



TORONTO

dmi:ADMC 2022

DESIGN AS A STRATEGIC ASSET

Academic Design Management Conference

The 23rd dmi: Academic Design Management Conference Proceedings

3-4 AUGUST 2022
OCAD UNIVERSITY
TORONTO, CANADA
WWW.DMI.ORG/ADMC

dmi: A | D | M | C

This conference proceedings version was produced on 20 July 2022

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ISSN – 2640-4702

Published by the Design Management Institute
24 Thorndike Street, 2nd Floor
Cambridge, MA 02141
USA

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Towards the economic viability of Digital Manufacturing: in search for a business framework through regional case studies

Luca D'ELIA^{a, b}, Viktor MALAKUCZI^a

^aSapienza University of Rome, Elisava, Barcelona School of Design and Engineering (UVic-UCC)

After phases of high-tech prototyping equipment and rapid democratization, Digital Manufacturing (DM) is looking for methods of doing business around processes and skills so far developed.

This ongoing Research aims to investigate the "market" sphere around DM: questioning how DM-based enterprises have set up their own commercial assets and how much their assets are influenced by locality when referring mainly to web-based clientele.

Collecting different case studies at regional level, mapping technologies, services, and competences, 21 companies linked to the DM world in the Lazio region have been identified and categorized by the type of service provided, the technologies adopted and the overall design field in which they could be linked to.

By this preliminary screening, direct interviews have highlighted three different types of manufacturers cataloged by their impact: "short-term" for those who offer the product, "mid-term" for those who offer the technologies and "long-term" for those who offer the competences.

The contribution aims to outline a framework of possible business models born around DM. Findings may help DM-based companies and designers to fit better in the contemporary market by adjusting their physical and human assets, as well as commercial practices and design strategies.

Keywords: Digital Manufacturing, Distributed Knowledge Economies, SME, Impact Analysis, Distribution Models

Introduction

Digital Manufacturing (DM) tools have already established their role in product design innovation processes, and they are being consolidated also as viable production technologies, which implies a rising recognition in the social, economic, and political sphere.

Adoption of DM processes always promises to industry the achievement of great advantages in productivity, sustainability, and design, while delivering new opportunities in the market. Those spaces that contain the technologies are so defined in a workflow that relies on a seamless conversion of design and engineering data into digital code to control manufacturing devices (Gershenfeld et al., 2017). Since its diffusion, even if the community of makers was widespread all over the world – if we consider that only approximately 135 million adults are – thanks to the increasing accessibility of the technologies as well as for the space, proper figures within activities that could lead these practices along productivity lines are very few.

Those technologies are currently developed worldwide in Research Centers, but these are often in precommercial development stages (e.g., in demonstrators or exploratory pilot projects). Overall adoption of advanced technologies by industry is lagging due to challenges with technology transfer from research to industry. For firms in search of innovative technologies to bring to market, the diversity of potential solutions presents a challenge (Graser et al., 2021).

Companies with interest in involving DM processes within their workflow lack an overview of proper technicians as well as an overall comprehension about technological use potential to evaluate their match with the own needs and business interests.

After phases of high-tech prototyping equipment and rapid democratization in the 2010's, DM is looking for methods of doing business around the technologies adopted, the processes involved, and skills so far developed. While the weight of the maker economy is increasingly relevant at a European level, on the level of national policies the effect of makerspaces is more noticeable when one descends into more restricted territorial areas, mainly on an urban or metropolitan scale, and between people who have interest and way of contributing to one's own territory (Lange et al., 2019).

In the following paragraphs, the paper questions the role of citizens within Open economy environment to underline how DM spread through a distributed system of local small entrepreneurial initiatives. The latter has been consequently investigated through a qualitative research approach described in the methodology paragraph that defined a clearer picture of the status of regional production capacity which has been deeper investigated through a series of action as direct interviews that lead to a SWOT analysis and the results.

Prior experiences in the Lazio regional context

The commitment of the authors Research Unit, the *Interdepartmental Centre Sapienza Design Research*, promotes collaborations with Regional Administrations, through Doctoral and Fellowship programs, to enhance and develop productive resources according to the needs of the specific socio-economic context. *UrbanM*, for instance, is a European funded project, which commitment arises from the demonstrated aspiration to overcome social barriers (Seravalli, 2014) both in physical terms, related to accessibility of those spaces, and in terms of creative and innovative thinking.

