FABLABS AND THEIR CONTRIBUTION TO SUSTAINABILITY IN THE CONTEXT OF SOCIO-TECHNICAL SYSTEMS

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ABSTRACT

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Since their first establishment at the beginning of the millennium, the number of fablabs has increased significantly worldwide. Fablabs serve many purposes, such as facilitating repairs, relocating production locally, educating on science and technology, or carrying out R&D in an open and disruptive manner. The innovation carried out in fablabs creates niche markets that are alternatives to the existing unsustainable, locked-in systems. This research explores the current state and future potential of personalized production within fablabs in France and Belgium as an alternative to mass production. For this, a hypothetical system is constructed on the multi-level perspective framework of the socio-technical approach. By surveying each element of this system, the trajectories are derived, and the transition pathways of the whole system are projected. The findings reveal that personalized production in fablabs carries a transition potential as an add-on to the existing systems; however, this potential is mainly dependent on environment-friendly and cost-effective technological enhancements. Moreover, special attention needs to be given by policymakers to promote the niche innovations developed within fablabs.

Keywords: Fablab, France, Sustainability, Multi-Level Perspective, Socio-Technical Systems.

ÖZ

SOSYO-TEKNİK SİSTEMLER ÇERÇEVESİNDE FABLAB'LAR VE SÜRDÜRÜLEBİLİRLİĞE KATKILARI

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Fablab olarak adlandırılan fabrikasyon laboratuvarlarının sayısı dünya çapında önemli ölçüde artmaktadır. Fablab'lar, tamirat ve onarımı kolaylaştırmak, üç boyutlu baskı teknolojileri sayesinde üretimi yerelleştirmek, bilim ve teknoloji konusunda eğitim vermek veya açık kaynak tabanlı araştırma-geliştirme yapmak gibi birçok amaca hizmet etmektedir. Fablab'larda gerçekleştirilen inovasyonlar, hâlihazırda sürdürülemez hale gelmiş olan sistemlere alternatif niş pazarlar yaratma potansiyeline sahiptir. Bu özellikleriyle fablab'lar sürdürülebilir dönüşümler için kilit oyuncu adayı haline gelmektedir. Bu çalışma, Fransa ve Belçika'daki fablab'larda seri üretime alternatif olarak kişiselleştirilmiş üretimin mevcut durumunu ve gelecekteki potansiyelini araştırmaktadır. Bu kapsamda sosyo-teknik sistemler yaklaşımının çok katmanlı perspektif çerçevesi üzerine varsayımsal bir sistem inşa edilmiş ve bu sisteme ilişkin bileşenler tanımlanmıştır. Her bileşenin incelenmesiyle sistemin bir bütün olarak dönüşümüne ilişkin tahminlerde bulunulmuştur. Bulgulara göre fablab'lardaki kişiselleştirilmiş üretim, mevcut sistemlere eklenti biçiminde katmanlar arası bir geçiş potansiyeli taşımakta ancak bu potansiyelin açığa çıkması, çevre dostu teknolojilerin uygun bir maliyetle ortaya çıkmasına bağlıdır. Ayrıca, fablab'larda geliştirilen niş yenilikleri teşvik etmek için politika önerileri getirilmiştir.

Anahtar Kelimeler: Fablab, Fransa, Sürdürülebilirlik, Çok Katmanlı Perspektif, Sosyo-Teknik Sistemler.

To my daughters

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LIST OF ABBREVIATIONS

2-D	Two Dimensional
3-D	Three Dimensional
ABS	Acrylonitrile Butadiene Styrene
AM	Additive Manufacturing
ANT	Actor Network Theory
CNC	Computerized Numerical Control
DIY	Do It Yourself
EU	European Union
Fablab	Fabrication Laboratory
GI	Grassroots Innovations
IPR	Intellectual Property Rights
MDF	Medium-density Fiberboard
MLP	Multi-Level Perspective
MIT	Massachusetts Institute of Technology
NGO	Non-governmental Organization
NSTC	National Science and Technology Council
OECD	Organization for Economic Co-operation and Development
PCB	Printed Circuit Board
PET	Polyethylene Terephthalate
PMMA	Polymethyl Methacrylate
PVC	Polyvinyl Chloride

R&D	Research and Development
RFF	Reseau Française des Fablabs (French Fablab Foundation)
SDG	Sustainable Development Goals
STE(A)M	Science, Technology, Engineering, Arts, and Mathematics Education
STEM	Science, Technology, Engineering and Math Education
UN	United Nations
UK	United Kingdom
US	United States

CHAPTER 1

INTRODUCTION

The quest for sustainability increases intensely in every sector and policy field. Scarce and polluted resources, climate change, socio-cultural challenges, irregular migration, and the economic recession due to Covid-19 pandemic are forcing all countries to reconsider their policies with a novel and transformational perspective. The search for more sustainable and environmental-friendly solutions is prominent in many sectors which can substitute the existing unsustainable, locked-in systems. Grassroots innovation movements emerge as a model that seeks innovative solutions addressing local issues and are organized with a bottom-up governance modality (Seyfang and Smith, 2007). Having their roots in the grassroots maker movement, fablabs (Fabrication Laboratories) are acknowledged as a type of grassroots innovation. Over the past two decades, since the first appearance in 2001, fablabs have spread rapidly, reaching around 1800 worldwide (fablabs.io). The fablab community has evolved during this period into a well-known international network.

A fablab is a small workshop that offers 3-D digital printing technologies which are currently costly and challenging to reach for individuals. The philosophy behind the establishment of fablab is trial and experimentation with the capabilities provided by digital printing technologies. The idea was first implemented in MIT Laboratories in Boston, US, in 2001, based on the longstanding knowledge accumulated by Neil Gershenfeld and his team. His famous manifestation “From bits-to Atoms: How to make almost anything”, (2012), presents the principles of digital manufacturing, which is a reference guide for fablabs. Although fablabs first emerged in the developed world, they rapidly spread to developing countries.

Fablabs provide an environment for citizens from any background, age, and socio-cultural class to design, model, prototype, and produce in line with their personal desires. With globally increasing numbers, competencies they accumulated over time, the visibility and legitimacy they gained in their community, and their motivation for sustainable production practices, fablabs are manifesting an alternative way of individual design and production against mass production and consumption. They address problems regarding sustainability by developing different alternatives in niche areas where the traditional systems may fail (Seyfang and Smith, 2007).

The "niche" concept of transition studies, which conceptualizes the "protected spaces" in which radical innovations may flourish without being affected by the dominance of the set regime (Kemp et al., 1998), well matches with the definition and practices of fablabs. Multi-level perspective (Geels, 2002) is a theoretical framework within the sustainability transitions literature, which examines the evolution of those "niches" as an alternative or a substitute to the dominant socio-technical systems in consideration with the dynamics of supply and demand from the bottom as well as political decisions and coercions from the top. Employing personal production within fablabs, it is possible to create long-lasting artifacts that respond to individual and local demands in contracts to mass/global production. Considering the two different modes of production (i.e., mass production vs. personalized production) as distinct socio-technical systems, it is possible to examine the extent to which the personalized production by fablabs attain a place in the set regime and landscape.

The research question of this thesis is constituted based on the theoretical assumptions provided above. It is a question of concern whether the fablabs contribute to the transition to sustainable production? If so, to what extent can they achieve this goal?

There are few studies in the literature that examine the relationship between the fablabs and sustainability. In order to answer the main research question, the components of the personal production system within fablabs, which emerged as an alternative to the dominant mass-production regime, are determined by adapting the theoretical framework, and each of them is examined, and the answers to the following questions are surveyed:

- How do the fablabs perceive the cultural meaning of sustainability?
- What is the role of technology in sustainable production?
- Whether and how do fablabs integrate Sustainable Development Goals (SDGs) in their agenda?
- Which organizational/user practices do they put in place to contribute to sustainability?
- What kind of sustainable artifacts do they create and put into use?
- How are the markets and networks evolving with the fablab community?

By exploring the answers to those questions, the pathways of the possible transition are discussed, and future projections are made.

The research was conducted in France and Belgium. After their first appearance in North America, fablabs have spread around the globe. France has the greatest number of fablabs hosted in Europe. With its leading number of fablabs hosted and country-specific features, France provides proper sampling for the subject survey. Due to the cultural resemblances and convenience, francophone Belgian fablabs are articulated to that sampling to enrich the analysis.

The thesis is organized as follows: In the following chapter, a detailed literature survey is presented on the grassroots innovation movements and digital fabrication workshops. After briefing the history, essence, and stylized features of the grassroots innovations, a comparison with the traditional innovation actors is made. With their firmness to care for sustainable communities, the contribution pathways concept is introduced, which will be further employed with the theory to propose a hypothetical system. Following that, a comprehensive survey is presented on digital fabrication workshops with related concepts such as peer-production and creative commons regime. The types of workshops are described, then the flow is focused on fablabs with a specific lens on sustainability and country-specific contexts.

In Chapter 3, the theoretical framework of the thesis is constituted. Firstly, sustainability transition studies are visited to present the socio-technical approach and multi-level perspective. Furthermore, socio-technical systems are elaborated, and

systems' elements are presented with relevant examples from literature. Fablabs are discussed from the lens of niches. Based on those discussions and the concepts accumulated in the first two chapters, a socio-technical system called "Personalized Production in Fablabs" is proposed with its inclusive elements. These inclusive elements of this system are further explored throughout the thesis to answer the research question. These elements are 'cultural meaning', 'technology', 'rules and regulations', 'user practices', 'artifacts' and 'networks-markets'. A part is reserved for presenting the "UN Sustainable Development Goals Framework", which is employed in this thesis to explore the contributions of fablabs to sustainability.

The methods utilized for this thesis are explained in Chapter 4. The convergent mixed methods design (Creswell and Creswell, 2018) is employed in the study, and both quantitative and qualitative data are collected during the survey. An online questionnaire is used to collect quantitative data, while observations and interviews are conducted to collect qualitative data. Exploratory and descriptive analyses are conducted with both types of data. Semantic themes derived from the analyses and further correlated with the proposed socio-technical system's elements.

Chapter 5 includes findings revealed by the analyses. Throughout the chapter, quantitative and qualitative analyses are presented side by side with a grouping under the elements of the personalized production system in fablabs. The substance of each element is explored in light of the findings and in its identified context to understand and explore the ways of contribution of fablabs to sustainability and their potential for a solid transition.

In Chapter 6, the findings of the study are discussed with their relevance to the theoretical framework and the literature. Each element is revisited, and its trajectories are assessed. The transition pathways of the socio-technical system are forecasted, and projections for the mid-run are made by examining the alignment of those trajectories. Furthermore, policy implications for an accomplished socio-technical transition are proposed. This chapter also mentions the study's limitations and presents suggestions for the future research agenda.

The appendix section includes the outline of the online questionnaire, semi-structured interviews' guideline and the codebook of the qualitative semantic analysis.

The significance of this thesis is based on three aspects. First, research on fablabs is a relatively new area, and there are few studies on them to explore their relationships with the sustainability concept. On the other hand, UN SDGs are a hot topic around the globe. The implications and country contributions are a matter of concern for policymakers and fundraisers. This thesis contributes to the literature as the first academic study to combine fablabs with their wealthy contributions to SDGs. Although French academia and policymakers have an interest in fablabs, this study is distinct with its sustainability pillar in the francophone context. Although country-specific contexts are essential for fablabs research, francophone data is also relevant in the global context, with its sufficient quantity and variety.

The second contribution of the thesis is the methodological contribution by adapting the socio-technical systems and multi-level perspective to propose personalized production within fablabs as a socio-technical system and identify the elements of the system. Although the niche notion of fablabs is mentioned in the literature, their role in a systemic transition has not been analyzed before. This is the first study that employs the socio-technical approach and multi-level perspective to explore the current state and future potential of fablabs for replacing the dominant mass-production regime with their accumulated skills and knowledge. This is done by exploring trajectories followed by each element to generalize the system's evolution in this study.

The third novelty aspect of the thesis is the policy suggestions made in line with the traditional and recent trends in science and technology policy studies. There is extensive literature on policy studies, and there is a recent call from scholars to address the challenges of global warming. By exploring each unit of the system, the failures in the niches are identified, and policy implications are made accordingly, which is the final contribution of the thesis.

CHAPTER 2

LITERATURE SURVEY

2.1. Grassroots Innovation Movements

Grassroots Innovations (GI) refers to independent, endogenous innovations developed by ordinary people in localized communities (Gupta, 2003). The term independent here means that grassroots effort is not bounded by the dynamics of the market economy and the set rules of the dominant regime. Grassroots innovation movements (GI) -by definition- are seeking alternative and bottom-up solutions for sustainability. While doing this, the needs and desires of the local community are at the forefront (Seyfang and Smith, 2007). Sustainability is "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (UN Brundtland Commission, 1987, Article 27), which has the social, economic, and environmental aspects. The participants in the grassroots communities do not need to be professionals, and they are not bound by the institutional rules as is in the formal sector while practicing innovation. The main driving force for these people is the social and economic needs that cannot be addressed by distant market actors or political institutions (Hess and Ostrom, 2007). They may innovate for the sake of the community as well as for their personal desire. People contribute to the GI movement due to their social and political attitudes rather than market dynamics. These notions make GI movements constitute diverse organizational forms mainly in the third sector (i.e., organizations that belong to neither public nor private sector); such as cooperatives, voluntary associations, or informal communities. These structures mainly sustain their presence through public funding, voluntary work, or mutual exchange (Seyfang and Smith, 2007).

From the historical perspective, GI movements are rooted in environmental and social movements (Smith et al., 2017). People who unite in a rural community or the countryside around the same social values create solutions for the environment they live in. Mostly it is their self-solidarity that facilitates the opportunity for such a creative atmosphere. These movements seek alternatives to the solutions offered by the global market for finding optimal solutions for the locals (Smith and Seyfang, 2013). While practicing this, social justice and environmental sustainability are primarily at the center of the quest for local solutions (Hess, 2007). The "Socially Useful Production" movement in the UK, the "Appropriate Technology Movement" in the South American countries in the 1970s-1980s, the "People's Science Movement", "Honey, Bee Network" in India and "fablabs, makerspaces, and hackerspaces through the globe" are the most well-known manifestations of the GI movements (Smith et al., 2017). Each GI movement has its behavioral patterns and evolution in the time frame due to the variables specific to its own. The most salient fields that GI movements are active are "clean water and sanitation", "local and organic farming", "renewable energy", "resource sharing" and "local manufacturing" (Smith et al., 2017; Hossain, 2018).

Due to the scarce resources and relatively high costs of raw materials, most of the innovations developed at the grassroots are modest and frugal (Gupta, 2014). Nevertheless, the benefits of the GI for sustainability basically come from their opening a floor for community involvement for alternative environmental and social products and processes on a small scale (Seyfang and Smith, 2007). Although they may not be the sole pioneers of sustainability transition, they provide diversification on this path. Relatively low irreversible impact on the environment and continuous connection with the community are critical elements for GI to be sustainable (Gupta, 2014). Their potential for developing and sustainable design and systems, exploring alternative ways of sustainable production and consumption, cultivating reparation, up-cycling, and community involvement for the closed-loop material cycles are also worth mentioning.

There is a division of labor in GI movements where people from different backgrounds bring diverse forms of expertise and experience into the collective effort (Middlemiss

and Parrish, 2010). The constitution of human capital is tangled in GI, where experts, amateurs, professionals, hobbyists, entrepreneurs, producers, consumers come and create together. Due to this diversity and inclusivity, tacit knowledge and learning-by-doing practices have a greater emphasis in GI rather than the dignified codified knowledge which is accumulated through expertise and institutional set-up. This indigenous form of tacit knowledge is acknowledged as a common good within the community, and IPR appropriation is mostly not practiced (Smith et al., 2017). "Commons" is a resource shared by a group of people (Hess and Ostrom, 2007), and knowledge is not an exception for this definition. The alternative intellectual property rights framework, so-called the "Creative Commons" licenses (https://creativecommons.org/licenses), is invented for appropriation and openly sharing the knowledge, which is quite the contrary of classical IPR regime. Therefore, commons concept and creative commons are welcomed at the grassroots whenever there is a demand for codification, appropriation, or sharing. The places for GI movements are both physical and cognitive, meaning that either localized spaces and neighborhoods can be accommodated as venues for the community actions or platforms/tools such as social media, newsletters, bulletins, third-party meetings will be utilized for communication and collaboration.

There is a need to draw a line between the GI concept and mainstream innovations to understand the GI better. The concept of mainstream innovation refers to innovation created for and within market dynamics. For evolutionary economics, the firm or entrepreneur is the driving force of innovation with the motivation to make a profit (Schumpeter, 1961). For the systems of innovation literature (Freeman, 1987; Nelson and Rosenberg 1993; Lundvall, 1988&1992; Edquist, 1997; Malerba 2002), the mainstream innovations concept embodies all the actors contributing to innovation such as firms, public and private R&D facilities, universities, and policymakers. Besides, referring to its classical definition, the term "Innovation" itself is aimed at commercialization (Oslo Manual, 2018). Therefore, when we express mainstream innovations, boosting competitiveness and economic growth are at the forefront (Fressoli et al., 2014). Given these circumstances, it is possible to highlight the social innovation-technological innovation or social economy-market economy dichotomy for GI and the mainstream innovations.

Nevertheless, there exists a partially transitive relation that joint innovations may be developed with the inputs provided by mainstream within the grassroots community. (Gupta, 2004; Fressoli et al., 2014). The inclusive innovation and social innovation (OECD, 2015) are the accompanying concepts together with the open innovation (Chesbrough et al., 2003) to this cooperation. Here the dilemma is that the possible grassroots developments might require adaptation to market dynamics. However, it might hamper the level of contribution to sustainability due to the market's cost-benefit balance (Smith, 2015). Still, it might be vital for GI to collaborate with the mainstream innovations for scaling up the skills and experiences gained (Fressoli et al., 2014). Table 2.1 below summarizes the stylized features of two forms of innovation: Grassroots and Mainstream.

Table 2. 1: Stylized features of Grassroots and Mainstream Innovations

	Grassroots Innovations	***Mainstream Innovations***
Leading Actors	3rd sector, Cooperatives, NGOs, social movements	Public/Private R&D institutions, firms, entrepreneurs, universities, policymakers
Preceding Values	Locally sustainable solutions, social inclusion, social justice	Economic growth, commercialization, scientific and technological advancement
Driving Forces	Community Spirit, local/communal requirements, social concerns	Market demand-supply relations, scientific/technological competency
Appropriation	Creative Commons Licenses, openly shared collaborative practices	IPR, scholar communication, better indexes
Supporting Sources	Volunteer work, self-sustaining community, local development agencies, donors	Public/Private Funding schemes, capital investors

Table 2. 1 (cont'd)

Type of knowledge	Tacit/Indigenous knowledge	Codified scientific and technological knowledge
Venue/Location of activity	Localized spaces, neighborhoods	Public/Private R&D laboratories, workshops, factories
Specialized field	Sustainability related Technologies (e.g., bio-agriculture, renewable energy, personalized manufacturing)	Emerging Technologies signaled by market and policy makers (e.g., nanotechnology, biotechnology)

Source: Adapted from Fressoli et al., 2014; Smith et al., 2017

The table above is helpful to apprehend the limits of grassroots, thus better conceptualize the policy to address the needs of communities. It is the traditional approach of science and technology policy to align with the mainstream innovations; therefore, novel approaches should be developed for enhancing and making use of grassroots innovations. Mostly GI escapes top-down policy's notice, the focal point of which is economic development and catch-up with the frontiers. In the meantime, GI may reject a possible imposition from top-down policy agendas as well.

Since grassroots innovations manifest in many different forms, it is not possible to bring a standard model or framework covering all cases. One of the reasons why qualitative research and case studies are often used to study GI (Hossain, 2018) is this great diversity. However, this does not mean that there are no common specificities among all GI. The framing concept, which is utilized frequently in social movement literature (Snow et al., 1986), is enhanced by grassroots scholars (Smith et al., 2017). Their framing includes the conspicuous common aspects and narratives of these diversifying GI movements: ingenuity, empowerment, and transformation.

Table 2. 2: Three framings for GI

Ingenuity	Determination of the movement to diffuse the inventions and innovations out of the community and seek ways for this goal. Since the ultimate goal is to influence the social environment through creative solutions, they desire to scale up the developments. GI seeks the interstices to infiltrate and start a normative change, whether by classical commercialization paths or articulation in public programs.
Empowerment	Cultivating the capabilities and skills within and outside the community to establish legitimacy. Although the know-how or materials are imported from outside, they are adopted for the grassroots community. Consequently, the community itself decides on the ways to deploy and diffuse the practices and skills earned in the process.
Transformation	The political stance that redefines the meaning of "normal". GI's organizational forms, their practiced pathways through sustainability transition, their disposing of knowledge commons instead of intellectual property rights, or their leaning to localization instead of globalization are all recognition of this transformation framing. That political stance also aims to draw attention to economic and social inequalities and offer a distinctive form of change facilitator.

Source: Smith et al., 2017

The "pathway" concept is also highlighted by Smith et al., (2017) pathway is the particular choice among multiple alternatives of transition to sustainable development. The pathway concept is quite helpful to analyze GI and its relationship with sustainability. The contributions to sustainability pathways for GI are defined as knowledge, artifacts, methodologies, infrastructures, actors and alliances, concepts, and capabilities.

