,875.00 €	
Investments for machinery and technology		
< 10,000 €	14	51.9%
10,001-50,000 €	7	25.9%
50,001-100,000 €	4	14.8%
100,001-300,000 €	1	3.7%
300,001-500,000 €	1	3.7%
500,001-1,000,000 €	0	0.0%
> 1,000,000 €	0	0.0%
Received State or European incentives		
Yes	11	40.7%
No	16	59.3%

As for the Italian regions in which the respondent Fab Labs are located (Table 2), it can be seen that the majority (5) are located in the North, exactly in Piemonte, followed by 4 in Emilia Romagna and 4 in Lombardia. As for the center regions of Italy, Fab Labs answered from Marche (2) and Umbria (2) and finally the southern regions which participated to the survey are Basilicata (1) Campania (1) and Sardegna (1).

Table 2. Region of location in Italy

	n	*%*
Basilicata	1	3.7
Campania	1	3.7
Emilia Romagna	4	14.8
Friuli Venezia Giulia	1	3.7
Lazio	2	7.4
Liguria	2	7.4
Lombardia	4	14.8
Marche	2	7.4
Piemonte	5	18.5
Sardegna	1	3.7
Umbria	2	7.4
Veneto	2	7.4

Analyzing which are the main customers of Italian Fab Labs (Table 3), it can be seen that individual customers (3.85) are the main subjects for which these laboratories work, followed by Practitioners (3.00) and Designers (3.00). On the contrary universities seem to be the institutions with which they work less (2.30).

Subsequently it has been asked to the respondent to indicate to which industry the products that they realize most within their Fab Labs belong. From Table 4, it can be seen that in majority they realize product for the Technology industry, in detail for the Electronic industry (3.48) and the Internet of Things (IoT) one (3.19). In addition to this, it seems that also products for the furniture industry are produced with a certain frequency.

Table 3. Italian Fab Labs' main customers

	N	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
Manufacturing companies	27	1.0	5.0	2.56	1.050
Individual customers	27	2.0	5.0	3.85	0.864
Practitioners	27	1.0	5.0	3.00	0.920
Institutions/schools	27	1.0	5.0	2.78	1.050
University	27	1.0	5.0	2.30	1.031
Artists	27	1.0	5.0	2.59	0.971
Designers	27	1.0	5.0	3.00	1.000
Cronbach's Alpha 0.834					

Table 4. Sectors with which Italian Fab Labs operate

	N	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
Fashion	27	1.0	5.0	2.11	1.086
Furniture industry / furniture components	27	1.0	5.0	3.07	1.141
Mechanics	27	2.0	5.0	2.93	0.829
Automotive	27	1.0	4.0	1.74	0.764
Food	27	1.0	4.0	1.89	0.892
Technology - Electronic	27	1.0	5.0	3.48	1.087
Technology - IoT	27	1.0	5.0	3.19	1.111
Technology – Software	27	1.0	5.0	2.63	1.115
Cronbach's Alpha 0.638					

Considering the type of product they realize most (Table 5), it can be seen that they generally produce any kind of prototypes, but with a certain frequency also finished products, and as underlined before, they work more with single customers than with companies.

Table 5. Type of realized products

	N	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
Products to be marketed	27	1.0	5.0	2.00	1.000
Finished products for a single customer	27	1.0	5.0	3.00	1.074
Prototypes for companies	27	1.0	5.0	2.63	1.006
Prototypes for a single customer	27	1.0	5.0	3.26	0.859
Cronbach's Alpha 0.844					

In a later phase the study tried to understand Italian Fab Labs skills and competences starting from the kind of advanced technologies most used inside their laboratory. As it can be seen from Table 6, laser cutters (4.33) and 3D printers (4.30) are used almost daily. These two tools are followed by the use of controls cards, such as Arduino (3.44) and CNC milling machines (3.41).

Table 6. Use of these machines in the Fab Lab

	N	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
3D printer	27	2.0	5.0	4.30	.823
3D scanner	27	1.0	4.0	2.63	1.043
Laser cutter	27	1.0	5.0	4.33	1.144
CNC milling machines	27	1.0	5.0	3.41	1.152
Vinyl cutter	27	1.0	5.0	2.59	1.083
Lathe	27	1.0	4.0	1.56	.801
Control Cards (Arduino or similar)	27	1.0	5.0	3.44	1.281
Precision punches for printed circuits	27	1.0	5.0	2.33	1.330
Cronbach's Alpha 0.721					

As for the major services delivered to their customers (Table 7), Italian Fab Labs offer a wide range of courses and training (3.85); in this regard the work of Mostert Van der Sar et al. (2013), showed that Fab Labs play an important role in design education. Moreover, they offer with a certain frequency support in the creation of prototypes (3.70), they directly print products with 3D printing (3.56) and give support to design new products. Therefore, these results show that Fab Labs are not only a practical place for creating objects, but also a place for sharing skills and competences, a pool of knowledge and technical-practical skills that are exchanged and shared between the staff and their registered users. These results show that Italian Fab Labs are near to the definition of Fab Lab given by their founders (Mikhak et al., 2002) that is to say a laboratory that is equipped with an initial selection of design and modelling, prototyping and fabrication, testing and monitoring and documentation tools.