Another example is the *CLab* project which addresses the theme of innovation of the Lazio artisan networks, through the intervention promoted by the *Lazio Open Innovation Center* in Zagarolo along with Sapienza Design students, to support businesses in developing new creative skills for products and process innovation. Starting from a study that already dealt in the past with the different business models of design for distributed manufacturing (Malakuczi & D'Elia, 2020), the Research aims to further investigate the sphere of "doing business" around DM system: to do this, it has been understood over time that the process and the forces involved in the production systems, instead of the final product, looking directly to a customer who is its producer as well.

Toward citizen-centered experience economies

The innovation development and its increasing accessibility shifted the focus of the feasibility matter from the technological side to an economical one (Greenfield, 2018). Technology has given to the educated and connected human being the possibility of acting as a new agent of change, following the footsteps of Cosmopolitan Localism (Manzini, 2015), the network of place-based communities that share knowledge, technologies and resources. These systems cannot refer therefore to a traditional standardized system (Phillips et al., 2016), but within an open framework, it need to access to those value of traceability, participation, and identification of individual participants in their actions (creation, sale, acquisition, modification, resale, and so on) that are proper of this phenomenon. Moreover, those places could be seen as sources of the diffusion of

technological culture, which overcoming the logic of DIY and referring to co-design models goes beyond mere production. Design education, which in this context assumes the role of empowerment for those citizens that, connected both to the creative resources and to the problems of the territory, are transforming themselves from consumers to proactive agents able to propose, design and build up solutions (Mason, 2016).

The intrinsic value of this network does not reside in a reliability of monetizing from the system, which is in any case widely recognized as common ground for Government's competitiveness at national level. As (Denning & Hayes-Roth, 2006) stated, to accelerate modern organizations development we need a change of perspective about value-based distribution this network relies on. While traditional organizations often take years to learn what information is valuable and how to make it flow, the current political and economic condition, still based on capitalism and a neoliberal model (Kempf, 2014; Klein, 2015) is progressively transforming the social models known up to now, favoring the commons models, which veer towards a post-capitalist economy (Dardot & Laval, 2014).

These dynamisms and *citizen-centered* places enable communities to find solutions through bottom-up interventions, starting by an innovation process that no longer passes through institutions or authorities (top-down). In a broader perspective, design supports autonomous communities (Morelli & Sbordone, 2018) by proposing solutions to problems that, according to Manzini (2014), open to a wider disciplinary field that goes beyond productivity, technology and the market (Villari, 2012). In a highly self-organized context, design plays a central role in understanding and developing social innovation by mediating public and private needs.

It is possible to notice how DM has had a strong impact at digital and organizational level providing a playground in which innovation on technological and social level has been developed and is still ongoing thanks to the support received by the Governments that have foreseen a strong competitive factor in it (Cooke & Schwartz, 2012). With the promises of a more sustainable production system today DM could be considered still far from the desirable vision of the "zero marginal cost society" (Rifkin, 2015). This "lack of reliability" resides in a system that, even if it could (ideally) access to a global market through a worldwide network of equivalent production tools and spaces, is still trying to identify an ideal economic model (Holman, 2015). Traditional mass production systems require direct connections to the clients along with a deep understanding of the end users and eventually in-person knowledge of the available resources (technologies, materials, processes). Distributed manufacturing, on the other hand, severs this connection, relying on comparable – and not always fully trustable – DM.

A physical product that is created and distributed purely as "digital" is therefore realized in an uncontrollable situation: this presents new challenges in terms of impact measurement (on different scales of retribution, success, infrastructures requirements). Within Design's discipline various approaches through the years have been developed from the Open-Source approach inspired by software development to a collaborative (co-design) practice, since it has been facilitated by the easy access to distributed creative resources and facilities (Gasparotto, 2019). Uncountable designs have been developed and diffused through the internet via 3D model, projects, and design sharing platforms (e.g., Thingiverse, Instructables, Github, Opendesk, Distributed Design Market Platform) open to feasible and useful product designs for Distributed Manufacturing, and some major online service bureaus offer their open marketplaces, which can provide revenues for designers.