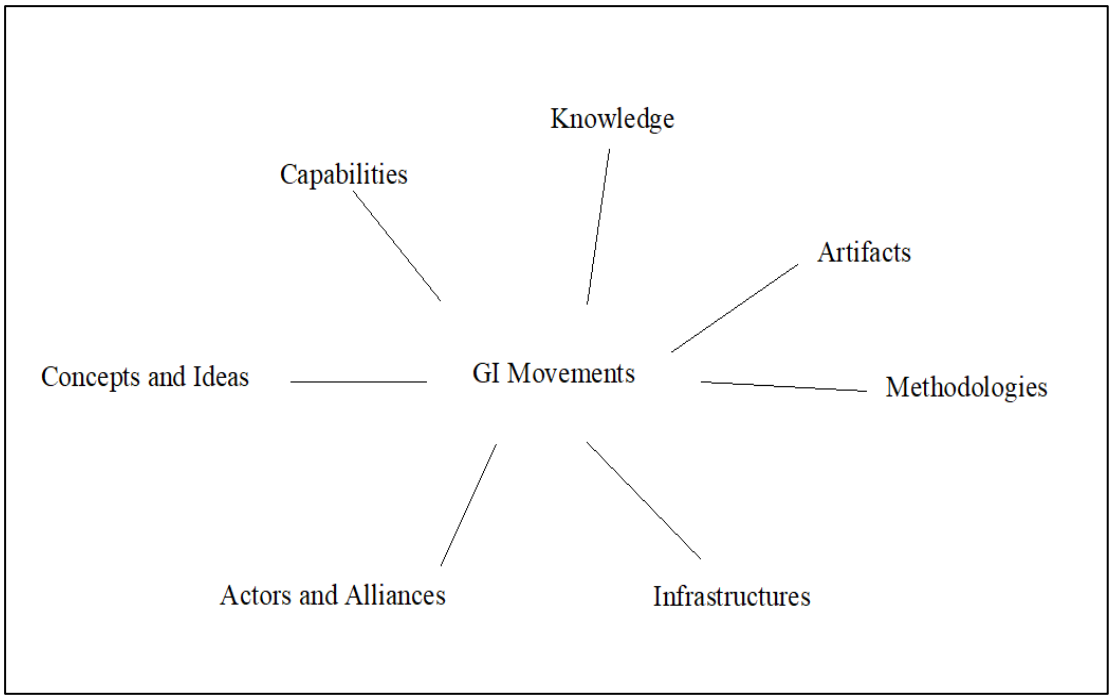

Figure 2. 1: Contribution pathways of GI movements,
Source: Adapted from Smith et al., 2017

The GI literature is a relatively novel area. The majority of the research in the field examines the well-known cases of GI and reveals the narrations in them (Hossain, 2018). Theories, models, or frameworks need to be built with the accumulation of knowledge in the meantime. Although the most prominent GI feature is its potential to open up new innovation practices (Smith and Stirling, 2016), it is evident in the literature that scaling-up is a severe issue and bottleneck for GIs due to their own perception of the issue, little attention of policy, their profile and rootedness in the local sphere, high member turnover and loss of key people in the community (Hossain, 2018; Gupta, 2014; Hargreaves et al., 2013; Feola and Butt, 2017).

The following section presents the literature on fablabs and makerspaces, which are the type of grassroots movements.

2.2. Digital Fabrication Workshops

3-D printing technologies are changing the world of manufacture by realizing prototyping inside small spaces. Desktop 3-D printers become affordable day by day (Benkler, 2006) and enable to mold atoms just like the desktop revolution did with the bits in the 1980s (Anderson, 2012). These technologies are desktop 3-D printers, desktop computer-controlled routing-milling machines, laser cutters, desktop-controlled embroidering, weaving, and quilting machines. The digital fabrication workshops equipped with these 3-D printing technologies have been increasing in number since the beginning of the 2000s. Syncing up with the DIY (Do-It-Yourself) insight, entrepreneurs, inventors, and hobbyists have created shared production facilities since then. So-called makerspaces, hackerspaces, and fablabs provide ordinary citizens access to these novel technologies as well as traditional equipment and design software (Smith et al., 2017). Here, the definition includes the shared physical space and the affiliated community (Halbinger, 2018). According to Anderson (2012), the maker movement has three central values:

1. Digital DIY, creating designs and prototyping,
2. Sharing the knowledge as part of a cultural norm,
3. Rapid sharing of designs for commercial or non-commercial purposes.

Therefore, the maker movement provides a basis for people to collaborate, exchange knowledge, and establish ventures by crowdfunding. Those aspects resemble solidarity within those workshops and pave the way for democratizing innovation (Von Hippel, 2005). The maker community experiments with the open exchange of knowledge (Dickel et al., 2014) and open innovation (Chesbrough, 2003). Moreover, they become key players in the innovation landscape of a city or territory due to the bridging role between the citizen and the firm level (Capdevila, 2014). There are many initiatives or start-ups that grow up within these environments (Anderson, 2012).

The knowledge generated in such collaborative environments can be regarded as a shared resource, so-called “commons” (Hess and Ostrom, 2007). Sharing a pool of resources ensures the decrease in economical cost over the users by distributing it across a community (Browder et al., 2019). Right at this point, Benkler’s (2002, 2006) commons-based peer production concept comes into the scene, which is a new mode

of knowledge production that is shaped outside the proprietary system, with social relations. According to his definition, the peer-production is neither motivated by market values nor managed by traditional top-down organizations and has main advantages over firm-based knowledge production. The concept is highly welcomed due to its potential to reduce costs over physical capital (i.e., human and infrastructure) and interaction and communication load between the innovation actors. The decreasing costs of innovating and the advantages of tacit and codified knowledge gained by peer-production give credentials for digital fabrication workshops to be a junction point from any background and interest of people to innovate together. Technical education is neither a requirement for sharing and creation nor a barrier, instead welcomed as a variety for skills building in the peer production spaces (Halbinger, 2018). The conception of DIY also enables novices to play with the artifacts to modify or repair them (Millard et al., 2018). With the notions of open-access and open-source, innovators have the legitimacy to freely access the knowledge online and without being subject to the boundaries of licensing or copyright rules (Suber, 2016).

As mentioned above, the shared pool of a resource -commons- can either be freely available to everyone, or the availability is framed for a subset of people, the latter of which can be defined as a standard property regime (Ostrom, 1992). Related to that notion, for the digital knowledge commons, the types of property rights are access, contribution, extraction, removal, management/participation, exclusion, and alienation (Hess and Ostrom, 2007). This classification establishes an alternative intellectual property rights framework for the digital knowledge commons (i.e., Creative Commons). Today six types of Creative Commons licenses (https://creativecommons.org/licenses) are used when the creator of work wants to give other people the right to share, use, and further develop upon a work that she/he has created. In that sense, the knowledge generated in the makerspaces or fablabs is freely available to everyone or the Creative Commons Regime is utilized for licensing the outcome.

User innovation is also a part of this picture where most customers or users provide valuable contributions to the design and production (Altman et al., 2015). Apart from

its economic benefits, user innovation ensures better user satisfaction which cannot be measured economically (von Hippel, 2013). The diffusion pathway of innovation is either presenting it freely to peers to test and use or promoting via commercializing channels (Baldwin et al., 2006; de Jong et al., 2015). Collaboration is associated with an increase in the diffusion of innovation (Ogawa and Pongtanalert, 2013). User innovation's social and economic benefit is scientifically proven (de Jong et al., 2015; von Hippel, 2017). It is also shown that innovation and "diffusion of innovation" rates within the makerspaces are significantly higher when compared to the innovation developed by single individuals, referring to the national innovation surveys (Halbinger, 2018). Therefore, digital fabrication workshops would be leverage for increasing the benefits of user innovation. Svensson and Hartmann (2018) demonstrate that makerspaces increase the rate of user innovation and the economic value of the innovation itself. Therefore, firms are getting accustomed to benefit from these new pathways of innovation by engaging themselves with the grassroots communities and finding ways to diffuse the innovation for economic gains (Flowers, 2008).

2.2.1. Basic Characteristics of the Community-led Digital Fabrication Workshops

The first manifestations of commons-based peer production were implemented in open-source software development. It gave birth to worldwide known products such as Linux operating system or Apache web server (Troxler, 2010). These enhancements were followed by commonly developed virtual platforms such as Wikipedia and spread to "shared machine shops", as Hess (1979) named them. Today, makerspaces, hackerspaces, and fablabs are the most prominent types of these "shared machine shops," which are primarily grassroots initiatives where maker movement is evident (Smith et al., 2017). However, there are some differences in their definition and way of execution. Referring to Troxler (2010), Smith et al. (2015), Rosa et al. (2017), and Rosa et al. (2018) and the web portals of the movements, the following definitions are compiled to frame the similarities and differences between the three types of premises:

Table 2. 3: The differences and similarities of the digital fabrication workshops

Type of Workshop	***Definition***
Hackerspaces	The first Hackerspace was founded in Berlin, Germany, in the eighties. The idea behind this, is to establish places for software programming, knowledge sharing, and collective learning. As they became more popular, they started to provide physical prototyping and electronics equipment as well. They are totally free in their existence, and they have their own community. Although they collaborate with each other via organizations called "hackathons", where they demonstrate the outcomes of the community, they are not connected via a formal network.
Makerspaces	The roots of makerspace stand on the MAKE Magazine and MakerFaire events. In these events, hundreds of people meet to get socialized and tinker in the making. Makerspace is an overarching term and encapsulates the other two types in its definition. Makerspaces are also driven by communities, and their main principle is being open to public access.
Fablabs	Fablabs originated from the well-known course on digital design and fabrication of Prof. Neil Gershenfeld of Massachusetts Institute of Technology Laboratories. The idea behind this was to provide spaces to the public to try and experiment with the opportunities digital technologies can offer. His revolutionary manifestation "From bits-to Atoms: How to make almost anything" (2012) comprises the accumulated knowledge built since 1998 in MIT Laboratories on digital manufacturing. With the funding of the US National Science Foundation, the first fablab was established in Boston in 2001. Then comes the ones in Costa Rica, India, and Ghana in the following three years. A shared charter was set in 2006, and every new fablab is acknowledged by another existing node fablab network. Moreover, Fab Foundation was established as an umbrella organization in 2009 for networking and coordination. Fab Academy is the formal training program organized by Fab Foundation that validated network nodes can give. It is prevalent amongst fablabs to support other nodes during inauguration, extension, or augmenting. The most distinctive feature of fablabs from the previous two is that formal networking and the same suite of equipment allow better collaboration within the network.

As presented throughout the section, the community-driven digital fabrication workshops are mainly active in digital design and prototyping, electronics, DIY hands-on manufacturing, or assembly. Moreover, education and research are amongst the most prominent activities in makerspaces and fablabs as well as the creative industries (Millard et al., 2018). Their relation to education, including STE(A)M related fields and vocational training, has been emphasized by many scholars (Blikstein, 2013; Hielsher and Smith, 2014; Rosa et al., 2017; Martin, 2015; Papavlasopoulou et al., 2016). Bringing the maker activities into schools of K-12 level education is shown as an asset for the learning habits of children of this level (Valente and Blikstein, 2019). Stanford University's *FabLearn* project is an example of that initiative, even involving university labs in the meantime (Angrisani et al., 2020).

Entrepreneurship concept is also crucial with regards to digital fabrication workshops (Troxler, 2010; Anderson, 2012; Barrett et al., 2015; Halbinger, 2018, 2020; Rosa et al., 2017) as their provision of equipment and knowledge is of great support for entrepreneurs to overcome the obstacles of starting a business.

In addition to the features mentioned in Table 2.3, factors affect the workshops' ways of execution. For instance, their tendency on social issues may vary depending on the community's history, including the founders and members (Hunsinger, 2011, p.2). Those workshops sustain their existence either by public funding or collecting fees from members (Troxler 2010), and publicly funded ones are hosted in the universities, schools, museums, libraries, or public institutions. In this regard, their business model and place of hosting are considered to be key factors on the way of execution as well (Hielsher and Smith, 2014). The publicly funded ones might not fully comply with grassroots specificities due to their financial dependency on the hosting or funding institution. On the other hand, commercial profit can also be a conflict for some participants of the workshops (Moilanen, 2011). Overall, makers are in the infancy period and struggling with the obstacles of sustaining the place and seeking better collaboration (Millard et al., 2018).

Local and regional networking is salient amongst the participants of workshops mainly to explore what others are making. For collaborating with the global network, web-

based services such as Wikipedia or self-developed open-source systems are utilized (Hunsinger, 2011).

As mentioned in Section 2.1, fablabs, makerspaces, and hackerspaces are recognized as part of grassroots innovation movements (Hielscher and Smith, 2014; Smith et al., 2017) by encapsulating their specific aspects about commons-based peer production, open-source and open-innovation within. Nevertheless, the literature shows that there are makerspaces or fablabs that mainstream innovation actors fund (e.g., universities, research institutes, public R&D laboratories)[1].

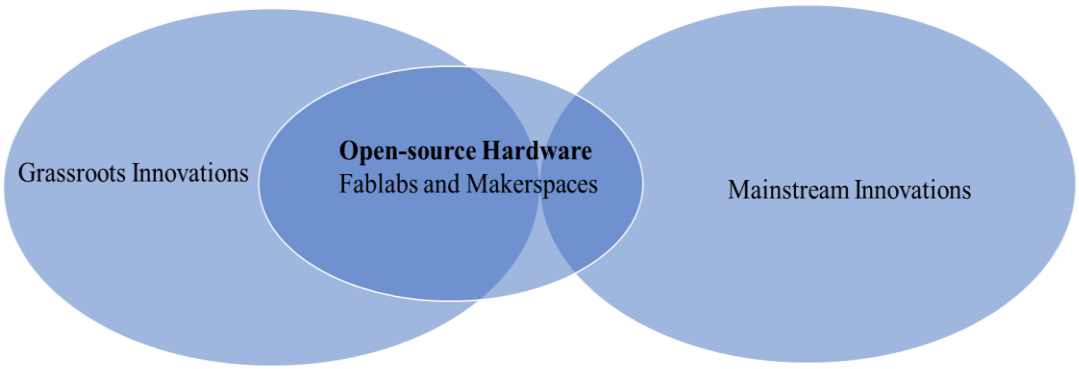

Figure 2. 2 : Where do fablabs and makerspaces stand between grassroots and mainstream innovations

Source: Author

Whether market-oriented or socially driven, these workshops have more than 3-D printing and digitalization. Due to their grassroots affiliation, they contribute to local development, community building, and social innovation in various ways, such as organizing workshops on these topics, hacking solar panels or making home-based systems for sustainable energy provision, hosting collective repair events, creating awareness on social inclusion (Smith, 2015). Makers not only produce brand-new artifacts but also re-create and assemble products with reuse principle (Rosa et al., 2017). The "third place" notion needs to be referred to here that is the social environment coming after people's home and working environment (i.e., the first place and the second place) (Oldenburg, 2001). The community-driven digital fabrication

[1] Please refer to Section 2.1 for Mainstream innovation actors.

workshops can be regarded as third places (Moilanen, 2012; Taylor et al., 2016). Here, civic engagement is highlighted, which is an inseparable aspect of grassroots initiatives. Social change, community inclusion, and creativity are amongst the ethos of participants (Lipson and Kurman, 2013, p.50). Although grassroots movements can be identified with some stylized facts summarized in Section 2.1, there are more specific facts about fablabs, makerspaces, and hackerspaces. Table 2.4 below summarizes the stylized features of fablabs, makerspaces, and hackerspaces as follows:

Table 2. 4: Stylized features of fablabs, makerspaces, and hackerspaces

Indigenous Concepts	***Hosted Spaces***	***Prevalent Activities/Motivations***	***User Profiles***
• Open-source • Open innovation • Commons-based Peer Production • Digital Printing Technologies • Decentralized Manufacturing • Democratized User Innovation • Sustainability • Entrepreneurship • Diversity/Equality	• Small-scale physical workshops (Community-driven/hosted by an institution/private) • Online Platforms • Ad-hoc events • Neighborhoods • Third places (Cafes, Museums, libraries, etc.)	• Collaborative design and prototyping • STEAM Education • Vocational Training • Awareness creating activities • Assembling, Repairing, Recycling, Reusing, Upcycling • Play • Creating	• Students • School Children • Researchers • Entrepreneurs • Artists • Crafters • Community Members • General Public • Hobbyists

Source: Adapted from Smith et al., 2017

Overall, the current literature defines the specificities on the identity of the community-driven digital fabrication workshops as summarized above. The following section will examine current literature fablabs amongst the other two.

2.2.2. Fablabs

What makes fablabs distinct from the other community-led digital fabrication workshops is their semi-formal network established by MIT. The list of all fablabs across the globe is available via an online platform (https://www.fablabs.io/), including the contact information and the set of devices possessed. Lab capabilities and a team of employees can also be accessed via this network. Although the origins and definition of fablabs are presented in the previous section, the official definition according to fablab.io web portal is:

> *A fablab is a place to play, to create, to learn, to mentor, to invent: a place for learning and innovation. Fablabs provide access to the environment, the skills, the materials and the advanced technology to allow anyone anywhere to make (almost) anything.*

Since the first establishment in 2001 in Boston, fablabs have spread rapidly, reaching around 2000 worldwide (fablabs.io). It is the local push that enables this spread. (Gershenfeld, 2012). The literature shows that the first seven years were an infancy period for the international fablab network, followed by a surge in 2012 and a constant rise till then draws an S-Curve (Osunyomi et al., 2016; Garnier, 2020).

The charter declared by Fab Foundation demands that the information produced in the fablab be shared openly and remain available for individuals to use and learn from it. The incubation step of commercial or entrepreneurial activity is welcomed: however, it is emphasized that expanding a business is out of the scope of fablab. The possible user groups listed on the Fab Foundation's website are public and private school children, artist/craftsmen, university students, entrepreneurs, and professionals. Referring to the values highlighted in this charter and the wide range of target groups, it is evident that "inclusivity and openness" is the key concept in the international Fab Foundation ecosystem.

As per spatial features, a fablab usually occupies a modest space such as twenty-to-two-hundred-meter squares areas (Bosqué et al., 2019; Eychenne, 2012; Osunyomi et al., 2016). There are also labs within the shared facilities or third places such as museums, town halls, co-working spaces (Bosqué et al., 2019; Garnier, 2020).

The equipment(s) that is expected to be in a fablab, in general, is more or less as follows: 3-D printers, laser engravers/cutters, embroidery machines, circuit makers, design software, CNC machines, and traditional wood or metal processing machines. 2-D and 3-D modeling software and design toolkits such as Rhino 3-D, Grasshopper, Arduino are complementary to that equipment.

The early research on fablabs is focused on the characteristics such as business model, typology, classification, target groups, and values. One of the first studies was Troxler's (2010) classification of the "innovation support model" and the "facility model". According to that study, most of the fablabs have difficulties sustaining the business, do not have a concrete business plan, and seek ways to find a complementary model to engage open innovation with private business. The open-source software model, which enables developers to generate income for sustaining the business by providing complementary services, would be an alternative for business sustainability. The surveyed fablabs are either private or hosted by a public institution, and the majority appraised themselves as a part of the grassroots community. Another initial research by Troxler and Schweikert (2010) demonstrates that very few labs involved the general public in their target group. The majority of the users were students, followed by researchers and then companies. Primarily they defined their competency as technology, and few of them added design and art aspects to this. The primary resources of income are public sources and the budget allocated by the hosting institution. Education and research are the main missions. An interesting finding in this study is that most of the labs defined their position as 'social tech' and 'green-tech', and none positioned themselves as 'high-tech' or 'smart-tech'. It is worth mentioning that there were only 45 fablabs at the time of these studies.

Eychenne (2012) made a categorization on fablabs dividing them into three groups as (i) educational, (ii) private business, or (iii) general public pro/amateur. Osunyomi et al. (2016) proposed four types of fablabs as such: "Community-based", "Education-based", "Business-based", and the "other" categories including (municipal space, independent research facilities, and science centers). For the labs hiring a fablab manager, the same study uses the term "self-organized" as well. More recent literature on fablabs mentions that fablabs either run a business or operate as part of an institution

or non-profit organization, and some of them have formal ties with MIT while many do not (Fleischman et al., 2016, Schneider, 2018). Garnier (2020) draws a line between "business-oriented labs" and "community-oriented labs" where entrepreneurship and technological innovation are at the forefront in the former and collaboration and openness are at the core in the latter. Geographical differences are a factor in the type of business models, where fablabs in North America are mostly business-oriented, while European fablabs are generally funded by public and private bodies as subsidies or grants (Osunyomi et al., 2016). It is worth mentioning that volunteer work is indispensable as a human resource for running the place in many cases (Bosqué et al., 2019; Bottollier-Depois et al., 2014; Osunyomi et al., 2016).

Regardless of this unstable autonomy and heterogeneity, the fablabs still contribute to economic and social development within their territories (Garnier, 2020) due to their being a knowledge intermediary and acknowledged innovation facilitator in their regions (Suire, 2019). It is claimed that fablabs are vital players for local development in digital transformation by providing the know-how to small enterprises and start-ups (Santos et al., 2018).

Makers have strong cooperation ties with the regional actors and each other to create an impact for sustainability (Millard et al., 2018). The well-known examples for the territorial role that fablabs play are the case of *Fab City* Programs. These programs aim to cultivate international and regional collaboration between fablabs and regional/territorial actors (e.g., public administration bodies, universities, associations) to propose creative solutions for the urban environment. Fab City Barcelona was the first of this program initiated in 2014.