Table 7. Services delivered to customers

	N	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
Printing of products	27	1.0	5.0	3.56	1.311
Support to the creation of prototypes	27	2.0	5.0	3.70	.823
Support to the design of new products	27	1.0	5.0	3.30	1.068
Support for finding the most suitable 3D printer	27	1.0	5.0	2.89	1.188
Support to the redefinition of the production process	27	1.0	5.0	2.89	1.013
Consultancy on materials	27	1.0	5.0	3.19	1.178
Provision of materials	27	1.0	5.0	2.37	1.391
Courses and training	27	2.0	5.0	3.85	1.064
Cronbach's Alpha 0.837					

Afterwards it has been asked to the respondent Fab Labs to indicate which are their main skills. As shown in Table 8, the main skills owned by these Italian laboratories are digital manufacturing skills (4.52), skills in using design software (4.26) and skills on materials (4.00). As for the skills less possessed, it seems that they have not so much knowledge on the Internet of Things (IoT) issue and on company products, and this second result is in line with the fact that Italian Fab Labs work more with single customers than with businesses and practitioners.

Table 8. Italian Fab Labs' skills

	N	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
Arduino Programming skills	27	1.0	5.0	3.41	1.448
Skills on materials	27	2.0	5.0	4.00	0.961
Hardware skills	27	2.0	5.0	3.81	1.001
Skills on business processes	27	1.0	5.0	3.63	1.115
Software programming skills	27	1.0	5.0	3.37	1.275
Skills in using design software	27	2.0	5.0	4.26	0.944
Skills on company products	27	1.0	5.0	3.33	1.109
Skills on Internet of Things (IoT)	27	2.0	5.0	3.26	1.059
Digital Manufacturing Skills	27	2.0	5.0	4.52	0.802
Cronbach's Alpha 0.848					

But what are the differences between products realized in a company and products made in a Fab Lab? (see Table 9) Which kind of product features can be exalted realizing a product in this type of laboratories? Fab Labs answered that first of all the territoriality of product is exalted (3.93), that is the fact that the product is a handicraft product, of a handicraft that has become digital, but which allows the same to enhance the locality of the product and its realization that is ad hoc for the customer. The second element that distinguishes Fab Lab products from companies'ones is the design: no more schemes to follow or molds to use; design freedom is the keyword of these laboratories (Hopkinson, Hague, & Dickens,2006). But Fab Labs believe that also product quality and ergonomics are features that are exalted when they realize their products.

Table 9. Features exalted by Fab Lab's products

	N	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
Design	27	1.0	5.0	3.89	1.155
Product Quality	27	1.0	5.0	3.74	1.130
Ergonomics	27	1.0	5.0	3.74	1.095
Territoriality	27	1.0	5.0	3.93	1.072
Security	27	1.0	5.0	3.19	0.962
Cronbach's Alpha 0.870					

Later, the propensity of Italian Fab Labs to the creation of eco-sustainable products have been investigated. The 51.9% of respondents declared to realize products paying attention to the use of quality materials that respect the environment (Santos et al., 2016). There have been found differences when they were asked how many eco-sustainable products were made within their Fab Labs. While some claim to achieve a few tens of products with such characteristics, others say to realize at least 40% of the total, while others still say that all the products produced have such characteristics and exclusively sustainable quality materials are used to produce them. Among the sustainable products made within the Italian Fab Labs there are recycled wood furniture, candles, cases for electronic cigarettes, custom furnishing items in hemp bioplastic filament, wooden bat house, smart hive, sensors for improving energy efficiency, control units for environmental monitoring, paperweight in recyclable plastic, sustainable packaging, wooden signs, tablewear and shells in recycled PLA.

When asking them why they realize sustainable products (Table 10) it can be seen that mainly these are produced by request of individual customers (41.2%), also territorial requirements is an important motivation with the 29.4% and finally these are produced for the community of Fab Labs (23.5%). Only one respondent in the entire sample declared to produce these kind of products for teaching and education reasons, therefore again this underline the poor connections between Italian Fab Labs and educational institutions such as schools and universities.