The field of additive manufacturing across different channels has been also intensively discussed during the recent health crisis on how distributed production processes have contributed: the announcement of the state of emergency has immediately revealed in the health facilities, as in the distribution of public activities, a serious shortage of technical devices. During this lack of medical supplies for privates, DIY techniques are applied to help personal fabrication solutions. Several items have been designed and produced in response to this crisis, and the scientific community has collected and medically evaluated dozens of open-source medical device designs opening to many ethical discussions about it since such contributions were coming from non-certified experts (makers) able to generate non-certified, but nonetheless useful, tools (Baudisch & Mueller, 2016).

It appears, then, that we need to not only re-visit the literature but continuously update our alternative conceptualizations of the economy and its role in structuring our relationship to the living earth and webs of life. For more resilient communities, the distributed system concept has emphasized good environmental performance, local people's preferences, quality of life and well-being (van den Dool et al., 2009), while particularly examining privileged regions in northern Europe. Distributed systems stand as a useful framework for understanding how we want to shape our local economies, even within a rapidly transforming, global environment with many industrial and post-industrial trajectories (dos Santos et al., 2021).

Research questions: a local digital businesses growth inquiry

By these premises, the meanings of those products that float in the system should deserve a better analysis in these terms to understand how the practice of Open Design shifts not only the creative context, but also the

distribution one. If the methods and channels of creation are as open as those of distribution (Malakuczi et al., 2020), they cannot refer to a traditional system, nor to a dead-end system of sale and purchase, but to insert themselves in an open framework that promotes traceability, participation, and identification of individual participants in their actions (creation, sale, acquisition, modification, resale, and so on), therefore questioning:

- How DM-based enterprises have set up their own commercial assets and what kind of local variations emerge?
- How much their assets are influenced by local or regional matters when their products are referred to a web-based clientele?

A highly variable resilience of the individual spaces corresponds to the growth phase of the global networks of laboratories encouraged by the PAs, which is leading to the contraction of the absolute number of the same. Having perceived this problem in Italy and throughout Europe, it was proposed to work directly and targeted on the operational policies of makerspaces, and the methodology described, to consolidate virtuous contexts capable of self-nurturing their growth by configuring an environment favorable to bottom-up innovation - even in contexts and networks of laboratories established with public investments and a top-down attitude.

Over time, several studies have monitored the impact of the Maker activity at different amplitudes (Maffei et al., 2015; Menichinelli, 2020) always identifying a hybrid, ever-predetermined mutable form of manufacturers, which prove to be extremely adaptive in time passing from production companies, to consultancy, to training with simplicity. These three aspects seem nevertheless to be a common ground in which various initiatives linked to the world of "digital making" revolve and in which it is possible to recognize (at least as regards the scenario Lazio region) the following degrees of impact strictly related to time reaction by the selected companies:

- Short-term impact: a first level of impact seeks an immediate economic return, and this is the authenticity of those initiatives that have based their business on the sale of products (which in the case of digital manufacturing we could consider *tailor-made*);
- Mid-term impact: a second level of impact looks at those companies that instead base the activity of their technological system on the basis of the request of those individuals, companies or other startups that outsource certain processes for the realization of their own prototypes or small / medium productions;
- Long-term impact: a third level of impact glimpse within the networks and the competences of a more profitable solution to sustain this manufacturing system, aiming to a future that considers not only the business itself at its center, but the people distributed in a massive and inclusive production system.

Methodology

While the presence and productivity of the maker economy is increasingly relevant at a European level, on the level of national policies the effect of makerspaces becomes more relevant the more it gets into more restricted territorial areas, mainly at urban or metropolitan scale, between people who have interest and way of contributing to their own territory. This research is therefore to be intended as a *Qualitative Content Analysis*, in which the method of qualitative data analysis deemed appropriate for examining the current regional scenario. The main focus of the research and analysis of those data has been developed through a categorizing system which could be able to describe and validate the qualitative aspect of the information retrieved (Kuckartz, 2019). It is important to notice how, within this approach, it could be possible to identify two main variants (Graser, Kahlert, et al., 2021): a deductive – in which the literature and previous knowledge could affect the “reading” of the data – and an inductive one – which could come from the content of the data itself. The Research used an *Inductive Category Development* approach (Kohlbacher, 2006) to categorize the subjects of the mapping part: it summarizes categories derived from the entire collected data aiming to understand “without bias owing to the preconceptions of the researcher” (Mayring, 2014). This approach finds similarities with the “open coding” process of *Grounded Theory* (Corbin & Strauss, 2008) a reiterative process relying on the constant evolution of those individuated activities based on the analysis and categorization of qualitative data, such as interviews, notes, and observations. Nonetheless the approach relies less on interpretative transformation and theory-building, keeping the analysis of the data collected as much away as possible from precognition (Sandelowski, 2000). In this way the targeted collection of additional data enables the research to focus the inquiry on data that has relevance in the field of study as the theory develops (Eisenhardt, 1989).