According to Schneider (2018), most fablabs define themselves as community-based spaces "run by citizens for citizens", which clues the inclusivity notion within. However, when it comes to gender equality and demographic representation, the existing literature shows that the expected inclusivity is somewhat limited. Specific research on gender diversity in fablabs demonstrates that the typical maker in fablabs is white, male, and wealthy – and the female percentage is between 10 - 30 % (Voigt et al., 2017). The underrepresentation of females in fablabs is shown by scholars;

however, it is stated that this is due to the same imbalance of girls' and women's participation in STEM-related fields (Carstensen, 2013; Guthrie, 2014). A study shows that makerspaces are welcoming environments for females, yet this study was conducted with tiny sampling that does not include any fablab (Bean et al., 2015). It is shown in other surveys on fablabs that the regular participants are "well-educated" and technology-interested people. Moreover, due to spatial features or institutional requirements (being on a university campus, working hours, possible fee rates), not all the fablabs are open to the broad public (Carstensen, 2013). The following table presents the typologies explicitly derived for fablabs from the discussions presented in the literature.

Table 2. 5: Typology of fablabs

Type	***Physical Space***	***Business Model***	***Profit /Non-Profit***
Institutional - Public	• Universities • Schools • Public Spaces (Libraries, museums, town halls, shared urban areas)	• Sustained or Supported by the Public Funding	Non-Profit
Institutional-Private	• Co-working Spaces • Business Offices • Design Offices • Foundations	• Crowdfunding • Private funding	Hybrid (Profit and Non-Profit)
Grassroots - Community	• Associations • Foundations • Third Places	• Sustained or Supported by the Public Funding • Volunteer Work	Non-Profit

Source: Author

2.2.2.1. Fablabs in France and Belgium

As mentioned in the introduction, this research is mainly conducted in France with additional sampling from Belgium. Therefore, brief information on the countries is presented in the following section.

France

The first fablab was the fablab Toulouse-Artilect Lab, founded in 2009 with affiliation with the Artilect association. With 241 fablabs (up to date), France is the leading country in Europe regarding the number of labs hosted. Italy follows it with 169 and Spain with 67 (fablabs.io). Apart from the international fablab community, the French fablabs also have an association called Reseau Française des Fablabs- RFF (French Fablab Foundation- http://www.fablab.fr). France also hosted the 14th of FabX events, where all fablabs meet and discuss global trends every year. The foundation is active on social media (Facebook and LinkedIn.) and regularly organizes events, including the French *OctoberMake* annual event.

RFF also has a scientific council established by scholars working on the related disciplines affiliated with the foundation. The members of this council conduct participatory research on fablabs and makerspaces in the French context. This council has produced a White Paper on French fablabs (Bosqué et al., 2018) to show the state of play in the country context. According to that report, fablabs in France are very interested in the formation and event organization. %81 of the fablabs offer formation activities, and %80 offer event organization. Out of 86% of the daily activities is repairing, followed by fabrication with a percentage of 80%. The prototyping activity is 69% among the professional activities, followed by joint projects with 68%. The study shows that 54% of French fablabs are located in the city's heart, and 12% are in the industrial zone, showing their existence in urban life. Again, in this study, it was stated that the French fablabs prefer to cooperate rather than compete. The third-place concept is highlighted several times in that study.

Another important study is “Etat de lieux fablabs et typologie des ateliers de fabrication numérique- Fablabs’ state of play and typology of the digital fabrication workshops” commissioned by the French Ministry of Economy and Industry

(Bottollier-Depois et.al, 2014). In this study, fablabs were classified according to their locations, the number of employees, visitor profiles, business models, daily and professional activities, fund resources used, and legal status, compared to their counterparts in the United States, the creators of the fablab idea. The most crucial finding in this publication is that French fablabs produce knowledge, know-how, and design rather than tangible material (contrary to the point of origin of the "making almost anything" motto). Target material-intangible goal, community dimension-service dimension, and citizen orientation-market orientation are three detected dilemmas, and four main typologies are presented for the French case. These are all public, business, institutional and professional. According to this study, French fablabs are far from the market, rely on public funding, and are less salient in international networking. As mentioned in this paper, "French want to be free from the supervision of MIT". A specific study in the French context claims that fablabs are tools for facilitating the independence of people with disabilities. In this regard, they are highly integrable to social and solidarity work for the society (Roussel and Fillion, 2019).

A recent report on digital fabrication workshops in France presented a typology of the main functions of workshops (Burdeyron et al., 2020). According to that study, three types of functions are identified within workshops: digital training, ensuring variety in services, skills, and target groups and supporting tools for professional business. The assessment made in this study reveals that the first two function pillars are more potent in France; however, the third function is not excluded, as well.

In France, specific public policies are targeted in third places by the "National Council of Third Places" and the "Association of France of Third Places". Those bodies are very active since 2018 and they include fablabs to their activities as part of local development (Garnier, 2020).

Belgium

There are 31 fablabs in Belgium. French is one of the official languages of Belgium, and there is a French-speaking community (francophone), especially in the Brussels-Capital Region. The francophone community has formal/informal ties throughout the globe and resembles social and cultural similarities.

The fablabs in Belgium do not have an specific fablab organization country-wise; however, they have affiliation with an umbrella association of fablabs in Benelux countries (https://fablab.nl/bestuur-stichting-fablab-benelux). The association's web page provides the list and contact information of fablabs in the Benelux region and only provides preliminary information. The traces of fablabs can be seen in local initiatives, one of which is "Brussels Smart City". This initiative determines six action areas as "smart" economy, governance, environment, mobility, population, and living environment. The fablabs in Brussels are the key actors of the actions determined in this plan. It is typical for Benelux countries, including Denmark, that fablabs are hosted by municipal and regional administration as well as cultural centers (Kohtala, 2016). The fablab is not salient as a keyword in the country's policy papers but is embedded in policies such as digitalization, transition, sustainable smart cities, most of which are also designed in line with the European Green Deal Action Plan (2019).

2.2.3. Fablabs and Makerspaces in the Context of Sustainability

The relation between fablabs/ makerspaces and sustainability is a matter of discussion in the current literature (Fleischmann et al., 2016). As presented in the previous sections, there are business-oriented fablabs with a focus on digitalization and entrepreneurship. Still, the essence of the maker movement with the grassroots origin, including collaboration, sharing, and commons-based peer production aspects, is indigenous to fablab activities. Many makers resist traditional business processes and manifest their political stance by establishing novel business models (Smith, 2017).

As Rifkin (2014) mentioned, the maker movement is highly motivated by sustainable production practices. There is evidence of makers' manifestation of contributing to sustainability (Millard et al., 2018). For the creators and participants of the fablab network, the maker movement's implementation of personal manufacturing is a solid alternative to mass production and consumption (Kohtala, 2016). The sharing and openness notion enables the facilitation of idle resources employing sustainable design, recycling, and reuse, a natural contribution (Bauwens, 2006, Bauwens et al.,2012). Through makerspaces and fablabs, various activities contributing to sustainability are realized, such as: designing and prototyping sustainable home energy

systems, organizing and hosting repair events, community building activities to create awareness on sustainability, hosting organizations for social innovation in the context of sustainability, facilitating upcycling (Smith, 2015; Smith et al., 2017, p.109). Yet it would be pretentious to say makers alone are the drivers of change for the dominant economic environment (Smith, 2017).

In their study Millard et al. (2018) analyzed the relation between maker movement and sustainability following the different aspects, including social, economic, and environmental sustainability. According to that study, makers successfully achieve social sustainability due to their ability of collaborative learning and production, hence improving human capital. The gender effect is quite significant in creating social value because the study shows that female-led fablabs and makerspaces achieve better social sustainability than male-led ones. Their innovation driver role and facilitating rapid prototyping for economic value are the primary evidence for economic sustainability. Creating a shift in the labor market is also an economic impact, yet it requires a longer-term assessment to be concluded. Sustainable consumption and circular material flows are the most salient outcomes of the environmental sustainability pillar; however, their impact in reducing emissions is relatively low. Overall, the study set forth that the maker movement achieved environmental sustainability less than the precedent two.

However, measuring the pillars of sustainability is ambitious. Currently, there are no measurement frameworks or manuals to support the decision-making on sustainability, and the data typology derived from the research findings is quite varied (Kohtala and Hyysalo, 2015). The most accessible pillar to assess is economic sustainability due to the easily quantifiable result indicators. Social sustainability is naturally the most subjective pillar to assess due to the reason that many stakeholders are involved who may have controversial views. When it comes to environmental sustainability, it is a matter of debate how to decide “what is good for the environment”. The life-cycle assessment is the only analysis approach developed until now, however it is worth mentioning that it has a complex and time-consuming process (Diegel et al., 2010).

In this regard, to assess the environmental impacts of digital printing technologies, Kreiger and Pearce (2013) applied this assessment methodology to RepRap 3-D

printers. RepRap is an open-source project for assembling and developing 3-D printers and became popular amongst makers for low-cost digital manufacturing (Söderberg, 2014). According to the assessment conducted on RepRap printers, Kreiger and Pearce (2013) show that energy consumed, and emissions are significantly reduced with these open-source 3-D printers. Nonetheless, Faludi (2013) has raised objections on the parameters assessed and reveals that the critical fact in environmental friendliness is multiple users sharing fewer printers and utilizing them at the maximum capacity.

Olson (2013) set forth an essential argument by claiming that personalized digital manufacturing has numerous advantages over mass production by making eco-designs, ensuring energy efficiency, decreasing consumption and waste (by recycling, reuse, or repairing), and most importantly, decreasing the transportation costs. Birtchnell and Urry (2012) also highlighted the potential positive impact of local manufacturing compared to mass production where the products are being departed from the other side of the world. It is evident from the literature that the environmental effects of digital printing technologies have weaknesses and limitations regarding the impact assessment. The evolution of the technologies in the mid and long term will identify the extent to which personalized digital manufacturing predominates environmental friendliness over mass production (Hielsher and Smith, 2014).

Additive manufacturing is at the core of 3-D printing technologies. It is the alternative to the traditional manufacturing method of subtracting (i.e., shaping the bulk of raw material by drilling or cutting) by adding the desired amount of raw material. This technology allows users to produce almost any complex object (Gershenfeld, 2012). The freedom it pledges with the computer-aided design software opens a path for creating personally desired long-lasting products and its potential in the high value-added sectors such as aviation and medical implants (Diegel et al., 2010).

The eco-design concept is also highlighted in the literature, emphasizing its ability to boost economic and social impacts by ensuring product longevity, which means producing objects of desire for long-term usability (Diegel et al., 2010). Nielsen et al. (2011) proposed eco-design principles with a claim that sustainability is an issue to be considered early in the design.

Unterfrauner et al. (2019) proposed that the potential of the fablabs and makerspaces with regards to their contribution to environmental sustainability is evident, looking at their daily practices such as circular material flows, repairing-recycling-upcycling, establishing localized supply chains, or awareness of the maker community. Increased and structured local collaboration is critical in cultivating decentralized production and consumption, according to these scholars.

While fablabs are spaces for distributed design and production, their relationship with sustainability is highly speculative. The heterogeneity of the fablabs and makerspaces makes it complicated to conduct a consistent and solid assessment (Hielscher and Smith, 2014). It is not precise that environmental sustainability is at the core of their ideology, therefore if desired, this issue should be considered seriously to move forward in fablab's daily agenda (Kohtala, 2016). There is a necessity for makerspaces to find ways to keep up and develop their commitment to sustainability (Smith, 2015). It is also evident from the literature survey that further investigation is needed to understand how makerspaces-fablabs align their way of operationalization with the current needs of sustainability agenda with all the economic, environmental, and social dimensions. The weaknesses and limitations regarding the sustainability impact assessment must be resolved by further research by exploring how fablabs take the sustainability notion in their daily practices or how the production and consumption culture is affected by distributed manufacturing (Hielscher and Smith, 2014).

2.3. Concluding Remarks

In this chapter, the current literature on fablabs as community-led digital fabrication workshops is presented in the context of GI movements. International fablab network is established by the nodes sharing common principles and values. Fablabs carry unique potential in multi-disciplinary areas and challenge the social and environmental setting with their accumulated knowledge and skills. Fablabs' relationship with sustainability is also surveyed within the chapter, and the relevant francophone literature is presented for possible links with this thesis. In the next chapter, socio-technical systems and multi-level perspective concepts are introduced within the sustainability transitions literature. These concepts construct the theoretical framework

of the thesis to survey the fablabs' current position in the personalized production with the help of the notions presented in this chapter.

CHAPTER 3

FABLABS IN THE CONTEXT OF SOCIO-TECHNICAL APPROACH

Until this point, discussions in the literature on fablabs are presented regarding their position as a part of grassroots movements on the one hand and as an emerging type of digital fabrication workshops on the other, including their relationship with the sustainability concept. Based on the information presented in the previous chapter, it is evident that fablabs show up in different geographies yet form a unique ecosystem and sustain their existence by undertaking various roles of the social, economic, and environmental settings in their regions. Fablabs produce not only tangible products which may or may not affect the setting but also create social value and accelerate a cultural change in the making. In this regard, fablabs are considered an experimentation ground for social change (Smith et al., 2017). At this point, the "niche" concept of sustainability transition studies comes on the stage. Niches are protected spaces in which radical innovations may flourish by experimentations and without being affected by the dominance of the set regime (Kemp et al., 1998), the definition of which well matches with the practices of fablabs and makerspaces.

The niche concept is one of the building blocks of the socio-technical approach of transition studies for sustainable development. Although sustainability transitions literature mainly examines the significant changes in systems such as transport, energy, and agri-food (Elzen et al., 2004, 2011; Geels, 2011), it is also convenient to conceptualize other systems wherever niche innovations emerge and cause a deep change in the set layout. *"Sustainability transitions are long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption"* (Markard et al., 2012, p.956). The primary standpoint of the socio-technical approach is examining the evolution of a novel system with its interaction with the culture, society, markets,

technology, and policy (Geels and Kemp, 2012). The multi-level perspective of niches, regimes, and landscape as part of the socio-technical transition is a framework to examine those relations presented and discussed in this chapter.

3.1. Socio-Technical Systems and Multi-Level Perspective

The socio-technical systems approach is influenced by the well-established literature of systems of innovation (Freeman, 1987; Nelson and Rosenberg, 1993; Lundvall,1988,1992; Edquist, 1997; Malerba, 2002; Perez, 2002), and contributing this research field by including different elements into consideration (Geels, 2004a). A socio-technical system comprises elements such as technology, markets, supply and maintenance networks, infrastructure, regulation, user practices, cultural meaning (Geels, 2004b). Rather than taking firm, sector, or the entire economy as the locus of analysis, the socio-technical systems approach deals with the interaction and evolution of actors in the social setting of the affiliated in a timeframe. Figure 3.1 demonstrates the modern car-based transportation system elements: Regulations and policies, maintenance and distribution networks, industry structure, markets and user practices, infrastructures (fuel and road), vehicle, culture, and symbolic meaning.

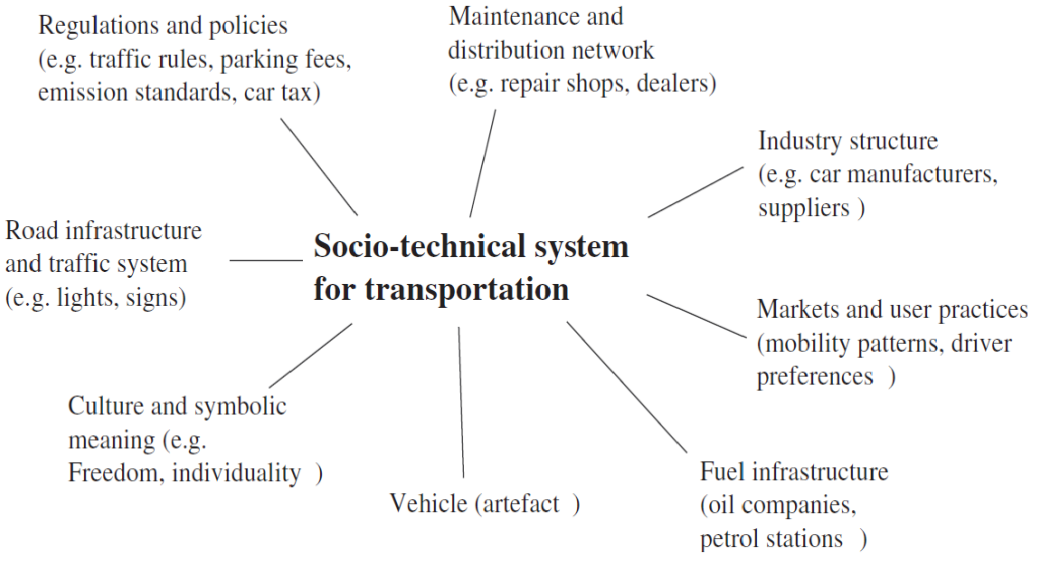

Figure 3.1: Elements of modern socio-technical system of transportation

Source: Geels (2004b, 2005)

The multi-level perspective (MLP) is a framework conceptualizing the dynamic interactions during a transition of a socio-technical system (Geels, 2002). MLP framework is constructed on the three analytical levels between which transitive processes interplay that result in a socio-technical system change. These levels are niches (the micro-level where radical innovations are born), socio-technical regime (the middle level where established rules and practices lay), and socio-technical landscape (the upper exogeneous level) (Geels and Kemp, 2012).

Niches

Niches are at the core of transitions. A novelty emerges in this layer and evolves by experimentation, as happens in an incubator. This niche incubator protects the novelty from the dominant market selection (Kemp et al., 1998; Schot, 1998). Niches either be in the form of modest market niches (Levinthal, 1998) or technological niches (Geels, 2004a). However, a novelty that emerged in a niche is eventually shaped by external influences such as infrastructures, rules, political concerns (Geels and Kemp, 2012). The niche-innovation literature (Schot, 1998; Kemp et al., 1998; Hoogma et al., 2002; Schot and Geels, 2008) identifies social processes realized within niches as the articulation and adjustment of visions, development of social networks, learning about the technology and the surrounding system. A niche possesses local and global elements where local refers to experiments gained in the tangible projects and global refers to the network of actors sharing the same principles, values, expectations from the experimented novelty. As the network gets more prominent, the shared vision becomes more articulated, and niches "gain momentum" (Schot and Geels, 2008, p.53; Geels, 2011, p.28).

Socio-technical regime

The socio-technical regime forms the meso-level of the MLP framework. Building on the technological regime definitions set forth by Nelson and Winter (1982) and Rip and Kemp (1998), which focuses on the engineering practices and cognitive routines evolving with a technological trajectory, Geels (2004) proposed the socio-technical regime concept including social actors such as users/consumers, academics,

policymakers, civil society, and other relevant parties. The stability of a socio-technical system is realized by the alignment between the actors in the socio-technical regime. After a socio-technical system is set, including its institutional regulations, cognitive routines, skills, and competencies, it is further stabilized by the social interactions and forms a sort of 'organizational capital' (Geels, 2005, p. 450). Since the existing regimes have lock-in mechanisms, only minor innovations can accumulate in the stable trajectory. Here the niches play a challenging role by deviating from the existing regime (Geels, 2011).

Socio-technical landscape

The socio-technical landscape is the broader political and economic surrounding level beyond the direct intervention of niches and regime actors (e.g., Norms, consumer habits, macroeconomic situation, etc.). It is the stationary level above all, where changes take place relatively slowly (Geels and Schot, 2007). The landscape may differ depending on where it exists; therefore, there may be multiple landscapes at a particular moment. Regimes are nested in landscapes (Geels and Kemp, 2012).

The transitions, also called regime shifts, occur by various interactions between these three levels within a timeframe. When niche innovations find an opportunity to diffuse at the regime level and the socio-technical landscape-level supports expanding this innovation by normative pressure or exogenous developments, a new socio-technical regime may come into the landscape (Elzen et al., 2011).

The nesting hierarchy in a socio-technical landscape may be triggered via external or internal drivers. These are normative pressures forced from the landscape level such as climate change, indigenous technical problems within the regime, changing user preferences, harsh competition between firms (Geels, 2004b).