Table 10. Motivation for developing quality and eco-sustainable products/prototypes

	n	%
Community	4	23.5%
Teaching and education	1	5.9%
External customers	7	41.2%
Territorial requirements	5	29.4%
Total	17	100.0%

Finally it has been asked to the respondent if they thought that technologies could have an impact on the working environment, and if this impact could be positive or negative. The motivation was to understand the general thought of those who work daily with these digital tools in order to understand if they perceive only positive sensations, or if they are also aware of possible dangers related to them such as for example the novice emission of Volatile Organic Compounds (VOC) from 3D printers which could affect the quality of air in indoor working environments, when they are printing objects. The probe of Indoor Air Quality (IAQ) has been highlighted recently in the literature by the works of Stephens et al., (2013) and Azimi et al., (2016). Interviewing Italian Fab Labs showed that except for 14.8% of them who have no opinion about this, the 81.5% thinks that digital technologies could have a positive impact on the working environment, while only 3.7% thinks they could have negative aspects. In detail, when asking them how much they think that 3D printer’s emission could be harmful for human health of workers, the mean value of the 5-point Likert scale obtained was low and below the threshold value of 3 (mean value of the scale: 2.48). Therefore, it seems that the problem of VOC emissions and Indoor Air Quality of 3D printers is not considered relevant from Italian Fab Labs.

5. Conclusions

The results show for the Italian reality, that, while some laboratories are still in an embryonic phase, with no or very few registered users, others are in full activity reaching over 100 users. In any case, the growth of Italian Fab Labs can be defined exponential, if one thinks that the first Fab Lab in Italy was born in Turin in 2012 and now, six years later, there are 134 laboratories recognized by the global Fab Lab network (http://fabfoundation.org/). Italian laboratories are characterized by ample space available, but limited capacity for investment in machinery and technology.

But, which could be the role of these digital Fabrication Laboratories in the economic panorama? This could be double, and affect the consumer and business side.

Thanks to Fab Labs consumers are becoming "co-designers", because they become able to get access to the design process, that is, concept design and product development, and express the requirements or even co-designing the product with the configuration toolkit (Tseng & Piller 2003). Makers might be called the new craftsmen of the digital era (Manzo & Ramella, 2015) and Fab Labs can help the market to change the design and production processes from "made-to-stock" to "made-to-order" (Tseng & Hu, 2014).

However, the study shows that manufacturing companies and practitioners represent together the second type of Fab Lab's customers. Fab Labs can be used to give entrepreneurs a low-cost space for designing and building prototypes. They should assist smaller firms in their process of digitalization in the Industry 4.0 era making available their digital manufacturing tools to those companies that do not have the possibility to make huge investments in this type of digital machineries, creating collaborative networks with them It is also essential that Fab Labs help smaller firms dealing with this industrial revolution making their knowledge available to them, and organizing training courses to develop workers with the necessary skills to face these changes in the industrial landscape. Making available their tools and skills Fab Labs would facilitate the process of industry 4.0 transition for smaller firms (Stacey, 2014; Murmura & Bravi, 2017; Santos, Murmura & Bravi, 2018b; Bravi, Murmura & Santos, 2017), improving their process quality management.

In this study it was asked to Fab Labs if they think that 3D printers and other digital technologies could represent the turning point that will allow the industry to enter a new industrial revolution, using always a 5-point Likert scale, the value obtained is 3.85. This result underlines that there is a fairly high awareness that these technologies can make noticeable changes in the global economic landscape.

In order to investigate why there is this belief, it has been asked why they think these tools could revolutionize the global economic environment. For some of them the real revolution that 3D printing will have is that of being able to decide the shape, quantity and quality of objects to be made, without the need to have a mold; design and industrialization processes are simplified and speeded up. Others think that the spread of 3D printing can also allow smaller industries and laboratories to prototype their ideas and see them grow faster. This having available, on the territory, laboratories such as Fab Labs that can take care, in a team, of the customization of design ideas and of their realization. Finally, others think it can have an impact not in terms of turnover but in terms of social impact, in responding to the needs of targets that cannot be satisfied by mass production.

The main limitation of the research is the fact that the study considers only the Italian economic reality of Fab Labs; however, this study could be taken as an element of comparison with other European and American Fab Labs realities, to highlight similarities and differences between the different realities.

For future research it could also be important to consider the side of consumers and businesses to evaluate how much they would be interested in developing mutual benefits relationships with these laboratories, developing with them collaboration networks.

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