This reiterative approach has been applied due the variability and hybrid nature of the Maker within the Italian scenario (without considering the instability of the entrepreneurial initiatives after the recent health crisis). While the pre-pandemic scenario has been characterized by a global trend toward neoliberal globalization – generating both a reacting anti-globalism and an altering globalism for sustainability – this last altering-globalism movement has reinforced the social role of technology supporting those hybrid communities in the physical space. Such hybridization requires focusing on re-placing technologies.

Impact case studies

As (Capdevila, 2014) stated, Fablabs are spaces for prototyping and where members can start a business from the activities taking place within it. However, according to the Fab Charter¹ commercial activities can be prototyped and incubated in a Fablab, but they must not conflict with other uses, they should grow beyond rather than within the lab, and they are expected to benefit the inventors, labs, and networks that contribute to their success. Therefore, places such as the Fablabs are not spaces to develop commercial projects. The activities focusing on the commercial exploitation of experiment results should be carried on outside the labs– or at least it should be. The Research, in this sense, is not pointing at the potential projects and startups that could be born in those public spaces (as its potential to lead and stimulate the birth of initiatives has been recognized by time).

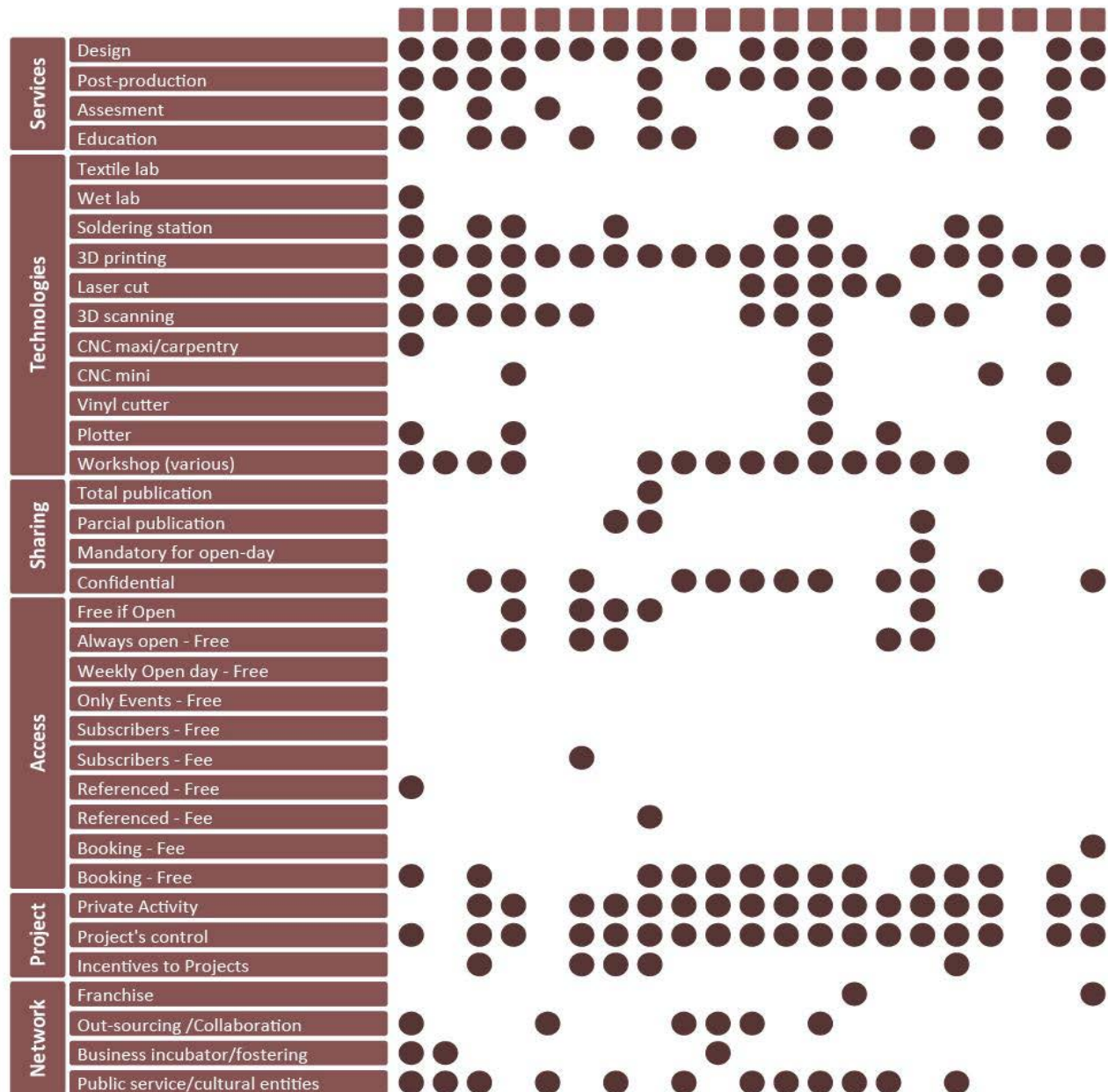


Figure 1 The table above shows the preliminary information retrieved from the internet and the feedback given via direct contact. Squares on the top row indicates theresponder, dots represent positive answers given to the questions reported on the left side column, which have been categorized by area of interest.

¹ <https://fab.cba.mit.edu/about/charter/>

From this critical point of view, this specific aspect of the public labs moved the Research to focus on already established initiatives, startups and properly launched businesses that are nowadays developing a service to locals and to a diffused clientele. Collecting different case studies at regional level mapping technologies, services, and competences, 21 companies linked to the world of DM in the Lazio region have been identified and categorized by the type of service provided, the technologies adopted and the overall design field in which they could be linked to (Figure 1).

Starting by the analysis of the information available online, direct interviews have been conducted with each entity registered, by mail and telephone call (also due the pandemic restrictions), questioning what kind of service they provide, their technological equipment, openness of the projects initiated at the lab, customer care, original projects developed, inclusion or relationship with a specific business network (including outsourcing). Indeed, it is the local, provincial, and regional aspects, in the role of PA, that assume the driving role of the new maker economy by intervening with policies and programs aimed at strengthening existing communities born from the bottom, bottom up, or in less consolidated contexts to act in a founding way by setting up individual or entire makerspaces regional networks with a top-down approach.