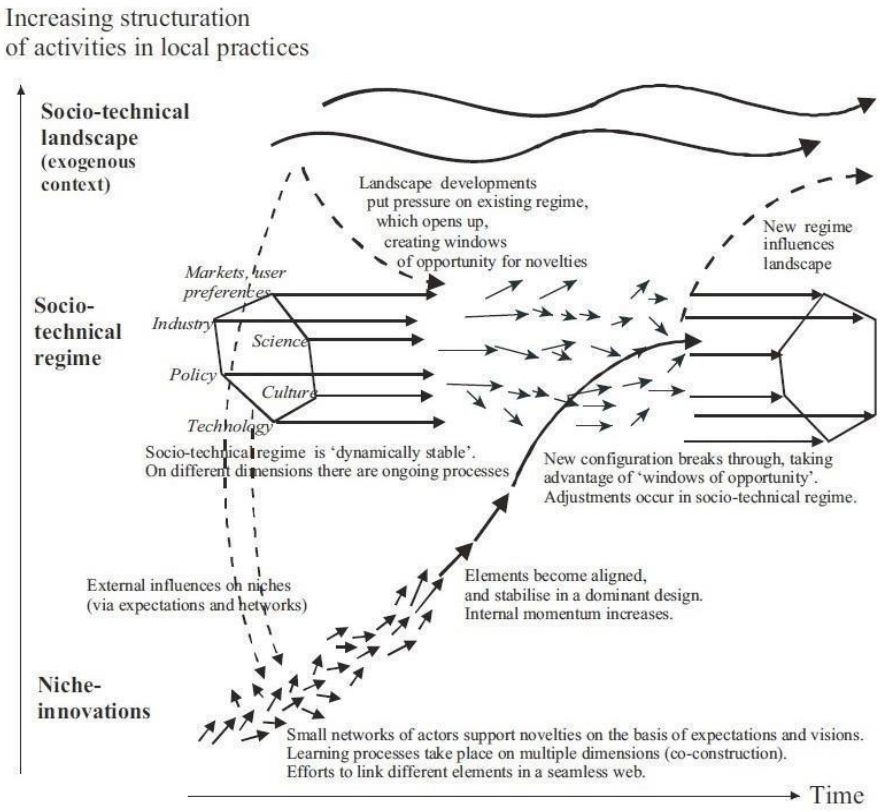

Figure 3.2: The nested hierarchy and MLP on transitions

Source: Geels (2011)

There are six patterns of transition discussed by Geels and Kemp (2012, p 59-68) by having studied several transitions. The first pattern, *"transition pathways"* draw four types of paths depending on the landscape pressure's extent. Those types of pathways are:

- **Transformation:** Occurs when there is sufficient landscape pressure; however, the niche innovations need to be matured.
- **Dealignment and realignment path:** Major tensions occur within the landscape (dealignment), creating an opportunity path for the co-existing niche innovations. This situation leads to realignment in the landscape and results in the leading of a new regime.
- **Technological substitution:** This pathway opens when all the conditions are ready for the regime change mutually, top-down from the landscape level and bottom-up from the niche level.

- **Reconfiguration pathway:** Niche-innovations are welcomed in the regime within a specified local context further followed by a wider adoption at the regime level.

The second pattern is the "Add-On hybridization pattern" within the MLP. When entering into the regime level, niche innovation does not have to compete with the existing regime but accompanies as a combination or as an add-on to the existing regime, as happens in the reconfiguration pathway. Another pattern is "Knock-on Effects and Innovation Cascades". According to that pattern, with the adoption of a novel innovation knock-on effects may be triggered that change not only the technology but also the periphery, including infrastructures, user preferences, regulations. The fourth pattern is the "Fit-stretch pattern," where a novelty appears as an improvement of an existing regime and evolves as a regime transition in a timeframe. The "hype-disappointment cycles pattern" refers to ups and downs in the acknowledgment and visibility of the novelty in the regime. The last pattern is the "niche-accumulation pattern," which most of the radical innovations resemble. Here niche innovation becomes self-sustaining by gaining ground in a niche market that eventually enters into a broader context by accumulation.

Today due to the increasing scarcity of natural resources, tensions occur in many socio-technical regimes. Compared to the past, it is more frequently observed that top-down fashion leads to the bottom-up add-on patterns or linking up in the regime (Berkhout et al., 2004). Socio-technical transitions change the technology, the structure, and the domain such as daily living and housing, working environment, trade, production, and policy-making (Markard et al., 2012).

3.2. Fablabs as Niches

Grassroots innovations are frequently discussed from the perspective of socio-technical transitions for sustainability literature. The emphasis here is the increasing political and moral demand to overcome the lock-in to unsustainable development patterns (Tukker and Butter, 2007). Grassroots innovations have numerous indirect impacts both environmentally and socially as niches where participants gain empowerment and confidence, further affecting the socio-technical system (Seyfang

and Smith,2007). Case studies are connecting the elements of the multi-level perspective on socio-technical transitions for analyzing the grassroots innovations (Seyfang and Haxeltine, 2011; Seyfang and Longhurst, 2013; Belda-Miquel et al., 2020). Unique features of grassroots innovations require special attention to be examined within the niche approach because GI is not market-oriented (Seyfang and Longhurst, 2013). The unevenness and diversity in GI lead them to play different roles in the niche regime (Boyer, 2015). The grassroots innovations-mainstream innovations dichotomy presented in Chapter 2 is salient here, again. While examining the diffusion of radical innovations emerging from the niches, the transition literature mainly focuses on regimes and landscapes led by mainstream innovations (Grin et al., 2010). GI have several bottlenecks such as weak infrastructure, low financial resources, and lack of professional skills compared to mainstream innovations (Seyfang, 2010). However, the socio-technical systems approach provides a backbone to analyze the behavior and evolution of GI as niches with its emphasis on the social actors, networks, and interactions in between. Grassroots movements promise rich empirical sampling to examine each element of a socio-technical system. For radical green changes in the production and consumption processes, innovation needed to be tackled at the socio-technical regime level (Berkhout, 2002).

GIs are considered "green niches" that shift into the dominant regime usually led by mainstream innovations. Grassroots developments in the energy sector are often examined in that frame and accepted as a prosperous experimental area for sustainable transitions. Grassroots designers of wind turbines in Denmark are one of the most salient examples of the alignment of the GI movement with policy, industry support, and the affiliated social movements of the era and became a mainstream industrial field (Smith, 2015). Three diffusion patterns are proposed for grassroots sustainable low-carbon housing niches by Seyfang (2010) and Seyfang and Haxeltine (2012) replication within the same scale, upscaling and translating the innovation to the central regime. Niches cannot change the socio-technical regime alone; therefore, policy implications can create the required political and social context. For grassroots niches, it is harder to diffuse into the regime unless the landscape pushes for sustainable reforms. Therefore, it is rare to experience radically sustainable transitions

emanating from grassroots communities due to their insufficient capacity and the dominant stances in the regime (Seyfang and Smith, 2010).

Commons-based peer production forms a socio-technical system on its own, possessing technical infrastructure, virtual and physical networks, and a group of innovators. This system revolves around common knowledge and culture, and it is independent of the pushes from the market or hierarchies (i.e., the regime) (Benkler and Nissenbaum, 2006). As mentioned in the previous chapter, fablab "is a place for learning and innovation" (fablab.io). Regardless of fablab's business sustainability, a fablab user has the freedom to play with the technology and create artifacts or social value. As intermediaries, fablabs open a window for the innovators and ordinary people to develop but, more importantly, appropriate technology or a product (Stewart and Hyysalo, 2008). Sharing idle resources, reducing waste production via daily routines (recycling, reusing), experimenting with eco-design are moral stances of fablab users against consumerist society (Schneider, 2018). Fablabs are seen as transformative social innovation by changing the set rules in education (e.g., hands-on practicing, K12 level training), investment (crowdfunding), post-consumerism (how things are made), and way of producing knowledge (Smith et al., 2015). For Anderson (2012) and Rifkin (2011), digital manufacturing itself is a part of the third industrial revolution claiming that everybody has the potential to be her/his manufacturer.

3.3. Conceptualizing Personalized Production in Fablabs as a Socio-Technical System

Replacing the personalized and reduced production and consumption with mass production and consumption is an opportunity window for fablabs to open out for better sustainability. Changing the meaning of "normality" is essential to the quest for sustainable services, practices, resources, and technologies (Shove, 2004). It is not a mandate to see a socio-technical system from a specific sectoral or technological perspective. With its grassroots stem, fablabs are candidates for increasing socio-technical diversity (Smith and Stirling, 2016), and personal manufacturing can be seen as a socio-technical system on its own. It is unrealistic to assume that fablabs will change the dominant production and consumption regimes alone (Smith, 2017), yet it

provides a sample to examine the potential of transition to sustainable production and consumption.

Assuming mass production and consumption as a dominant socio-technical system and (through fablabs and makerspaces) personal manufacturing as an alternative system, we can seek the transition paths. In order to do this, the elements of the hypothetical socio-technical system of personalized production are determined similar to the demonstration presented for car-based modern transportation system in Figure 3.1; by taking into consideration the GI specificities of fablabs. Therefore, the concepts presented in Chapter 2 are revisited at this point, which are stylized features of GI and fablabs presented in Table 2.1 and Table 2.4, respectively, in conjunction with the contributions to sustainability pathways concept for GI, which is presented in Figure 2.1. Those concepts are the essence of the grassroots movements such as open innovation, desire for sustainability, community spirit in the local context. Same concepts apply for fablabs with a digital fabrication notion and STE(A)M education as the primary stylized features. The contribution pathways of GI are knowledge, capabilities, ideas, methodologies, actors and alliances, artifacts and infrastructures (Smith et al., 2017).

Determining the elements of the proposed system is essential to reveal the substance of the possible transition to socio-technical regime and landscape by examining the contribution of each element. Geels (2004b, 2005) determined the elements of the socio-technical systems with an eclectic view by transcending the disciplinary boundaries. The elements of socio-technical systems are drawn from various concepts, which are,

- Technological regime concept of evolutionary economics including firms, cognitive routines, and agents (Nelson and Winter, 1982),
- The elements determined in sectoral system approach (Malerba, 2002),
- The large technical systems such as electricity networks, railroad networks, telephone systems, and the Internet (Hughes 1983, 1986, 1987),
- Social Construction of Technology (SCOT) approach (Pinch and Bijker, 1987; Kline and Pinch, 1996) which takes the social actors as a focus such as developers, users, policymakers and with interpretative flexibility and explains

the gradual consensus on the acknowledged meaning of elements by the social groups,

- Actor-Network Theory (ANT) (Latour, 1987, Callon et al., 1986; Callon, 1991) focuses on linkages in and around emerging technologies.

Based on this eclectic approach, the transition scholars adapt the elements of the socio-technical system to be examined in its relevant context. For example, Schot et al. (2019) determined seven elements for the energy system: "energy regulations and governance", "energy production and distribution networks", "energy use and markets", "energy culture", "business models and industry strategy", and "science and technology structure for energy". For the car-based modern transportation system, the elements are determined as "regulations and policies", "maintenance and distribution networks", "industry structure", "markets and user practices", "infrastructures (fuel and road)", "vehicle", "culture, and symbolic meaning" by Geels (2004b, 2005).

In this thesis, I adopted the same approach relying on the examples in the transitions literature and taking into consideration the grassroots specificities of fablabs and determined six elements with their specific content for the socio-technical system of personalized production as demonstrated in Figure 3.3 below:

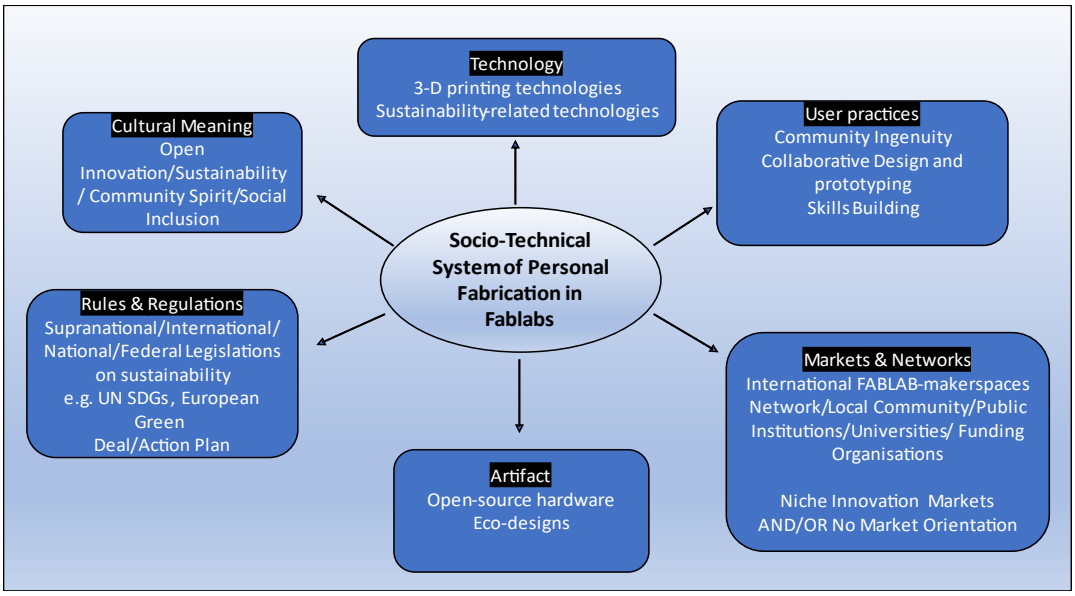

Figure 3.3: Elements of the hypothetical socio-technical system of personalized production within fablabs as niches
Source: Author

The proposed elements with their specific context for fablabs are provided below:

1-Cultural Meaning: The transition literature uses the cultural meaning of the system as values and symbolic meaning, including ideas and aspirations (Shove et al., 2012) for the users. The meaning of a system changes in response to the mutually constructed relationships of the social groups in the system (Kline and Pinch, 1996). For the modern car-based system, freedom or individuality are proposed as cultural meanings for users (Geels 2004 b, 2005). For the personalized production system, those value propositions can be open innovation, desire for sustainability, localization, sharing, community spirit and social inclusion.

2-Technology: Traditionally, technology is the study of arts and crafts, whose meaning has expanded in time, including purposeful invention and deployment of those inventions to the market (Rip and Kemp, 1998). In daily life, the term is interchangeably used with artifact; however, Rip and Kemp (1998) mentioned that technology has various aspects, including functions and organizations such as engineering practices, production procedures, product characteristics. As explained in the literature review, it is the recent technological developments in additive manufacturing (AM) and digital printing that enables personal manufacturing in fablabs. Therefore, this element indicates the technological advances, the ways, and means of a novel mode of production, which are 3-D printing technologies AM and sustainability-related technologies for the proposed system.

3- Rules and Regulations: The transition studies utilize this element referring to legislative regulations that catalyze the novel system to be acknowledged rapidly and widely (Geels 2004b, 2005, 2007). Those regulations are also considered as landscape push from top-down in the MLP concept. For this case, any supranational, international, national, or federal legislation regarding sustainability is concerned, such as United Nations Sustainable Development Goals Framework (2015) or EU Green Deal Action Plan (2019).

4-User Practices: Practices are the routinized type of behavior (Reckwitz, 2002) that endures during a specific action with a recursive character (Shove et al., 2012). Competencies, expertise, maintenance skills, know-how, and techniques are esteemed

as elements of social practice by Shove et al. (2012). I include the regular patterns of user behaviors or the custom procedures into the user practices element for fablabs. Collaborative design and prototyping, documenting, gaining community ingenuity, building competencies are the most common practices in fablabs.

5- Artifact: According to Pinch and Bijker (1984), technological artifacts are outcomes of mutual work by engineers and social actors to address users' interests. According to them, there is a continuous cultural construction and reinterpretation of artifacts. The meaning of a novel technology changes with the responses from the social groups and shapes the artifacts derived from that technology, and at the end, the artifact alters the social relations in a mutual way (Kline and Pinch ,1996; Latour, 1987). Rip and Kemp (1998) imply that artifacts are channels of social change between the three layers, the niche, regime, and landscape.

In the transitions literature, the physical entities used or originated by the actors utilizing the socio-technical system constitute the content of the artifact element. The vehicle itself is the artifact in the modern car-based transportation system (Geels, 2004b, 2005). For the fablabs case, I propose open-source software and hardware projects, eco-designs, sustainability-related gadgets to constitute the artifact element.

6- Networks and Markets: The interaction and interplay between the several social actors in a system's network determine its evolution. Pinch and Bijker (1987) mentioned that technological success is dependent on the robust and broad social groups who adopt and promote it. The links between the actors are continuously evolving to reform the socio-technical system's elements (Geels, 2005). Fablabs have an advanced international network and close relations with mainstream innovation actors such as public institutions, universities, or funding organizations. Being a type of GI, fablabs are not market-oriented yet have linkages or partnerships with the market actors as part of their collaboration networks. Moreover, entrepreneurs aim to commercialize products personally produced in a fablab by benefiting the networks and partners of fablabs. Therefore, 'networks and markets element' is proposed together for this system while they are usually examined separately in the transitions literature.

3.4. United Nations 2030 Agenda

Ever since its adoption, the Brundtland Commission Report (1987) "sustainability" concept has become a part of the public's daily lives and agendas of policymakers. 17 UN Sustainable Development Goals are declared within the 2030 Agenda, which provide a global framework to understand better the main challenges and areas to be focused on for the sake of the planet and future generations. The framework provides a well-enhanced indicator framework consisting of 230 indicators. The SDGs and the indicator framework include several economic, social, and ecological aspects with cross-cutting issues relating to the science, technology, and innovation policies. Brief information on each of the 17 goals are provided below.

- SDG No 1 - End poverty in all its forms everywhere: The first goal includes targets related to eradicating extreme poverty in several dimensions. These include increasing the access of the poor to social protection, proper technology, financial and natural resources, having equal rights and ownership of property, and building resilience to crises, including natural disasters, violence, and economic recessions.
- SDG No 2 - End hunger, achieve food security and improved nutrition and promote sustainable agriculture: This goal targets preventing malnutrition, especially for the poor, including infants and children. The indicators are related to increasing the food quantity and quality for all, while seeking sustainable agriculture.
- SDG No 3 - Ensure healthy lives and promote well-being for all at all ages: This goal targets to combat child and maternal mortality rates, increase access to reproductive healthcare, and decrease the rates of communicable and non-communicable diseases.
- SDG No 4 - Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all: Education is a crucial factor for a sustainable and secure world. This goal aims all children and adults to have proper education and training, including primary education and vocational training.
- SDG No 5 - Achieve gender equality and empower all women and girls: Reducing the inequalities between men and women in economic life and

eliminating all forms of violence against women and girls is the primary mission of this goal.

- SDG No 6 - Ensure availability and sustainable management of water and sanitation for all: This goal highlights the importance of access to clean water and sanitation as a human right. Preserving clean water resources and reducing pollution is aimed with cross-border collaboration where necessary.
- SDG No 7 - Ensure access to affordable, reliable, sustainable and modern energy for all: Accessing energy is crucial for achieving the development goals; hence it is vital to increase the use of renewable energy and ensure efficiency in resource usage. This goal provokes clean energy usage via technological development, investment programs and support schemes.
- SDG No 8 - Promote sustained, inclusive, and sustainable economic growth, full and productive employment and decent work for all: This goal combats forced labor, human trafficking, child labor, and unemployment and creating decent jobs in the tourism, finance, insurance, and banking sectors.
- SDG No 9 - Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation: The essence of this goal is to enhance technological development to create jobs and sustain economic development while seeking efficient and environmentally friendly clean technologies.
- SDG No 10 - Reduce inequality within and among countries: The goal includes indicators on increasing the participation of developing countries in the decision-making processes with international organizations and regulating better migration policies.
- SDG No 11 - Make cities and human settlements inclusive, safe, resilient and sustainable: The goal targets affordable and safe housing, transportation systems and regional development. Protecting the cultural and natural heritage and planning human settlement are also essential dimensions of the goal.
- SDG No 12 - Ensure sustainable consumption and production patterns: This goal calls for decreasing the waste production and sound management of waste by recycling process as well as controlling the chemicals. The companies and governments are encouraged to align with sustainable practices.
- SDG No 13 - Take urgent action to combat climate change and its impacts: Decreasing the carbon emissions and preserving the ecology is crucial for the

planet's future. It calls for countries to urgently align with the UN Framework Convention on Climate Change to remedy the hazards of global warming.

- SDG No 14 - Conserve and sustainably use the oceans, seas and marine resources for sustainable development: This goal mainly targets protecting coastal ecosystems and marines, designate fish farming, stop overfishing, prevent oceans and the biodiversity within.
- SDG No 15 - Protect, restore and promote sustainable use of terrestrial ecosystems: This goal combats the extinction of the species, protecting flora, and fauna and illegal trafficking of wildlife products.
- SDG No 16 - Promote peaceful and inclusive societies for sustainable development: This goal includes many social aspects, such as reducing corruption by establishing accountable institutions, preventing illegal activities on vulnerable groups, increasing social justice by non-discriminatory legislation, and ensuring participative decision-making processes in all countries.
- SDG No 17 - Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development: This goal calls for developed countries to share their resources with the globe for technological development, capacity-building, equal trade, and better systems and institutions.

Figure 3.4: 17 Sustainable Development Goals of United Nations

Source: UN Communication Materials

In order to fully reach the SDG goals, significant structural changes must be realized in all sectors, and countries should be aligned with these goals by implementing proper policy interventions (Sachs et al., 2019). Since dominant socio-technical regimes have a static and lock-in character, transitions for sustainable systems require a collaborative effort from actors of all sectors (Markard, 2011).

In this study, a special attention is given to the UN 2030 Agenda, to reveal the rules and regulations element of the proposed socio-technical system because it provides an enhanced framework to explore the substance of the efforts and work realized. The framework is employed in the survey to explore the level of contribution of fablabs to sustainability.

3.5. Concluding Remarks

The literature survey revealed the potential of fablabs as an alternative to the dominant mode of production. The MLP concept welcomes the niche innovations that are not subject to the competition but accompany a combination or add-on to the existing regime. Utilizing these concepts, personalized production within fablabs is proposed as an emerging socio-technical alternative to mass production. In order to explore the extent to which this system takes part at the regime level, the elements of the system are determined and surveyed. Figure 3.5 below conceptualizes the theoretical assumptions employed in this thesis.