By this preliminary screening, direct interviews have been conducted with three identified categories of digital manufacturers. To better understand the Lazio entrepreneurship assets and evaluate its social value, skills and proximity impact, the research has developed an interview campaign with specific 5 figures that for their profile resulted to be more relevant over their community and local activities. The responders have been selected based on the heterogeneity of their technological asset, value proposition and service provided. Semi-structured interviews, that averagely last 2 hours each, have been carried on according to anthropological investigation methods, and ground theory, characterized by low structured questions - giving the opportunity to reach a topic throughout conversations - and holistic evaluation (including non-explicit commented context).

From the interviews transcripts, the Research has carried on a SWOT analysis – which stands for Strengths, Weaknesses, Opportunities, Threats analysis – for each of the main categories that resulted from *Qualitative Content* analysis.

Results

Those interviews brought to highlight the perception that responders have regarding the actual impact of DM on the public (whether there are actual clients or potential ones) along with the attention paid by the institutions towards them. As anticipated above, those activities highlighted a sort of quality of impact which has been categorized as such (Table 1).

Table 1 The following tables illustrates the results of the SWOT analysis retrieved from the interviews conducted with the individuated initiatives on the timeframe to which they have been associated to.

Impact timeframe	Short	Mid	Long
Value offered / exchanged	Products	Technologies	Competences
Main characteristics	Internalized production	Interdependent process	Consultancy/training activities
Strengths	Production's responsiveness	Accessibility	Research & Education
Weakness	Communication bias	Technology missuses	Facilities management
Opportunities	Public participation	Networking	Clientele diversity
Threats	Government's responsiveness	Stability	Collaboration mistrust

(Short-term impact) those who offer the product

Completely internalizing the production line, these business assets offer different kinds of product based on clientele needs. In this case the type of impact is totally based on the reliability of the design and the technology adopted within the activity. From the data retrieved, available online and via direct chat the Research gave a first frame of the overall products available on the market at regional level.

Strengths

Their strengths rely mainly on the democratization aspect of DM. This is a common thought related to DM technologies which are going time by time and with exponential rapidity more accessible and user friendly. It has been possible to see a sort of romantic view from private business sites that are still thankful for the power that has been given to them via desktop technologies and the openness of the knowledge behind it.

Weaknesses

On the other hand, innovative startups in Lazio seem to have to face a general misunderstanding from PAs which does not consider – or not enough for their needs – the immaterial necessities which their activities have. Those necessities comprehend mainly communications solutions and staff management. The latter especially is affected, for them, by a low alphabetization regarding new technologies in schools and universities.

Opportunities

DM network is one of the main bases which most of DM related initiatives (if not all of them) rely on. Especially in the last five to ten years, the internet, the Open concept and its derivations, peer-to-peer interactions has empowered the private and enhanced the ability to participate and distribute tasks and activities.

Threats

However, it has been reported from the interviews how in Italy and especially in the Lazio region the relation with local PA is affected by a lack of responsiveness which does not match with the entrepreneurial frenzy and objective needs. This slowness, which in some cases became an anachronistic delay, is majorly perceived as a general misunderstanding of “innovation” meaning (without denying that could be from both sides). This led the responders (and we will see it also in the next paragraphs) to also question their role as “innovators” which seems to them to be not recognized enough (or at all in some cases) by the institutions.

(Mid-term impact) those who offer the technologies

As public service accepting to print other projects, prototyping for start-ups or start small productions. In this case the impact of their activity is based on the request and the complexity of the final product. From the information retrieved, it is possible to notice how the intrinsic value of the activities is developed around the network and each specific know-how.

Strengths

To improve the quality of the service provided, the businesses that put on the market their technological implant, usually have to deal with the necessity to update their staff to the use of specific technologies with other specific techniques. Usually, the machines those services use are desktop or built on the spot – not to mention the well-known DIY and hacking approach that most of the Makers have within this phenomenon. Therefore, it is necessary to always have a proper formation to the use of them in order to provide the best quality. This know-how is most implemented in the maintenance of the machines and the assistance to the makers, since inner policies most of the time do not let this knowledge get out of the business.

Weaknesses

As for previous cases, also for this asset the perception of a general misunderstanding of the DM seems to be extremely relevant: both from the clientele perspective – which still suffer from a misconception of DM especially related to 3D printing technologies – and from the PA perspective – which do not recognize at official level the role of manufacturers within these activities that are officially enrolled in the Chamber of Commerce as “Fashion studio” or “Digital/Marketing service”. Indeed, businesses that provide privately this kind of services, perceives that their ATECO code would represent more the product instead of the whole production system.

Opportunities

For this type of services as well, most of these activities rely on a network of partners that most of the time are developed around complementary principles: those machines that for economic reasons or reglementary limits are not possible to be internalized are then distributed.

Threats

In fact, this network is for them a precious value which is in some cases jealousy preserved by the owners, since it is considered the actual resource in which they evaluate their impact based on the variety of technologies they can access to (and therefore that can resell to their clientele).

(Long-term impact) those who offer the competences

Those private design studios and labs who offer their skills to put in place those best practices aiming to exploit the full potential of distributed production. From the information retrieved, it is possible to notice that also for this case knowledge and know-how are the actual value of these spaces, which however look to a return that has longer-lasting repercussions and that aim at a broader perspective.

Strengths

For many activities DM based which have struggled especially during the pandemic emergency, the core has shifted to the educational mission directed both to the public (such as schools or private courses) and, for a few more cases, to industry. The perspectives of new user-driven literacy standards strengthen further the confidence of the PA which often adopts these training services (currently generally entrusted to specific centers such as Fablabs or other state bodies) for updating and the implementation of structured courses in schools and social recreation centers. An important (and therefore expendable) aspect of the knowledge gained by these laboratories (referring mainly to the figures who live together), this supply of knowledge can pass through specific projects commissioned by third parties that require R&D consultancy services from specialized laboratories.