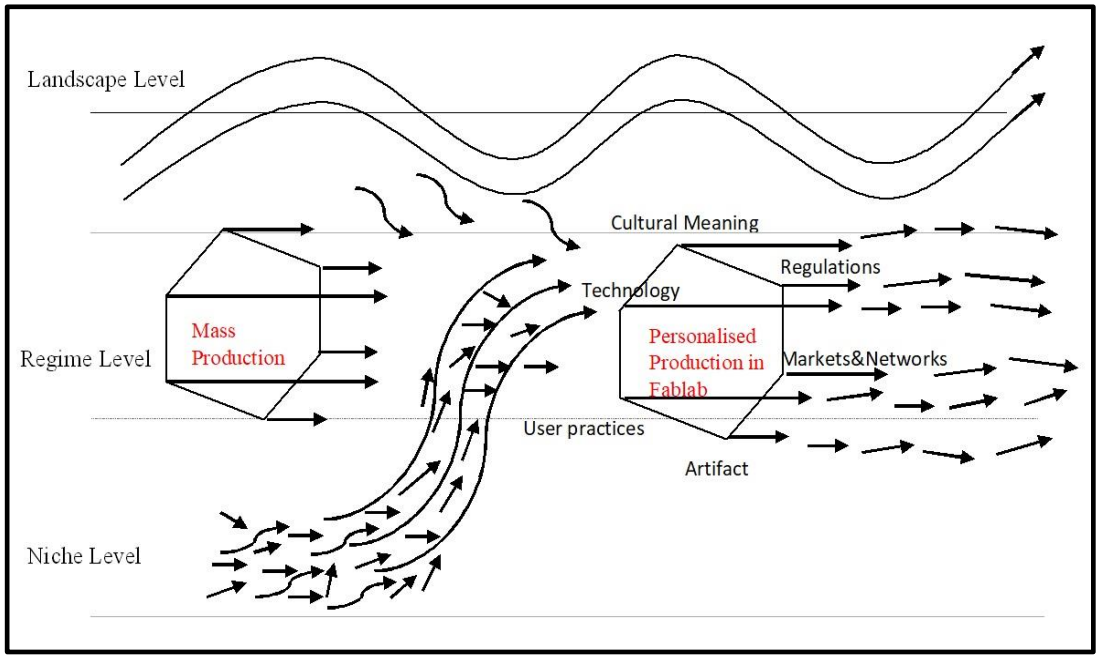

Figure 3.5: The nested hierarchy of the proposed system and alignment of trajectories in the landscape

Source: Adapted from Geels (2011) by author

The interlinkages between the proposed elements play a vital role in the transition of a system by trajectories on multiple levels. Each element displays its own trajectory in interaction with the other component in the system. By exploring each element's substance and mapping out the conditions for fablabs, it is aimed to make projections for the future and device policy suggestions for better sustainability achievements within localized communities. The following chapter presents the methodology employed for this exploratory survey.

CHAPTER 4

METHODOLOGY

In this chapter, the research methodology utilized for the study is described by presenting the research approach, research design, methods and worldview adopted, data sampling procedures, data collection, and data analysis, respectively.

This study aims to explore the role of fablabs in sustainability transitions by employing a specific theoretical framework (i.e., MLP on socio-technical systems) explained in detail in the previous chapter. Therefore, the research has been conducted with this theoretical lens, and data analysis is realized accordingly.

4.1. Research Approach

As summarized in the previous chapter, being a type of GI, fablabs can be analyzed as niches where personal digital fabrication is practiced, and alternative innovations emerge. The theoretical background of the thesis is established on the literature of community-driven digital fabrication workshops in conjunction with grassroots innovations movements to understand better the properties of the international fablab network and its evolution in time. Since the fablabs have the claim for sustainable transitions and their very existence as niches, it allows them to be examined under the lens of the multi-level perspective of socio-technical systems approach for exploring their role in sustainability. The socio-technical systems approach indicates critical elements of a niche to enter the socio-technical regime for fostering sustainable transformation. Based on the above-mentioned theoretical assumptions, the elements of the socio-technical system for personalized digital fabrication within fablabs are determined as “cultural meaning”, “technology” , “rules and regulations” , “user practices”, “artifact” and “networks and markets” in Chapter 3, each of which to be examined throughout the thesis in order to answer the research question of “do fablabs

contribute to the transition to sustainable production and to what extent can they achieve this goal?". The 17 UN SDGs are accommodated while establishing the inquiry as a framework to understand the sustainability perception and contributions of the fablabs.

In this regard, a convergent mixed methods design (Creswell and Creswell, 2018) is utilized for this research taking fablab itself as a unit of analysis. The pragmatic worldview is embarked on, which enables researchers to focus on the research question(s) instead of methods liberally and utilize multi-methods to derive knowledge (Morgan, 2007; Patton, 1990). The pragmatic worldview does not bind researchers to stick into a single method and gives freedom to formulate inquiries by using both quantitative and qualitative methods to explore the reality in its social, historical, and political context. That is why most pragmatists accommodate a theoretical lens to reflect the actual dynamics of the surveyed context (Creswell and Creswell, 2018).

Mixed method research is helpful to elaborate on quantitative data by using qualitative data collection and analysis. The convergent type of mixed method enables researchers to present and compare findings side-by-side. This method is adopted in this thesis, and qualitative and quantitative data are merged and jointly presented under the derived themes in the findings. While doing this, steps of inductive logic of qualitative research are followed such as:

- Collecting information
- Forwarding open-ended questions
- Analyzing data and find themes
- Derive broader patterns or categories
- Posing generalizations or theory with the help of literature.

4.2. Data Collection

For this research, I collected primary data through observations, an online questionnaire, and individual semi-structured interviews. The research is conducted in France and the francophone region of Belgium. The descriptive quantitative data is

gathered via an online questionnaire, while I collected and compiled the interpretive qualitative data during the observations and interviews.

At the beginning of the research, the number of fablabs in France was 221; it is now approximately 240. After their birth in the United States, fablabs have spread into Europe over France. French fablabs have strongly tied personal and formal networks and show a dense population all over the country. Considering the size and population, Belgium also hosts a sufficient number of fablabs (31). As known, Belgium has a francophone region that has strong cultural ties and resemblances with France. These two countries provide a proper sampling for testing the hypothetical socio-technical system proposed within the thesis. Therefore, I employed fablabs from these two countries (only the francophone ones in Belgium) for the study to construct a homogenous data sampling.

4.2.1. Observations

The field research was initiated with a three-day direct observation in a fablab. I established face-to-face conversations during this observation, took photos, collected documents, and kept field notes. Following this, I drafted an online questionnaire based on the literature survey, the theoretical framework adopted, and the initial observation.

In order to enhance knowledge and test the pertinence of the questionnaire regarding the research's scope, I attended a full four-day workshop (October Make 2019) in Nancy, France (17-20 October 2019). The workshop was organized as an annual networking and collaboration event by RFF (The French Fablab Foundation). There, my position as a researcher was a participatory observer. During the workshop, I took photos, kept field notes, and participated in the discussion groups. The question set of the online survey is finalized with the feedback gathered from the members of RFF's scientific committee and ecology group. By identifying the potential fablab managers for the interviews, I established the initial contacts with them during this workshop.

Another direct observation was conducted during the UN meeting on fablabs, and SDGs held on 10-11 December 2019 in Geneva, Switzerland. I attended discussion

sessions and took notes on the projects and insights about the sustainability of fablabs worldwide. The other observation was my visit to a recycling space, working closely with the fablabs in Brussels. There I took photos and noted my observations during this visit. Table 4.1 provides a summary of the observations realized.

Table 4. 1: List of Observation Sessions

Observation Sessions	***Venue***	***Time***
Individual Observation	Fablab LaPalaisse, Paris, France	22-26 July 2019
October Make 2019	FabLab La Piscine, Nancy, France	17-20 October 2019
OSI Geneva Forum	United Nations, Geneva, Switzerland	10- 11 December 2019
Individual Observation	Rotor DC, Brussels, Belgium	14 February 2020

4.2.2. Online Questionnaire

I utilized SurveyMonkey to design an online questionnaire in the French language and distributed it to 294 fablabs in France, "registered as fablabs" in the international "Fablab.io" database and European MakeryMap database (http://www.makery.info/en/map-labs/). The invitation emails include links forwarding to the questionnaire page. Simultaneously RFF promoted the study on their social networks. The fablab managers were requested to answer the survey on behalf of the fablab entity. The questionnaire was composed of 29 questions under three sections, namely "General questions", "Their projects regarding SDGs" and "Partnerships". The outline of the questionnaire is provided in Appendix B of this thesis.

The poll stayed open for two months, and I sent reminders to the recipients who did not open the link. Among 294 recipients, 174 looked at the questionnaire link, and 65 responses were obtained from the questionnaire poll. Forty percent of the respondents entirely filled the questionnaire, 60% percent have partially filled it (skipping either

one or two sections of the questionnaire). The partial filling might be that they do not have tangible projects and partners regarding sustainability or skipped that section. After closing the poll, I analyzed the results via SurveyMonkey built-in tools. I employed the quantitative data for descriptive purposes in the thesis to enrich the interpretive qualitative data.

4.2.3. Individual Interviews

I initiated the interviewing soon after the opening of the questionnaire poll. A semi-structured interview guideline was prepared to guide the interviewees. The interview guideline included complementary descriptive questions to the questionnaire and detailed open-ended questions to explore the concepts for interpretive purposes. I compiled the question sets according to a logical flow of a conversation and elements sought within the theoretical framework. According to that guideline, fablabs were asked whether they contribute to sustainability, if so, how do they achieve this, what are the daily practices they implement, how are their relations with partners take place, what kind of solid projects do they implement, what are the technologies on which they gain experience, what kind of skills they develop, what are the cultural perceptions of fablab communities on sustainability or social concerns, their relation with market actors. The outline of the interview guideline is provided in Appendix C of this thesis.

Two sets of individual interviews were conducted during the study, the first set was realized in France, and the second was conducted in the francophone region of Belgium.

For the French interviews, I utilized a mix of snowball and purposive sampling methods to recruit participants. For Belgian interviews, I employed convenience sampling. The first interviewees to be recruited into the study were the ones contacted in October Make. Following the first three interviews, I sent e-mails to fablabs in the Ile-de-France region (where accessibility is convenient, the fablab population is quite dense, and the sampling from different typologies is sufficient). In these e-mails, I presented the content of the study and requested their consent to participate in the study. I realized the visits and interviews with the ones who responded to the request

affirmatively. The founders, the fablab manager, or a deputy were recruited to the study for the interviews. I requested them to respond on behalf of the fablab, and the interviews took place in the fablab environment lasting from forty-five minutes to one hour. Photos were taken, and interviews were audiotaped with the consent of the interviewees. The interviews were done in English; however, there were instances that interviews skipped into French as they were not native English speakers.

For the France case, there was a fairly equal distribution of grassroots, private, and university fablabs compared to their population rate per typology in France. Out of 10 fablabs interviewed, three were university hosted, three were private, four were grassroots fablabs, and one was public fablab. Table 4.2 provides the typologies and legal status of the interviewed labs in France, the Ile-de-France region.

Table 4. 2: List of French labs interviewed

Interviewee No	***Typology***	***Legal status***	***Age of fablab (years)***	***Gender of the fablab manager interviewed***
I1	University hosted	Company	3	Male
I2	Public	Industrial and commercial public establishment.	6	Male
I3	University hosted	Unit of University	3	Male
I4	University hosted	Unit of University	3	Male
I5	Private	Company	3	Female
I6	Private	Company	8	Male
I7	Grassroots	Association	7	Female
I8	Grassroots	Company at 3rd sector	3	Male
I9	Private	Company	5	Male
I10	Grassroots	Association	6	Male

Following French interviews, I organized a four-day visit to Brussels where five fablabs and a recycling-repairing facility were visited. By utilizing the same interviewing methodology and guidelines for the Belgian labs, I conducted the interviews. Photos were taken, documents were collected, and interviews were recorded with the interviewees' consent as it was in the France case. For the Belgian case, three fablabs were grassroots, and two were hosted by a local administration body. The interviews took approximately one hour and were done in English. Table 4.3 provides the distribution according to the typology and legal status of the interviewed Belgian fablabs.

Table 4. 3: List of Belgian labs interviewed

Interviewee No	***Typology***	***Legal status***	***Age of fablab (years)***	***Gender of the fablab manager interviewed***
I11	Public	Unit of Local Administration	4	Male
I12	Grassroots	Association	4	Male
I13	Grassroots	Association	5	Female
I14	Grassroots	Cooperative	8	Male
I15	Public	Unit of Local Administration	2	Male

4.3. Data Analysis

The quantitative and qualitative data were processed one by one. The interviews started before the closure of the questionnaire poll. After the closure of the poll, I analyzed the questionnaire results via online facilities provided by SurveyMonkey. This tool provides enhanced built-in facilities such as visual charts, statistical tables, and log data that compiles and presents ready-made reports. I make use of those reports to present the quantitative data in the findings section.

For the qualitative analysis, I collected anecdotal data from research diaries and took notes during the meetings. On the other hand, a bilingual expert who is confident in both English and French is recruited for French and Belgium interviews transcriptions. After transcribing the audiotapes and online records into word processors, the files were transferred to NVivo, semantic analysis software that enables researchers to organize and manage data in the qualitative and mixed-method analysis. By this tool, the interviewed fablabs clustered according to their typology and country. The visual material can also be organized to the qualitative content in NVivo.

Firstly, coding was made without applying a theoretical bias and from a generic point of view. With this approach, I generated 174 codes from the interviews. The list of generated codes concerning their frequency in the interviews is presented in Appendix D. Then, I grouped the generated codes under themes by correlating with the socio-technical element and the possessed aspects. The proximity and relatedness with the quantitative and qualitative data are regarded while grouping the themes and interpreting the findings of the study. Table 4.4 below presents the derived themes related to the theoretical perspective and type of data source.

Table 4. 4: The list of themes derived and the related element

Socio-Technical Element	***Aspects Addressed***	***Themes Derived***
Cultural Meaning	Open Innovation/Sustainability/ Community Spirit/Social Inclusion	- How do they define themselves? - Governance - Motivations of users to participate - Missions and vision of fablab - Social Inclusion and Solidarity - User Profiles
Technology	3-D printing Technologies /sustainability Related Technologies	- Field of Expertise - 3-D Printing Technologies and Sustainability
Rules &Regulations	Supranational/International/National/Federal legislations on sustainability	- Perception of Sustainability and UN SDG Agenda - Contribution to SDGs - Factors Affecting the Level of Contribution
User Practices	Community Ingenuity/ Collaborative Design and Prototyping/ Skills Building	- Skills Building - Responsible Consumption and Production Practices (Reusing, Repairing, Recycling-Upcycling, Waste Management)

Table 4. 4 (cont'd)

Artifact	Open-source hardware/ Eco-Designs	- Eco-Design - Ecological Projects - Environmental-Friendly Materials - Circular Material Flows
Markets and Networks	No-Market Orientation/ Niche Markets International FABLAB-makerspaces Network/Local Community/Public Institutions	- Business Models - Collaborations - Personalized Production and Local Value Chains

4.4. Concluding Remarks

In order to answer the research question, I utilized the theoretical framework with the employed methodology. After the literature survey, I conducted observations with the French fablab community to construct the methods to be employed. To explore the fablabs' roles in sustainable transition by practicing personal manufacturing, French fablabs were surveyed via an online questionnaire and further analyzed with interviews by adding a sampling from the francophone Belgian fablabs into a whole sample.

During the study, concepts like user practices of fablabs, their relationship with the partners and international network, perceptions on social values and meanings are surveyed via questionnaire and interview guideline. After the transcription of the interviews, each sentence is analyzed and -where relevant-turned into semantic codes and themes. These themes are further aligned with the theoretical elements to present the study's findings and establish grounded discussions. Utilizing the concepts provided by the theoretical framework, I attempt to explore the trajectory of each element and the possible transition pathways of the system I proposed. The derived findings will be presented with relevance to the theoretical framework under each element in the following chapter.

CHAPTER 5

FINDINGS

In this chapter, the quantitative and qualitative data derived from the questionnaire and the interviews are compiled as themes and presented under the concepts proposed within the theoretical framework. Outcomes of this chapter are also visited in the discussions chapter to establish an argument for the future projections and policy suggestions. Throughout the chapter, the quantitative data derived from the questionnaire is presented side-by-side with the qualitative analysis derived from observations and interviews. This presentation is made under the themes generated from the semantic analysis of the interviews, where the richest data exist. For particular themes, I also articulated anecdotal data obtained from attended events to the relevant theme.

The quantitative analysis includes descriptive data about French fablabs, such as how they describe themselves, their primary income resources, their field of specialization, their activity purpose, and the type of commons licenses they utilize. Moreover, analysis of collaborations provides information about partner typology of French fablabs. The questionnaire also provides data on the level of contribution to each one of 17 SDGs by calculating the references of projects implemented by fablabs.

The qualitative analysis includes anecdotal data obtained from the diaries and notes taken during the observation sessions/interviews and transcriptions of the audio recordings of the French and Belgian interviews. The qualitative analysis involves themes such as decision-making processes, user profiles, and motivations, skills built, social inclusivity, perception of sustainability, contribution roles to sustainability, responsible consumption and production practices, and factors affecting the different perceptions.

Those themes derived from quantitative and qualitative analysis are clustered under the headings, which are the elements determined as components of the personalized production system in the theory sections. These elements are namely: Cultural Meaning, Technology, Rules & Regulations, User Practices, Artifact, Networks & Markets. Figure 5.1 demonstrates the six elements of the proposed socio-technical system, and throughout the following sections, I present the findings in this perspective.

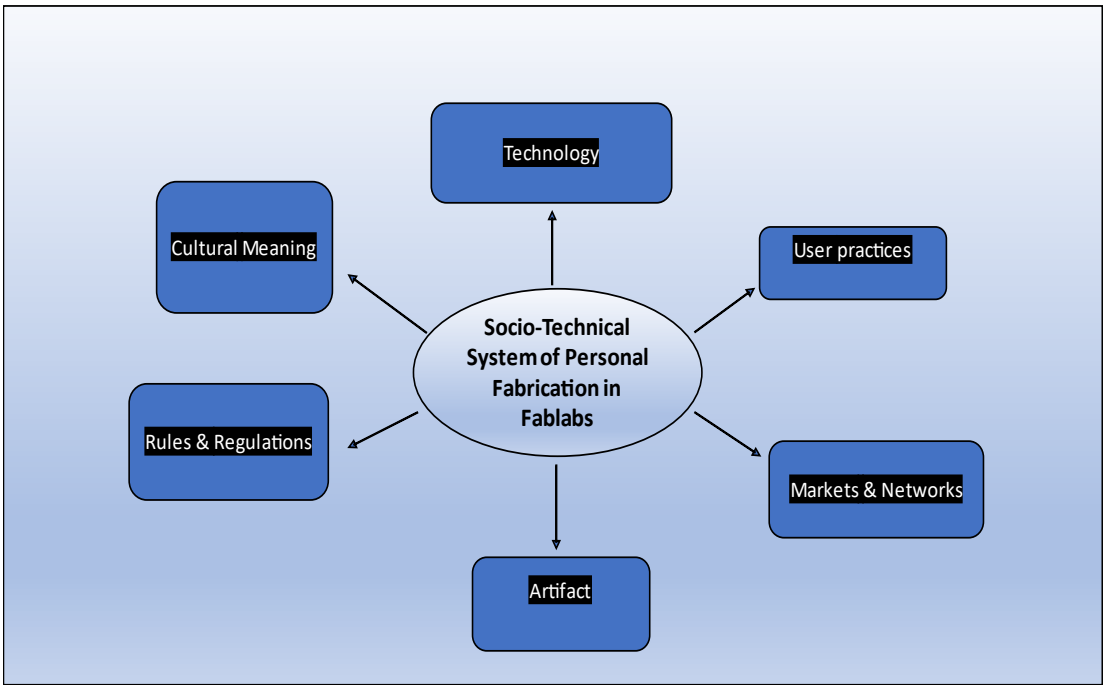

Figure 5. 1: The six elements of the personal fabrication in fablabs

Source: Author

5.1. Cultural Meaning

This element stands for the symbolic meanings, endogenous values, basic characteristics, and self-definitions that appear in fablabs. This element is placed first as a key findings section since it provides essential information for further analysis of the rest of the elements. The themes to be presented in line with the findings under this element are how they define themselves, decision-making processes, motivations of the users and founders, mission/vision of fablabs, user profiles, and inclusivity.

5.1.1. How do they define themselves?

Fablab's self-perception was surveyed in the online questionnaire. Among all other possible definitions, French fablabs define themselves as "third place" at the first place followed the definition "community", "education and formation center" and "prototyping center" accordingly. They can use other terms as well as a second and third identity. In this case, the first and second choices are swapped and with a slight difference "community" definition comes at the forefront.

Table 5. 1: How they define themselves

	third place (%)	***Community (%)***	***education and formation center (%)***	***prototyping center (%)***	***citizen laboratory (%)***	***economic development center (%)***	***Incubator (%)***	***member of international network (%)***	***arts and crafts center (%)***
first of all, we are	23,08	21,54	21,54	18,46	4,62	4,62	3,08	1,54	1,54
we are also	10,77	20,00	13,85	21,54	16,92	7,69	4,62	0,00	1,54
and also	19,35	12,90	11,29	9,68%	12,90	8,06	1,61	12,90	3,23

The data provided in Table 5.1 shows that the French fablabs see themselves as third place at first. The self-definition of "community" is followed by "education and formation center "and "prototyping center". The percentage weight in these first four definitions is sustained as their second and third choices. This data is consistent and meaningful regarding the theoretical fundamentals of grassroots innovation movements where the third sector and community spirit are at the forefront. The ratio of the definition "arts and crafts" center comes at the end, although fablabs are digital fabrication workshops where many craftsmen participate. A remarkable result is the low rates of "being a member of international network" for French fablabs. This finding validates the previous literature on French fablabs mentioning the introverted character of French fablabs in international networking. It seems that this is still the situation.