Weaknesses

As per many public laboratories distributed in the Lazio region, the access to the machines is limited and, in some cases, not allowed, leaving the practical part to a conceptualization step or to a digital modeling level. This barrier is sometimes due to poor care of the machines, in other cases to a difficulty in managing spaces. It has been reported that some of the selected projects unfortunately do not look beyond the world of hobbies and a DIY mindset that is still difficult for the business sector to place within a consolidated business plan.

Opportunities

The heterogeneity of the profiles participating in the courses or requiring these training services is noted. Some are mainly driven by curiosity (especially when we talk about private individuals where the average age is between 20 and 30 years). In other cases, they are young startups intent on participating in tenders to finance their projects. Training in this sense is very varied and in some cases the background is not considered at the beginning (as it is usually information that emerges along the way), opening to mutual contamination.

Threats

The regional entrepreneurial initiative reported in almost all the responders a sort of mistrust or serious concern about its future, which is perceived as threatened with a short-term end, especially when it is confronted with local companies that suffer or have been crushed from different crises or that require to be supported with great difficulty through projects of lesser impact. If on the one hand this fear has spurred the businesses in search of greater foresight, on the other hand they cannot help but be afraid for their own stability.

Conclusions

Developing the analysis of the businesses and their categorization it has been possible to glimpse a correlation between their impact with their entrepreneurial asset. With this regard, *Short-term Impact* actions, struggling to reply with enough rapidity to their own needs, tends to be referred more to a centralized system organization. In contrast to the distributed system model, a centralized system is usually characterized by large production units located mainly far from its customers (whether they are individuals or organizations). Its stand-alone production units demand high control of essential activities and, thus, decision making is often centralized. This concentration of decision-making and management power, which over time we could almost define as obsolete in the economic and social transformation we are experiencing, seems to have characterized the birth of some of the most prolific activities in the Lazio region which aims to an immediate return of their action. Nonetheless, it presumably came as the fastest response possible at the time of birth of those initiatives (which we have outlined mostly comes from a period that goes from 2015 and 2017). It is therefore possible to notice how the technological transfer has marginally affected those business models which have foreseen a production chain development through a personalization and customization process. It seems that the more those services are closed in competences and technologies the more the activity itself tends to expand its distribution but nonetheless marginally (if not collaterally) have a social impact.

Getting further on *Mid-term Impact* activities, their asset, that could be mistakenly perceived as distributed one, is closer to a decentralized system organization. A decentralized system is characterized by small-scale

production units that deliver their goods and services via light distribution networks, directly to customers, whether individuals, entrepreneurs, or other organizations/institutions, increasing customers' control over essential activities. Thus, the cost and time for implementing or changing them is also variable. It could be possible to notice a completely different impact, if put in comparison with the previous case, where those realities that tend to be more open also tend to be more localized and limited despite the potential.

Getting to the third *Long-term Impact* analysis, the Research has instead noticed various connections more related to the distributed system organization, while we keep distances from the physical product for immaterial values. While distributed systems involve small-scale productions closer to end-users that have – that has also control over essential activities – those systems could be translated in many forms of participation such as stand-alone, or peer-to-peer, but always connected to each other to share various forms of goods and services. Moreover, it is not unknown the concept of distributed production when discussing Information/Knowledge topics – for instance via a computer which is the basic hardware for such production (Powell & Snellman, 2004) – located by the end-users or peer-to-peer connected with the end-users, whether individuals, entrepreneurs and/or organizations/institutions. If the knowledge is therefore produced in such a system sharing open information and data, they will be more likely to become what (Honavar et al., 1998) described as a Distributed Knowledge generation Network, which may, therefore, be connected with other similar networks. If properly designed, they hold promise to promote sustainability on a multi-local level.

The broad diversity of the economies born in the Lazio Region make it challenging to introduce a well-defined framework and is not intended to be an overview that could cover an entire globally diffused phenomenon (Ranjbari et al., 2018). In particular, some of the competences put on the market have created controversies about their relationship to basic values that are traditionally associated with the sharing economies concepts (Pouri & Hilty, 2021). The main aim of this very first report is to provide a neutral and inclusive descriptive framework, we lay the ground for discussing the normative aspects separately and with explicit reference to normative frameworks such as sustainable development, as we do in other contributions to the discourse. This contribution aims to outline a framework of possible business models born around DM. Findings may help DM-based companies and designers to fit better in the contemporary market by adjusting their physical and human assets, as well as commercial practices and design strategies.

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