In addition to quantitative data on "Definition", some interviewees also expressed their opinions on the theme. For instance, I2 said that:

> *It is an atelier (a workshop) about experimentation and appropriation. About taking hands-on technology. In the fablab, some people do things; they make things with their own hands. But they also socialize a lot. And we try to work more on social innovation than technological innovation*.

For the community spirit, the mention of I10 can be given as: *"I think that is the strongest thing here. A small co-working space. Here everyone knows everyone. And everyone likes everyone. So, we have some special times where we have dinners together. We are all friends"*. The traces of social relations can be found in these narratives, which validates the grassroots aspects of fablabs.

5.1.2. Governance

Grassroots communities are democratic environments where community members contribute to the decision-making process in a collaborative manner. According to the findings, the governance and decision-making processes in French fablabs vary per legal status[2]. For the ones with the private company status, the management board mainly consists of founders who are responsible and accountable for the critical decision taken. Nevertheless, there is still a democratic environment for the fablab staff and community to voice the management board about their preferences and expectations. The comments of I6 can be instantiated here.

> *Here, it is very top-down. The co-founder is building a company, and so most of the time they decide, but in another way, … my colleague and I – who are the fablab managers – are very free in dealing with the space, the choices*.

I9 also stated that *"it started as a private company, because of investment, and so on... but the decision-making is on a democratic model"* as a supportive comment for the evidence of open channels for negotiating and governance.

For the community-led fablabs, legal status can be either a company or non-profit, subject to laws enforcing them to establish management boards to be accountable to the community and the government. In this modality, the governance is even more

[2] For the legal status of the interviewed labs please refer to Table 4.2 and 4.3.

participatory, that the community members can be a part of the management board on a rotation-based system. Evidence of the participation is in I8's statement:

> *We represent them. They listen to us because...We propose, and the management board decides on the basis of activity and the rentability of the activity. If our needs go in the same direction of the social project on the neighborhood, for example, they are ready to finance some projects*.

I10 also stated that; *"At the general meeting we elect the board of directors, it is composed of a maximum of 8 persons for now. So, they are all elected".* I15 mentioned the importance of the well-established community on inclusive governance when asked whether their members participate in the decision-making process: *"Not exactly, because we are too young and we do not have a strong community just as other fablabs build on the community. We are built turned upside down. So, we have to build a community to make it possible".*

For the ones hosted in universities, fablab staff has a realm of authority for the daily operations; however, they are subordinate to the manager of administrative units to which they are affiliated. It is not usual for them to cooperate with grassroots fablabs if the lab manager does not have a specific interest and persuasive ability over the superiors. I3 has epitomized that situation as *"*I*t is 'bottom-up' inside 'top-down'. A good solution. But with the comfort of money"*.

There is one example of a public fablab in our interview group. Legal-wise, its situation is similar to university-led fablabs; however, the fablab management team has a far better sufficient budget for operations, well-defined authority, and privilege to cooperate with any type of fablab as long as they consider appropriate. I2 commented on the situation as *"There is a big organigram. Totally more than 1000 people. In fablab we are 15. We have a bit of autonomy on how we work on everyday life, but the main axes are part of a more global strategy"*.

5.1.3. Motivations of users to participate

The motivations of the users for their participation in fablab are surveyed during the interviews. The derived codes from respondents' answers are as follows: Access to fabrication tools, discover digital fabrication, knowledge sharing, research, vocational

training, having place/desk to work, community spirit, and matchmaking. According to the analysis presented below, there are both economic and social concerns for participating in fablabs. The variety in motivations is presented via the following quotations.

I2 mentions that, as fablab managers, they do not highlight any specific motivation not to reduce the inclusivity of the target group:

> *For testing, experimenting, but it is not for production. We do not prioritize any use of the fablab. If you want to do a little present for your mother, or if you want to prototype something for your business, we do not make any reservation.*

Social ties, feeling like a community member, sharing experiences, social-vise and professional-vise can be user motivations that I6 mentions*:*

> *In a way, it is also an atelier, for the people who have access to the place. I have friends in here. I spend two hours, three hours more than my work time here. Because we are doing board games, having beers, and I think that's the case, maybe not for most people, but a lot of people here that they are here not only as a workplace but also something more. And mainly people came here at first because it's not so far from their place, and there are the machines, which at first are the most important thing, and in the end why people leave, and why they don't leave mainly, is because of the community. So, if people don't feel it with the place, they just leave. If the business doesn't work for them, they leave. But mainly people stay because there are a lot of people around, they make connections and friends, they make business. Some opportunities...*

Although access to equipment is the significant reason to participate in the workshops, this participation may initiate via personal ties as I5 stated: *"We know them, through the network, the personal one, and once you have a space, an interesting one, where they have many machines and accessible machines, so this is great for them"*. Once users become a part of the community, they also make use of the social network gained via fablab for professional purposes. I9 commented on that aspect as such:

> *They need space, machines. They need space where they can cut, make a lot of things. But there is also another part. It is a space where they can meet other people. Talk about their projects. Maybe find someone who can help them. On the work side, on the economic side*.

I9 added commentary on the professional side of motivation as:

> *We give them access to the space, to tools, to develop their own projects, to try and make money. ..... Use also this tool to develop something you care about; you really want to work on. So that they appropriate the place for themselves*.

Formation and education activities are natural in fablabs as presented in the literature survey, and the findings are supported accordingly. I3 replied when asked about the motivation of users: *"There are many reasons. There is the education aspect. There is the vocational training aspect. There is the research approach. There is support to research. There is the community development"*.

As shown above, users are mainly motivated by the opportunity of accessing the equipment which is made reachable to them via fablabs. This opportunity is utilized for both the economic or social desires of the users, and fablab managers give room for them to behave freely. This accessibility will further be mentioned in the following sections regarding the affordability dimension, as well.

5.1.4. Missions and vision of fablab

The mission and vision concepts are closely related to the former concept of motivations of users. What the fablab supplies meet the expectations and requirements of its community. The surveyed fablabs asked whether they have a specific vision or mission. There are cases that the finding of this question overlapped with the user motivations. For example, I9 commented on their mission as such: *"Our job is to link people with each other"* where he highlights the *matchmaking* concept, which is also mentioned in the previous section.

Other concepts also appear by scanning the data on mission and vision such as social inclusion, spreading the scientific culture, openly making, training and digital literacy, sustainability, social innovation, and serving the neighborhood. Ensuring social inclusion and solidarity are seen as primary missions by most of the surveyed fablabs with various aspects, therefore, is elaborated further in the following sections.

Openness is salient in mission manifestations as expected due to the philosophy and common charter of the international fablab network. I1 commented on how 'open'

they are as *"The idea with the … Lab is that everyone prototypes in the center, in front of everybody. So, there are no hidden projects here; because it is an open lab, you must share documents. That is the idea"*. I9 supported the concept by mentioning: *"And also for everyone the idea is to open the space, to share their knowledge. And how to use the tools and so on. A space to democratize these tools and this new economy, and so on"*.

Sustainability appeared few amongst the vision manifests; however, I will get into this notion and how it is comprehensively embedded in fablabs missions in the upcoming sessions. As an example of sustainability as a significant aspect of the fablab's vision by I5 as:

> *A big house, with creative people who are aware of the environment, climate, and consequences of each action they are doing, but we are not fighting with them to check, produce. No, we are really focused on having qualitative production in a sustainable way, with upcycling, using various materials that we throw, really naturally.*

The importance of locality and acting with the neighborhood is mentioned in some cases as happened with I8: *"So our philosophy is solidarity and social engagement, with the neighborhood – the neighborhood because we are in the neighborhood and we are in connection with local actors, but we would like to do this on a larger scale"*. I10 gave a supportive comment for the locality as well: *"We try to be really close with the neighbors. Even though it's not working that well, because it's always hard to get yourself known in your neighborhood. I think lots of people here are attached to that location"*.

The public Fablab I2 mentions digital literacy and spreading scientific knowledge: *"This is a fablab firstly was a place to train, to work on digital literacy"*. I2 mentioned that the goal of the public organization that they are affiliated to is *"Spreading the scientific culture. And we think that the thing that we do at the fablab is a way to approach scientific culture".* He further elaborated this notion: *"We try to work more on social innovation than technological"*.

5.1.5. Social Inclusion and Solidarity

Social inclusion is quite salient in fablabs surveyed. I revealed the following findings when I surveyed the gender dimension of this concept. There are very few female fablab managers in France and Belgium. Out of 15 interviewees, only three fablab managers were female. I observed that male percentage is also higher in the user profile. The situation is mentioned by I15 -who is one of the female fablab managers- as:

> *It is the main profile that the white guy with a diploma, you know, typically fab lab. It actually has to be open to everybody if you want to innovate on the socio aspect of the environment. So that is our mission, I guess*.

The deputy of this fablab is also a female. When asked whether this is a specific choice, I15 replies as:

> *No, it is absolutely not a choice. But it happened that way. And actually, it is a lucky thing, because as I said, the wonderful mission is to be as open as possible and to see two women here. It's something that helps people about that thing because they think if she can if she can work with this milling machine, they can do it also. It is also easier for women to come in, but also to any kind of minority if you are breaking this white guy and mastering thing*.

I11, a manager of a fablab located in the poorer region of Brussels and which specifically targets children, mentions the social inclusion in the fablab as such:

> *We have kids from everywhere. So, some kids from our neighborhood. And it is not the rich advantage. We got other kids from another city (region). So, it is a mix of social class, and also it is a mix between girls and boys because it is two boys for one girl now*.

The surveyed fablabs have been specifically asked whether they target vulnerable groups or minorities. The following type of groups was mentioned during the survey, either as specially targeted groups or the ones with which the fablab has at least one collaborative project or work:

- Elderly people
- Handicapped
- Homeless people
- Refugees/ Asylum seekers
- Less educated people
- Unemployed

- School children from low-income families

For example, I2 states on their project designed specifically for disabled people:

> *It is a super project that we host at the ..... We try to make some young people meet some people who have a handicap, and the goal is to try to make all these young people try to find a solution for the everyday problems of these people…*

I9 mentions a collaborative project where they undertake an essential role as a fablab as such:

> *We are involved in this project since three years. And you know it is a 3-month program. As a fablab, we give access to the tools, and then we share knowledge about how to design, how to prototype and how to produce... This program is to connect teenagers with disabled people*.

Combining this with his previous example, I9 also presents another example: "*It is a construction project made with a company... and it's fully made in wood, housing for people seeking asylum*".

I12 provided an example on their project supported by EU Regional Development Fund (ERDF) targeting social cohesion as such: *"So we have a neighborhood. In the summer we have a summer school. So, it is five weeks and 100 euros per topic. It can be free if you are a job seeker … The Feder (ERDF) supports this"*. I8's example is similar to the previous:

> *We at the Fablab create what we call a "Parcours de demandeur d'emploi" (path for jobseekers), it is a series of "ateliers" for unemployed people or young people. "Parcours de jeunesse" (path for youth), and "parcours de demandeur d'emploi". For young people, it is six times two hours on for example construction of a garden, a big place for plants and flowers. It is fully documented, and it is linked to development*.

I9 makes an attention-grabbing contribution on the possibilities of fablabs' interaction with socially vulnerable people:

> *With the fablab, we made some workshops, some meet-ups, open to everyone to raise awareness about what we are making here. But in more concrete terms, we welcome for example, l'Armée du Salut*[3]*, Emmaus*[4] *(they have a refugee*

[3] L'Armée du Salut: Army of Salvation is an international humanitarian organization.

[4] Emmaus: Is an international solidarity movement targeting homeless people

center on the other side of the Place des Fêtes), and they already came here to make food for people. We also welcome the association …… – people who have been on the streets came here for some nights to sleep here in these meeting rooms.

I4, one of the managers of university-hosted fablabs, gave an example of a collaboration project implemented for elders:

> *For example, we had a project with ENSAD (National Applied Decorative Arts School), it is a Ph.D. And these are projects for elderly people... to calm down these persons, they built a small concept and created a thesis about it. It is a thing with music*.

The rich social dimension accompanying the digital printing workshops is salient within the fablabs surveyed. It is a question of concern whether it is specific to the country context or not. I5 mentioned that: *"In France, we have this open-minded vision, this social vision, and this is really important toda*y*"*. This vision has its origins in the networks founded far before the establishment of fablabs. When I asked why fablabs in France is denser compared to the other countries in Europe, I9 replied as such:

> *We have this density of fablabs in France, it is more about – since a lot of time, we always have a lot of organizations, people joining each other to co-create, to share about robotics, or... "L'épais Brouillard", it is an organization, a big one, they exist. A long time before the beginning of fablabs. So, it is already existing*.

The examples of social and solidarity work throughout the survey were quite salient, as can be traced by the examples presented above. Regardless of their typology (whether be grassroots or not), the majority of the fablab managers have specifically emphasized social work as an inseparable concept within fablabs and their communities. This concept is also an essential pillar in the sustainability context and UN 2030 agenda, which I will be examining in detail in the following sections.

5.1.6. User Profiles

Information on user profiles are gathered via qualitative analysis. There is an embracive variety in the user profiles of surveyed fablabs. From the qualitative analysis, the following profiles are identified: entrepreneurs, students, youth, designers, school children, artisans, engineers, architects, artists, doctoral students,

farmers, graphic artists, landscape gardeners, and start-ups. This finding aligns with the literature review on grassroots innovations and digital fabrication workshops, mentioning the GI and fablabs are targeting citizens from any background without taking expertise as a prerequisite.

Grassroots fablabs have more comprehensive user profiles compared to other types — even youth and school children. I7 mentioned that they only target children: *"No professionals. Only we are serving for the children"*. I9 complemented this situation as they usually serve professionals but have explicitly targeting school children on weekends. On the other hand, the university-hosted fablabs have doctoral students, researchers inside their target groups. Specialized fablabs may have specific target groups such as farmers, architects, artists. I4 gives an example on the entrepreneurial side of the user profile: *"And sometimes we help some start-ups to create, not a product, but a prototype, but not just a prototype, it is more tangible..."*. I6, as a private fablab manager, stated that:

> *This place was built, created in 2012. It is almost eight years. It was after the co-founder, realized there were a lot of craftsmen in ...., which is one of the biggest cities in terms of craftsmen and artists in France, and so she decided to create a place for them.*

I14 which is also a private fablab draws a similar view: *"And today more and more entrepreneur, analysts, and architects are now more. The proportion of craftsmen is much bigger"*. I12 mentioned their primary target group as an example of diversity in the user profiles: *"In the beginning, it was really a place for artists. So, presenting a particular artwork".*

The vulnerable groups or minorities analyzed in the previous section can also be accepted as a user profile since they benefit the facilities of fablabs. The mentioned professions, people from any age, background, and social class are also validating findings for the inclusivity and openness of the fablabs.

As a result of the quantitative and qualitative analysis, I presented the themes related to the first element (i.e., Cultural Meaning) above. According to that, the fablabs in our sampling see themselves as third places and community before the workshop

notion, which signals their social and political attitude. Neighborhoods and communities are the social capital on which they construct the spaces and contribute to local issues. These extensive examples demonstrate that the fablab community creates a social value by executing projects for minorities and vulnerable groups, as well as they aim to welcome variety in their user profile. While doing this, they respect the expectations of users, which are mainly: accessing the equipment, receiving training on digital printing technologies, and prototyping their personal projects. Their prominent missions are providing accessibility and promoting the technologies housed in combination with solidarity work, and they have a solid commitment to those missions.

5.2. Technology

This element indicates the novel technology(s) that causes niche innovations to occur and accumulate in time. It is the additive manufacturing and desktop 3-D printing technological revolution that opens a new path for fablabs. The equipment related to this revolution is already presented in the literature survey, and fablabs declare their equipment pool on their web pages. Therefore, in the qualitative analysis, I surveyed how this technology is utilized in specific fields and traced the capabilities of the technology regarding sustainability. In line with this approach, the following themes are presented under this element: “field of expertise” (including device types, workshop types, and specific themes) and “3-D printing technologies and sustainability”.

5.2.1. Field of Expertise

With the online questionnaire, the French fablabs are surveyed to see whether they have a specific field of expertise. As presented in Figure 5.2 below, “Digitalization” is the leading field of expertise, followed by “Education/Formation” for the France case.

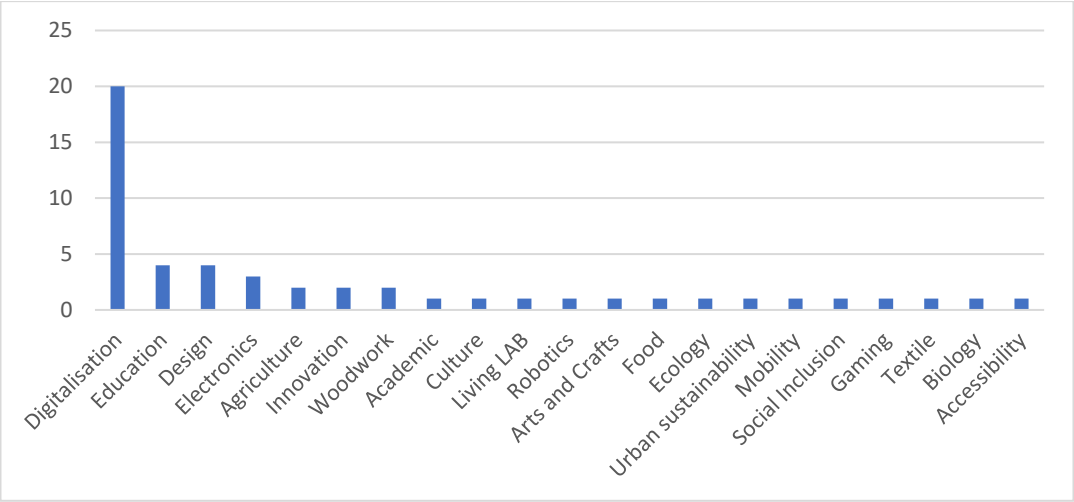

Figure 5. 2: Field of Specialization

This finding is elaborated further during the interviews, and the interviewees were asked about the equipment they possess within fablabs. I observed during the visits that devices are located according to their purpose of use, and for many cases, workshops are defined as units of fablabs in accordance with that equipment pool.

The fablab, which I6 is a fablab manager, is a typical example of this. This lab is designed under an innovation center of a university; therefore, the situation is defined by him as: *"We have six labs; I show you each one. It is a lab. For now, we are six fab managers…"*. During the visit, he showed those six labs in relevance with the equipment, which are bio lab (biology laboratory for breeding and agriculture), media lab (photography, graphics design, virtual reality), electro lab (PCB-printed circuit board design, electronics equipment), meca lab (mechanical work and wood workshop), data lab (digital design, 3-D conception). Those six workshops are complementary to each other. However, if a user builds a private project which she/he does not prefer to share openly, he uses private workshops. Any project implemented in this fablab is documented and shared open source. Users can benefit from all the workshops to implement an open project. In this model, it is possible to mention the expertise in the fields.

I7, which runs a relatively small fablab, mentions the role of specialization as such: *"Do they only come from this neighborhood? No, they come from everywhere. We have people from Ile de France from afar because we offer robotics workshops that cannot be found anywhere. And at a cheap price"*. When I asked whether they have any field of specialization as a fablab established under an engineering faculty, I4 mentioned that they are active in so many fields; however, provided an example on the partner university fablabs stating that: *"X... Lab, this school is oriented towards logistics and more mechanical systems. For example, Y... lab oriented towards astronomy, and they create Fusées(rockets)".*

Referring to their website, I5 is asked whether they are specialized in textile; she said: *"Yes, textile and design. They come here because we are the first ones who are really into this textile design case"*. I12 highlights the artistic work that can take place in the fablab: *"So for example, when you have some artist residency here, and further their artists were invited in the residency to produce their work. It was shown in an exhibition about how you see contemporary art"*.

Apart from the fields derived from the questionnaire, software programming, robotics, pedagogy, logistics, mechanics, embroidery, astronomy, and urban agriculture are mentioned during the interviews.

Fablabs declare their equipment pool on their websites, but sometimes it may not be up-to-date information. The following devices are also mentioned during the visits: Vinyl cutter, textile machines, 3-D embroidery and quilting machines, CNC (3-axes or 5-axes), milling machine, ink printers.

5.2.2. 3-D Printing Technologies and Sustainability

It was mentioned in Section 2.3.3 that there is an ongoing debate on the impacts of digital printing technologies and sustainability. During the interviews, I surveyed this issue to understand the ecological impact of digital printing. The findings of the qualitative analysis indicate that the fablab managers are concerned about the effects of the digital printing technologies and are not fully convinced or satisfied that those technologies are environmentally friendly. It is the small scale of production serving

sustainability rather than the technology utilized, according to many fablab managers. Here the main issue is the raw material, which is supplied as fused filament and can either be made of petroleum such as ABS (Acrylonitrile Butadiene Styrene) or biodegradable materials such as PLA (polylactic acid).

I6 provided a comprehensive explanation on the issue since he has searched and tested many types of raw material before:

> *The problem is for the plastic, because if you test for the plastic with halogen, for example, PVC, polyvinyl chloride, when the laser burns the plastic, gas is given off, with chlorine, and the chlorine is not good for the lungs. And the chlorine can react with the water in the air, and it becomes hydrochloric acid, which is not good for the machine too. So, it is forbidden to use PVC or halogenated plastics. That is why we use polycarbonate or PMMA (Acrylic). But there are some vapors too, it is not good for health. I participated to the MDF (medium-density fiberboard) workshop. Because you use wood fiber, and you use many formaldehyde resins. It is petrochemical, it is not really good for health... and I take part in many colloquiums, and I read many papers about the quality of the air in fablabs. An example of health concerns: in the first year of the fablab, we use a plastic called ABS. And styrene is not good for the health because there are many vapors, and micro-particles. And PET is the same – like the Volvic*[5] *bottle – or we use corn starch PLA (polylactic acid). We use mainly PLA acid instead of ABS because it is well-known that ABS is not good....*

The PLA choice over ABS is mentioned by other lab managers too, with an additional mention to the technical requirements ensured in the fablab environment. For example, I8 stated that:

> *3-D printings, especially printings, could be not really ecological. Because... the raw material is ecological, because it's from corn. So you can reuse it, you can compost. We don't use petroleum because we can't guarantee to the public a good condition of utilization. We don't have closed machines. And we have an instruction system but not that material like material from oil. It requires a more protected environment. We don't like, and we don't need because this one is used a lot for industrial prototyping. So, your products need to be really strong. We don't need this.*

I6, who also uses PLA filaments, gave a pessimistic opinion on the PLA side too by saying that: *"At first, I was very happy to know PLA is from a renewable source, and that it could be recycled. But as time goes by, I have come to understand that there is*

[5] Volvic is a brand of packaged mineral water

no real way to recycle it" with an implication on the inadequacy of the current technology and the cost-effectiveness.

The findings presented in this section reveal that off-the-shelf consumables of the 3-D printers are not ecology friendly today. Moreover, precautions need to be taken by the fablab managers to eliminate the possible hazardous effects for the users and the environment.

5.3. Rules & Regulations

This element indicates any legislative initiative catalyzing a transition to sustainability. Countries adopt several legislations on environmental sustainability. In this research, I utilized the UN 2030 Agenda, including the 17 SDGs, as a framework to understand the sustainability notion and contribution that take place in the fablabs. I chose the UN SDGs framework due to its convenience and structured categorization in the questionnaire and interviews with the respondents. The findings in this section are presented in line with this framework.

5.3.1. Perception of Sustainability and UN SDG Agenda

According to the interview data and observations, unexceptionally, all the fablab managers are susceptible to sustainability issues, except from one case working only with children under the age of sixteen who took the formation notion as a locus. Even if a user does not come with this awareness on sustainability into fablab, the fablab managers try to control the desire for digital printing of unnecessary objects as I2 mentioned: *"their little figure, their little hero, their little object"*, which the user do not really need and make use of.

Nevertheless, despite this explicit sensitivity when talked about the UN SDG framework, they always took time to view the SDG headings, which some find crowded and mentioned as I2 did: "*I know why I know the main picture but not in details*" or "*way too many items where you do not have the intermediate object*".

When I presented the global indicator framework in detail with 230 indicators, the SDG frame was ambiguous for them. I10, for instance, expressed his comments as:

> *There seems to be a lot of overlap. It's not even overlap, it's interdependence. That's what I feel, that's what I see. And at the same time I feel it is under the table. Those are the kind of problems you cannot solve. But you have to do something. You cannot find the right entry point. So, I think it's a good thing that it's really large*.

According to my observations during the visits, the titles of the goals define themselves successfully for an ordinary citizen, rather than reading the sub-indicator list. I9 put a great emphasis when asked about the UN SDG agenda as:

> *An alternative place, where we already have all these themes, which are in fact part of the identity of the place and the activities that we carry, that we also endorse, that we welcome. For example, we will more easily welcome an organization that promotes new methods of food preservation, for example, than a huge storage company ... There is already a very strong sensitivity to all these issues. What is causing climate change? We try to answer it ourselves by consuming locally*.

I1 draws attention to the obstacles on the assessment of the SDGs agenda, stating that:

> *It is always difficult to measure something, especially if it is not objective. If I take an extreme example: to talk about male/female equality, in Europe it's a certain discussion, I'm sure that in other countries it doesn't mean the same. We can improve it in all countries, but if you go to Sweden of course it's better than in France, if I take a dictator in Africa, it's not the same question. So, I think the idea is good, but the application all over the world should be different*.

I3 had a supportive declaration on the assessment issue, saying that: *"They are limited by their definition. We need to go beyond. It won't be easy. I think there is a lack of assessment. And leadership on how to assess. And self-assess... Alignment between the practice..."*. I3 was solely working on raising awareness on SDGs and try to align the fablab with SDGs agenda had the most significant concerns on the general perception of sustainability issue in France and worldwide. He (I3) also noted the following quote:

> *My experience, with or without the fablabs, is that in France, when you start to talk about environmental issues and so on, it's an issue, but there are many others. It's diluted. I don't want to discourage people who are really concerned, but it's like the modern way of approaching an issue. Like you split it into parts. No, it's going to be easier to manage. But people don't have a systemic view. That's what I don't like. If I don't connect things together, if I don't have a systemic approach, then I'm almost useless. That's my point*.

He defends the idea that, either people or institutions should interiorize the sustainability concept in all aspects of life as an integral approach. Indeed, I observed

that among the interviewed fablabs that there is an auto-control or tacit agreement between the fablab managers and users to think about ecology and sustainability as an indigenous aspect of their activity. Fablab managers take the initiative to convince the users to be more sensitive on the matter. For instance, I1 states:

> *You can think about what you are doing. Like the first page: is it really worth to make it? That one is: can you reduce the plastic content? There it is more like: if it's to repair the device, of course you can use plastic. But it's kind of simple guidelines...*

When asked on that issue whether they have written or unwritten rules to put sustainability at the front I9 replied as: *"It's not written. If you don't respect the unwritten rules, you can come here. But when we discuss about the project, it's always like maybe you could do it this way"*. A pro-argument from I8 is as follows:

> *We try to say to our users: Before you think to buy something, think if you can reuse. Before this, think if you really need to do this, and do this in this way. And then if you really need, we can think to reuse something*.

None of the fablabs interviewed made a formal self-assessment or alignment study with the UN SDG framework -or other conceptual patterns- to set forth a sustainability policy or an agenda. However, that does not mean that it is a fictitious concept. As presented in the flowing sections with several practices and projects, the surveyed fablabs contribute to sustainability.

5.3.2. Contribution to SDGs

Firstly, to understand the contribution role of fablabs to sustainability, I utilized quantitative analysis via the online questionnaire in the first place. The French fablabs were surveyed whether they have tangible projects and outcomes regarding sustainability and asked them to relate these projects with three SDGs.

According to the results obtained from the questionnaire, French fablabs contribute to "SDG No 12: Responsible Consumption and Production" with %19.70 most, followed by "SDG No 4: Quality Education".

Table 5. 2: The percentages of contribution to each SDG

No	*Name*	*Percentage (%)*
1	SDG 12: Responsible Consumption and Production	19,70
2	SDG 4: Quality Education	10,61
3	SDG 11: Sustainable Cities and Communities	9,85
4	SDG 9: Industry, Innovation, and Infrastructure	8,33
5	SDG7: Affordable and Clean Energy	7,58
6	SDG 8: Decent Work and Economic Growth	6,82
7	SDG 10: Reduced Inequality	6,82
8	SDG 15: Life on Land	6,82
9	SDG 3: Good Health and Well-being	5,30
10	SDG 13: Climate Action	4,55
11	SDG 17: Partnerships to achieve the Goal	3,79
12	SDG 5 Gender Equality	3,03
13	SDG 2: Zero Hunger	2,27
14	SDG 14: Life Below Water	2,27
15	SDG 6: Clean Water and Sanitation	1,52
16	SDG 1: No Poverty	0,76
17	SDG 16: Peace and Justice Strong Institutions	0,00
	Total of Projects	100,00

When re-presented in Carl Folke's wedding cake model[6]; the results show us that the leading contribution dimension is the economic dimension followed by the social dimension. The projects contributing to the ecological dimension of the sustainable development goals are %15,16 considerably low when compared to the precedent two. The 17th goal on Partnership for the Goals is only %3,79.

[6] Carl Folke has developed the wedding cake model and grouped the SDGs o see from three different perspectives.
https://www.stockholmresilience.org/research/research-news/2016-06-14-how-food-connects-all-the-sdgs.html

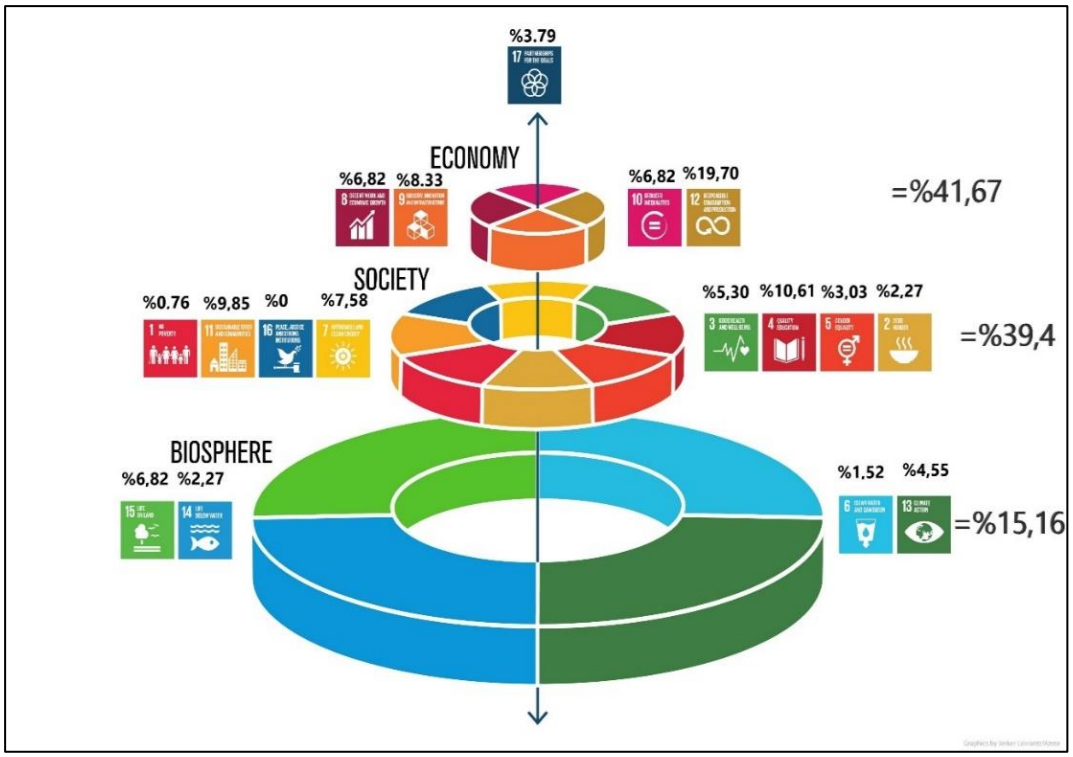

Figure 5. 3: Re-distribution of SDG contribution on wedding cake model

Apart from the quantitative data, according to qualitative analysis, SDG 8-Decent Work was followed by SDG 12- Responsible Consumption and Production, SDG 4-Quality Education, and SDG 10- Reduced Inequality simultaneously mentioned by the fablab managers in the interviews. For SDG 8 contribution, they mentioned activities such as: Organizing massive open courses for job seekers, vocational training for all target groups, efforts for enhancing digital literacy for all age groups. I4 provided an example of that by stating: *"For example, in economic growth and decent work, we welcome in the frame of MOOC (massive open courses), some job seekers"*.

Although they contribute to SDG No:8 Decent work through their services provided, when asked about their own working conditions and payment regimes, excluding the publicly funded fablabs, they mentioned the frailness of their conditions. For instance, I9 said: *"We do not pay enough, because we cannot"*. I10 supported this situation as:

> *We are offering decent work and decent work conditions, though sometimes it's hard. But we have a hard time offering a decent salary. I think that's the*

part where we can't say we offer decent work. We are not paying everyone what they deserve, in my opinion. Although we are paying what we can.

I8's statement was in the same direction: *"There is a staff turnover because they are exhausted, they are not well paid"* validating the fragility of human resurces within fablabs.

5.3.3. Factors Affecting the Level of Contribution

The qualitative analysis reveals that fablabs operating with public funding support have more freedom for acting socially responsible. The dichotomy of being for-profit or non-profit becomes apparent at this point. During the interviews, I asked the fablab managers whether the business modality affects their contribution to sustainability. Some refrained from answering the question mentioning that they do not have an idea. The majority of the fablab managers (including profit-making ones) declared that they believe that non-profit fablabs have a better potential for sustainable contributions. Even though they have more number users, private fablabs operate in a more closed circuit and rarely cooperate with the others. I3 has commented on this factor by saying: *"With the private sector, the fact of producing something for money, basically we bring someone just to see in principle sometimes. Just for need. And it's hard. It's not our case. We don't have to do that"*. When challenged on the possibility of a corporate organization to act socially responsible, he then answered: *"There is always that suspicion of greenwashing*[7]*, social washing"*.

The fablabs, which do not have financial concerns, such as those supported by associations or local or federal governments, have more freedom to design and implement projects and initiatives on sustainability. On the other hand, the fablabs who deal with "financial sustainability" allocate less time and effort to align themselves with the UN SDG agenda. I2, who is public fablab manager, argued the issue as:

> *I think that our business model has to be more flexible for some things, and so we mainly focus not on rentability (profitability) but really on our social goals,*

[7] Greenwashing: Behavior or activities that make people believe that a company is doing more to protect the environment than it really is. Source: Cambridge English Dictionary

> *in a general way, not on economics. Even if we lose money, we do not really care because that is not our goal. We have a public objective.*

The fablabs surveyed often seek public funding through calls for project proposals whenever available. The content of these calls directly affects their projects, and therefore their sustainability contributions. Among the surveyed fablabs, it was my observation that the Belgian fablabs have a specific awareness of EU funding provided via regional administration bodies while not any French fablabs mentioned explicitly it. Out of five fablabs surveyed in Belgium, all of them said that they had benefited from the social cohesion fundings from EU Regional Development Funding (ERDF) which they named "Feder" either when starting the fablab or during their lifetime.

I11 talked about this subsidy stating that it facilitated the opening of their fablab: "*So young to say because it is only four years now. I think it's special for fablab, it's for kids. It's a feder, for the European project and it's so last year now. So now they want us to continue".* I12 added a similar contribution: *"So I talk about feder. So, in 2016. We received the feder fund on social cohesion because we are in Moleenbeek*[8]". I13 said the following while explaining how the fablab started:

> *This is a program financed by a part of the commune, embarked on from the region and big bounce from European Union, I don't know, it's really kind of a feder or something, but it's a program for, say, seven years and then tried to separate support and develop activities in a specific neighborhood.*

I14 has not personally benefited public funding; however, it rents the place at a cheaper tariff due to the same funding provided to the landowner, which is a public institution itself:

> *We almost do not have any subsidies. But we received a little grant in the process of becoming a cooperative, a grant. ……the place is being renovated and acquired by the owner under a feder grant. but thanks to the…. The rent is lower than the market price too. So indirectly, we benefit from the feder. But we have no relation with the feder.*

[8] Molenbeek is one of the 19 municipalities in Brussels-Capital-Region, some parts of which are under gentrification

And I15 supported the role of funding to start the fablab by stating*: "At first this fablab obviously I won as a public fablab, etc. it's a center. It's really fully public. So, it means all the financial aspects are as subsidies from the federal"*.

There are relatively few findings on the effect of other legislations, one of which is I1's comment on the regulations regarding agriculture:

> *European condition force to reduce pesticides. So, they have no choice now; they know it. They have to evolve that way. And so, with our goals and culture, we try to improve it that way. So, for us it is normal*.

The other contribution was I3's statement informing on the new legislation in France:

> They *are going to have to. There are loads coming. You know, in France, in September, they voted laws for the circular economy. And companies are disappointed. Some of them. If you take ….(the brand name). Where they do not assemble computers, they cannot recycle themselves. Because they don't have the facilities. This is an issue for them. They have sold it. And they are really listening to what is possible. This is one of the many examples, I think. There is a way. It is up to us to take it on board*.

The findings on the Rules and Regulations element are presented via the UN SDG framework. When re-presented in Carl Folke's wedding cake model, it was the economic pillar where the French fablabs contributed most. On the other hand, the narratives compiled from interviews (presented up to now) highlights the social contribution more than the economic. This notion might be because "SDG 10: Reducing Inequalities" is accepted as an economic pillar in Carl Folke's model, where the surveyed fablabs perceive the subject goal as a social concept. Most fablab managers interviewed do not keep up with the national or international policy agenda but rather seek public funding to sustain the place. Therefore, public funding schemes directly affect the content of their projects, such as social cohesion.

5.4. User Practices

The fourth element is the user practices that imply the custom patterns and procedures that users have. Under this element, the fablabs surveyed what kind of practices they have in a daily routine within the fablab. In that sense, the qualitative analysis provided detailed information on the concept. The themes derived are: Skills building,

documenting, responsible consumption, and production practices, including repairing, reusing, recycling-upcycling, and waste management.

5.4.1. Skills Building

Building skills is closely related to the grassroots empowerment concept presented in Chapter 2. Building skills ensure gaining legitimacy in the community, which is indigenous to grassroots ingenuity and empowerment. During the interviews, I observed that fablab managers and users try to gain experience on the technology in a collective learning environment. Getting acquainted with the equipment and the materials, learning by doing, disassembling and reassembling the equipment, handling the maintenance by the human resource within fablab instead of outsourcing, documenting the projects to codify the knowledge, and training the trainers are the skills determined by the quantitative analysis.

According to that, many fablabs assemble and program desktop 3-D printers themselves. The international fablab community has rich literature and documentation on this technology. This richness also enables the maintenance of much equipment by themselves without support from producers or vendors.

For self-production of desktop printers with a trial-and-error approach, I10 gave this example:

> *Here we have machines: so, 3-D printers. What is interesting is that they were developed by a friend of ours—called DOOD (Digital Object on Demand). And so those are the early prototypes. Now there are lots of problems with them*.

I3 commented on the concept as such:

> *I can give you part of the intentions of... the root of the Fablab network is that we don't buy anymore... we won't be buying any more from vendors. Laser cutters, like that... Some of us, like me, but doing something else, are working on machines we can make in Fablab that are the equivalent of that one. And for probably less than half of the price. A machine that makes a machine, we call it MTM. There are even the students – like Neil Gerchenfield's students – are working on that*.

An example of the maintenance skills is the following statement of I1:

> *It is part of the natural way of learning stuff. Like we are doing in the west. In the rest of the world, I think in the fablab world, yes, because it is a response to some fantasy. Like you can rebuild indefinitely all the stuff. Here potentially you can build stuff, destroy it, rebuild it, it's part of the fantasy around fablabs*.

When asked whether they can intervene the machines in case of a failure, I4 replied as:

> *Yes if we have a problem on some pieces, this machine, is a reaming machine. If the sub-parts are complicated or very specific to the tools or to the machine. But for example, this machine was like this. And it was a student who modified all the fiber. And for the students, for repairing, it is do-it-yourself too.*

I5 replied to the same question in a very confident way: *"Yes. We are managing this on our own. We are doing that alone, yes"*.

The documentation is crucial for fablabs to ensure the openness, sharing, and disseminating the gained knowledge. I observed that this is a desirable thing in the surveyed fablabs; however, it is not always achieved to the full extent. For example, I6 mentioned he personally documents projects but cannot force the users stating that: *"Almost never. Most of our users are really traditional artisans. They are working. I actually use it a lot for the projects I do, but..."*. I1 is a sensitive fablab manager on the issue, even he targets to produce scientific papers on the projects: *"You can find everything on our Wiki. Because we have a lot of visits, we try to explain it. But there, you have the first version, the second version, and that's the third one, but we don't have yet a kind of paper"*. He also mentioned the reproduction of a reuse project of the other fablab: *"It is really easy, a lot of videos. It' is made in a lot of fablabs"*.

Learning by doing in a collaborative manner was already presented in citations; however, Fab Academy is a more formal version of this issue. Fab Academy is a program designed by MIT, lasting for six months, and can only be given by the verified nodes of the fablab network. There needs to be a certified fablab manager who has completed the program before. At the time of the survey, the fablab managers provided the information that there are only three nodes in France verified as Fab Academy, and it is up to the fab manager's availability to open the course in that specific year. Two of the fablab managers interviewed (I1 and I3) are nodes of Fab Academy.

This activity is very prominent for these two; hence it pioneers new nodes to start a fablab and establishes a good reputation for themselves which can be related to the empowerment concept. This empowerment is evident in I3's following statement:

> *In my understanding, coming into development, when we started here there were a few fablabs, and most of them were not – and are still not – giving Fab academy as a course. So, it's one thing to be a Fablab, but to create a community or be a part of it, is to embed the programs from the fablab network. You are a Fablab and then you are part of the community.*

I1 here mentions the importance of documentation for knowledge and skills gaining by relating it to Fab Academy:

> *We want at the beginning to show you (the user) what you can do with the device. The first idea is just a good picture of the device. And a lot of specifications, but it is not very interesting. Here the idea was to build a code on every device. So that is the code on the big CNC that we have. I can show you a little... Also, I do that thing during the fab academy, so everything is open, so it is well documented also.*

During visits and interviews, it was one of the indications that not every fablab manager sees Fab Academy as a must to be legitimate as a fablab manager. I10's statement can be evidence of this observation when I asked whether he preferred to attend the Fab Academy: "*Personally, it is thanks to the fablab that I have managed to develop my other activities, with other fablabs, like design thinking, training, working with companies... Because I know how to use those tools, to be able to create value*".

5.4.2. Responsible Consumption and Production Practices

Facilitating 3-R principles (Re-use, Re-cycle, Re-pair) is revealed as significant fablabs practices in my survey. The quantitative analysis provides rich evidence on these practices, as presented below. As I5 summarized the concept:

> *We are discussing, well first this should be maybe in their daily habits. Which means: how do you recycle fabrics? How do you see your activity inside the makers? Who is working with the 3 R's cycle, the 3 rules, that we have to use, and then we are challenging them into co-creation, new ways to collaborate with all the other ones.*

Repairing

Repairing and making long-lasting artifacts has less impact on the environment than recycling unsustainable materials, according to many fablab managers. Therefore, they train and make people responsible for what they consume and help them better choose their products to move towards more sustainable consumption. In Paris, for instance, there are regular organizations by fablabs where hundreds of people come together with objects to be fixed. Having the self-maintenance as a first choice which was mentioned in the previous section, is also a part of repairing before outsourcing. Fablabs train and make people responsible for what they consume and help them better choose their products to move towards more sustainable options. I2 gave examples of repair-café like organizations they regularly host in the following quote:

> *We host the repairing organization two or three times a year. And it's like 200 or 300 people who come with some object to repair. So that's the classical Repair Café. Also, once a week, we have some specific workshops where – when we work with people too – understand how they can make a diagnosis of some problem on the object and try to repair it. And we work with this organization also. But on this time, we try to make these people get more skills, to be able to repair things by themselves.*

I7 added a similar comment: "*We recover computers, equipment that no longer works, things like that. We repair them and put them back in service, us here*". I8 defended the repairing as an essential fundamental skill to be promoted in a fablab by stating:

> *I give you an example of this. Last week we had a boy who came with his mixer. A cooking mixer. Broken. He went to X (Electronics Department Store) and he asked, and it was 60 euros. He was here for a 'parcours de jeunesse- (youth path)'. He was one of the guys who built this one. And then when they proposed 60 euros to repair it he said: No, I go to the fablab. So, the idea: to transmit to people this kind of reflection. OK. A broken object, I can repair.*

I3 commented on how he sees the reparation in fablab as:

> *But if they can repair, they can play a role. People are using Repair Café and stuff like that. The reuse, if you can take out parts, they're going to do something else. The remanufacture. It's tricky, but you can recondition materials into bigger ones, mill it, and laser cut them. It's tricky, but it's the knowledge that will be valuable. The refurbish is the problematic one. There might be a business model opportunity if you know how to…*

There is an exception among the surveyed labs. Its fablab manager replied unfavorably to repairing by mentioning it as a choice: *"But there is also the repair cafe. And we're*

not a repair cafe, but it's not really repairing things. But we are trying to build things, answering their specific need".

It is salient in these quotes that the fablab managers see repairing as a skill on its own that requires desire, technical and material knowledge. Users build the required skills only after they play, explore, and experience the machines by cutting, milling, embroidering the sample materials, which are traditional ways of learning.

Reusing

Fablabs are seeking many ways to increase the reuse practices. First of all, there is a sort of an auto control implied by the fablab to the users for reusing materials wherever convenient. Users are guided and convinced to reuse a material before using a new bunch of raw material. There are always filament leftovers from the rolls or other raw materials, which fablab managers try to use for the next project, prototype, or production. I13 gave an example:

> *Some process to help people learn how to avoid making leftover on their own project and how to help them prepare for the next one. Now, I want to add them to help me in this process to organize it by size, maybe. And we have this policy of simple policy. Okay. If you have a project, you can use for free, all the leftovers. So, we reuse most of them and warning you to use as small as possible.*

A similar policy is mentioned by I10:

> *In fact, every time there is a project, someone buys materials, but there are always leftovers, so we store them. And we kind of say it is yours for two months. If you don't use them now, after it's for us, and we can use them to give to people. And then it really depends...What people need, huge sheets like that, there is like two of them, but if it is small parts, then we just give it to them.*

I8 explained how he and his colleagues apply auto-control for necessity and reuse by stating:

> *The rest of the laser CAD, I did not throw in the trash, but I reused them. This kind of mentality. We work for this here, and I think it works. We try to say to our users: Before you think to buy something, think if you can reuse. Before this, think if you really need to do this, and do this in this way. And then, if you really need, we can think of reusing something. If you have good practices and processes, you have good materials. If you want to reuse, if you don't buy every time, your reflection is how can we develop a process of reusing.*

Here he also implies that by practicing reuse repeatedly, users may find ways to increase the quality of reused material that might be damaged or inappropriate for reuse. I9 gave another example that they give away their material to be reused not only to their users but also to associations which can make use of it utilizing the fablab equipment:

> *They use them– it's an association in Ménilmontant, a small workshop, people can come here to make a chair, for instance, like something in wood, and they also organized a workshop with... So, they came here to take some wood, and to use it in their workshop.*

I6 contributed on the subject as such:

> *Actually, there has been one big project we have been working on, which was the remains of the civilization of the IRD (institute of research and development), so we made that using only waste and leftovers of their own. And also, I used some protective wood, which is used in transportation, and which is not of bad quality but "abimé" (damaged), so I had to manage how to get it clean and stuff.*

Both the reusing of materials and products is very prevailing in fablabs. They collect materials and goods to be reused, as well as give them away to be reused by other parties. In that sense, they are actors of a circular economy within their periphery. This practice plays an essential role on enhancing the quality of reused materials and knowledge on the lifecycle of each material utilized. Reusing also contributes to the meaning element by changing the users' perceptions by steering them to fix and reusing before buying a brand-new product.

Recycling-Upcycling

The great majority of the interviewed fablabs are practicing recycling the material scraps resulting from the implementation of other projects. They mostly reserve spaces for the storage of the materials to be recycled. These materials can be collected from donators and even the streets of neighborhoods or supermarkets. The big issue is separating and managing these "waste" to be re-used, presented extensively in the following chapter. There are reserved spaces within fablabs, big or small- depending on the facilities. For example, I5 highlighted recycling when talking about that space:

> *We have to throw what we have to throw. But all the rest we are trying to use, so we have many many storages inside here. We have 330 square meters, which*

is quite big. And in this place, we have today 10% of the space which is dedicated to storage and is separated – each element - into this recycle thing.

Another comment on recycling was made by I10, stating that: *"People making furniture out of recycled parts. Those are also faux plafonds (false ceilings); they're something they got back from other places. This is kombucha leather. These are designers who use only recycled materials. This is recycled plastic".*

I14 has a reservation on recycling issue stating that it is more critical to create long-lasting things than to recycle due to its technical burdens by this sentence:

We see often discussing with the craftsmen that ways of processing the wood and making things that last and they can be repurposed afterward. .... much more important than recycling it at first. If we take the recycling example most of the wood, we find it is shitty wood from IKEA. Actually, if we recycled, we do shitty second lives, which would be dead. The next iteration. It has much less impact than using good first and good resources first and good material at first.

Plastics is the most recycled material in the surveyed fablabs. Some of them mentioned a project called "Precious Plastic", which is an open-source device for recycling regular plastics. I2 declared his idea on the importance of recycling:

That is the main part of our job. Facilitation. Exactly. So, I was talking about repairing, but also we have been doing a lot of things about recycling plastics. Different kinds of recycling plastics. For example, we have been doing some workshops where we just take some plastic bags and make them stick together, and after we use it like some textile.

I8 produced a precious plastic in his fablab and showed during the visit:

I think the project we have most connected with this is the project of precious plastic. It is linked to resilience and recycling materials, etc... The material is completely from recycling. This is using the markets for the products... So, we recycle completely everything, in this case.

The tracks of recycling can also be found in the questionnaire data regarding their tangible projects for recovering electronic waste or local recycling of untreated plastic waste or small low-tech wind turbines made of recycled materials.

Waste Management

As mentioned above, the fablabs try to reuse proper materials as much as possible; however, industrial waste is expensive to recycle. Particular companies can do it, and most of the fablabs cannot afford this. During the interviews, sometimes fablab managers showed around and spaces reserved as garbage to reuse or recycle materials. Mainly, waste is used for reuse rather than recycling or upcycling, which is more complicated and costly. On the other hand, excessive waste can also be a problem to be addressed. This problem is clearly defined by I6 -who runs a crowded and ample space- in the following quotes:

> *No, this is the everyday rubbish, so there is no problem with this, it is more like industrial waste, like all the wood and metal leftover, which is the biggest volume of waste. And so, we have to pay for a special company to pick it up. That is one thing, the other thing is about waste, so there are people and ... and there is legislation. This is very hard to deal with. Basically, if I wanted to deal with the dust, from the wood cutting, I would need to put an "aspirante" (extractor device), a machine that would suck the dust in. It is like 15 cubic meters, and so I have no place to put it in here... So, I would then have to pay a special company to come and collect it from the inside with a special engine... It is money. Money and place we don't have. And the same thing goes for all the little pieces of wood we have leftover. I have been in touch with companies that do recycling of it, but as they come only for us, or for two companies around, it gets a lot more expensive than the traditional way of doing it. And so we cannot afford it. Mainly this is the reason why we cannot do much about. Sometimes we have people coming asking if they can take things, so that is always OK, we authorize people sometimes to come and take things, but ...*

As seen above, there are serious precautions to be taken about the industrial waste, and it is a common problem for fablabs how to treat it. Managing the waste in-house puts a physical burden, and outsourcing waste management puts a financial burden on fablabs. I1 explains the hardness of waste management in-house by highlighting the technical details: *"With the laser cutter. Yes. The waste needs to be treated in a certain way. We need to garbage it in a certain way. It is really toxic".* With an articulated question, he also mentions the bureaucratic obstacles to collect electronic garbage:

> *And, especially in France, there is that problem of who is responsible for it? So, if they give it to me, they are still responsible. If someone cuts himself with it or does something, they have to find back who made it, who gave it, and so it's really a big problem.*

When I further asked about the Belgium case (he was formerly living there) he answered: *"It is the same if it was with public money. I cannot buy a reused device. I*

want to buy a really big robot, and it is really cheaper if it's reused, but it is impossible with public money".

It is the case that public procurement legislation has obstacles to purchase second-hand materials, and that causes a barrier to reuse and recycle for publicly funded fablabs. Hands-on learning by doing and collaborative experience by sharing and codifying the knowledge plays a crucial role in gaining skills in the fablab. Competences can either be gained through formal accredited programs or trial and error. This is the same for the reuse-recycle and repair practices as well. The surveyed labs try to enhance their capacity on these practices and overcome the technical or legal obstacles in the meantime. Accumulated skills would improve the empowerment and confidence of fablabs to implement novel projects those are challenging to the set regime and address the environmental and societal problems in urban life.

5.5. Artifact

This element identifies the creations made by the fablab community. Since the concepts surveyed in this study are mainly related to sustainability transitions, I examined the artifacts related to sustainability with a locus. Both the quantitative and qualitative analysis provided insights on the subject, and those analyses are presented under the two themes:

- Eco-design and ecological projects,
- Environmental-friendly materials and circular material flows.

5.5.1 Eco-Design and Ecological Projects

As presented before in Folke's wedding cake model, the proportion of contribution to the ecological dimension of UN SDGs is comparatively low. In this section, the questionnaire data provides information on the ecological projects of the fablabs. According to the answers to the questionnaire, remarkable examples are provided as tangible projects ongoing within the fablab environment. These are:

- hydrogen-powered electric bicycle project seeking for carbon-free transportation in coordination with the local municipalities for networks of hydrogen fueling stations
- locally manufactured kiosks that sustain on solar energy to enable energy self-sufficiency and reduce car dependency
- mechatronic units that sense the seeds in the soil and allows small plots of land to be worked. The process results in a reduction of pesticides usage hence preserve soil and vegetables
- printing of certified organic cotton fabric and inks instead of synthetic one to limit the pollution in the textile industry
- robots capturing floating waste in ports
- sea dressings to heal corals that decalcify due to global warming via 3-Ds
- custom made prosthesis for a disabled person (she built it for herself with the volunteers), easing her head movements and decreasing her dependency on the chair
- assembling a controller device for manual wheelchairs made from garbage motors and batteries of electric bikes
- establishing a network of solar energy carpooling terminals in rural areas to reduce the
  car addiction
- mobile game application with augmented reality that simulates the food choices of the user with its impact on the water, soil, and living beings
- sensors made by agricultural vocational high school children to measure the impact of climatic conditions on beehives in the territory
- construction of a small low-tech wind turbine as a generator from recycled material, which became a workshop offered by fablab to companies for creating awareness on the Green IT / low tech approach
- creation of a circuit for the recovery and upgrading of materials used for the creation of projects (recovered textile bag, pallet furniture, laser-cut plastic sheets)
- recovery of 3-D printing waste to remake yarn/fiber

A few qualitative analyses can be provided here, one of which is about the sensibility on the living beings of I1's commentary: *"We try to improve conditions for vegetable life, but also animal life. So, from now we do not work with projects involving animals. ..We would accept projects for animals if we are certain it will improve their condition".* He also provided another example on reducing pesticides:

> *Another one I did not show you is, it's more like an electronic sensor, On the potatoes. There the idea is to predict the moment when the potatoes are in the fridge, to avoid putting chemical on them.... It is clearly less chemical, so it is 'vie Terrestre' Improve food quality (SDG 3).*

For the final example, as I mentioned in the previous sections the "Precious Plastic" is a frequently replicated artifact created by a Flemish fablab which enables the resilience and recycling of any type of plastic. Those artifacts are put into use by their creators or customers. The social and environmental functions they possess further affect the artifact's meaning from the users' point of view that is more beneficial for the planet and human beings.

5.5.2 Environmental-friendly materials and circular material flows

Using environmentally friendly material substances instead of prevalent cost-effective ones is desired and exercised by the surveyed fablabs. However, there are obstacles related to technology. As explained in detail under the "technology" pillar, most of the fablabs prefer PLA filaments to ABS due to their biodegradable label; however, the decomposition of this material is complicated and costly now. Moreover, it is not only the question of material but also the technique to utilize the equipment that makes it more ecologically beneficial. As I1 commented:

> *And eco-friendly materials, we try to sensitize them, but it is not an easy answer. So, a 3-D printer is not directly, a laser it is difficult, CNC you can work any material, but the problem is the less easy technique. So before doing that you have to learn a lot. So it is not the easiest, but we do it.*

For more traditional workshops such as wood, I6 provided an essential insight into using materials:

> *Actually, it is only their raw material. That is one thing about this. We keep the place with the wood, but we cannot use the wood the people use because it is not like raw wood. Most of the business model of carpenters today is not about*

> *massive wood, classic wood, it is like "contreplaqué", processed. There is glue in it, so we cannot burn it, so we cannot do anything with it, and the same thing applies to the wood dust. We could have given it to gardens. Some come to collect the "coffee grounds", but they cannot take the sawdust because there is glue in it, and so you can't do anything. Environment-friendly materials are pretty rare. For instance, I can never use raw wood; it's always processed because of price. As time goes by, I start to use more and more plastic because, in the process of working with it, it goes faster, so that means money. So, I have not been able to do much about the materials I use.*

Those commentaries reveal that utilizing ecologically friendly materials is not economically feasible yet. However, fablabs are a playground to try and test for the possibilities, as I5 mentioned:

> *This is part of our logic, and how the whole team is briefed on... For example, for the screen-printing activity, we have a member working on that. He is developing the whole natural screen printing with natural inks, which means natural ingredients. So, this is really tough. He is testing, experimenting this thing today.*

For the circular material flows, the surveyed fablabs in Brussels mentioned that there are gentrifications ongoing in the different regions of the city and many materials for reuse can be collected by fablabs if they want as I11 informed*:*

> *But for the moment, it's the new questions in Brussels, this circular material flows matter flow and is very important Brussels. But we have a lot of places where we can find easily this thing. Did you see the wood pieces? Wimo (Wood in Molenbeek). Make a very good job to collect the recycled wood in local and all the regions. It' a very good job.*

I12, located in the same region as well supported the findings on the situation by stating*: "And there was woodworking project. So, we work in partnership to do a design which is also publicly funded. Regular production is a for circular economy to make regular production".* I15 mentioned the gentrification situation also by saying: *"It is like being on a circular material flow through upcycling ……. for example, all those panels coming here in Brussels by a garbage collector. No, it's not building. And de-build the building and we get material from there".*

Throughout this section, the artifact pillar is presented with a mix of qualitative and quantitative data. The concept is examined with a narrowed lens of ecologic sustainability to understand the solid outcomes that emerged from fablabs. According

to the analysis conducted for this pillar, there is significant potential for ecological design and manufacturing within fablabs. However, technical, and economic obstacles decrease the extent to which radical ecological innovations may occur. In the following section, I further elaborate on the economic side of the picture.

5.6. Networks & Markets

The final element is the networks and markets element, where mainly the findings on the economic dimension are presented. Fablab's business modality, income-generating status, and interaction with the markets, value chains, institutions, and partners are of the primary concern of this section. In this part, I provide both quantitative and qualitative analyses to examine the relations between the fablabs and their surrounding network. The presented themes include business model, augmenting the business, Collaborations, and the externalities on personal manufacturing.

5.6.1. Business Model

Fablabs operate with various business models. Sustaining the place is a significant concern, as mentioned before in the literature survey. Therefore, fablabs surveyed their primary sources of income and whether they operate for profit or non-profit via questionnaire. Moreover, specific questions were asked during the interviews on their business modality. Most of the French fablabs act for non-profit goals, according to Table 5.3. Great majority of the fablabs are not interested in profit-making. Under the "others" choice, we encountered a specific type of for-profit firm; however, this profit is only spent for operational sustainability of the fablab.

Table 5. 3: Purpose of Activity

Type of Activity	*Percentage (%)*
Non-profit	73,85
Other	20,00
For profit	6,15

The quantitative data is enriched by qualitative analysis as well. For example, I1 stated on their business modality as:

> *…The building and the devices are half university/half public money ratio, and all salaries – it is like three-fifths of all salaries – are paid by the federal for the Open Lab. But that is new; before that, it was the university. And then we need to have an economy, that's why we have the private lab.*

Even fablabs ask money for services provided, it can be quite modest as I2 told:

> *Almost all of our tools are freely accessible except some specific machines…. You can access them with an annual membership, but it is not expensive:95 euros per year. If you are a student, unemployed or under 30 then it is 30 euros per year.*

This low price or free of charge policy increases the inclusivity in the fablabs. "Symbolic prices" can be charged in some cases not to be underrated by the users. *"Because if you give everything for free, it might become worthless for them"* was a concern mentioned by the same interviewee during the visit. Yet, there are entirely free cases like I8 as well with *"the philosophy is totally free for public, our philosophy is solidarity and social engagement, with the neighborhood".* I5 provided a different example on their business model as such:

> *We have a part which is non-profit and another where you can provide some services. Private services to some organizations. It's for designers who don't have the machines that are required to design, don't have specific machines. So, we provide this kind of service, yes.*

I4 mentioned that they do not have a business model at all by stating that: *"No. Today, there is no real business plan. In some fablabs, there is a 'cotisation' (subscription fee). And here we have no fee. It is open for all the campus".* For entrepreneurial activity, fablabs mostly request users to cover the expenses of the consumables, such as I3 mentione*d: "You're responsible for your materials. You buy them somewhere. We don't sell. That's it".* I10 explained their business model as:

> *We have two main ways of functioning. During the week, it is a more professional public. Upstairs, we have got some residents, corporate residents, which means they have their own hot desk. Their own place. It is their desk. Lots of architects. Also, designers, graphists, paysagistes (landscape gardeners). Whereas downstairs it's more designers, also architects, a few people that work here day to day, such as the team and me for example. But then you also have the people that need to work in the maker space and just sit there for the day, for the week when they have bigger projects.*

The questionnaire data provide insights into the main lines of income. According to that data, the primary income line is "services provided" followed by donations (including public funding). The answers given under the "Others" choice well fall under the first two definitions.

Table 5. 4: Resources of Income

Income Line	***Percentage (%)***
Services provided	58,33%
Donations	37,50%
Other	33,33%
Contributions	25,00%
Space rental fees	20,83%
Machine access fees	8,33%

For some cases, there charge reasonable membership fees to the regular users, and machine access fees are determined per hour mainly. Services provided include prototyping and designing for and with the users. One of the examples including the mix of these services in their business modality is the fablab run by I14:

> *Different types of memberships are based on flexibility if you want to come during outside working hours. It's the center that the membership is just accessing the place. But using the machinery up to usage per hour. And actually, the logic behind all that ….making a framework that allows people to mutualize their means. You can and do think of space as a result of that because it's so contributory. … So do the real goal is to make that production means commons. So that's building the machines, the knowledge, everything. So, the simplest relationship is that people pay the membership and in exchange, they can use the common.*

He continued his commentary with this example:

> *A woman arrived in the workshop to make somewhat limited metalwork. There was zero infrastructure for that. So, she takes a little corner, and she brings the things. And it was a starting point for the metalwork because she needed it. And then X... arrived in and made it better. And then the pros arrived …. From the voluntary contribution- because people wanted to have a space that was more suited to their needs. Actually, that is at least as important to the*

> *membership than that because it is not monetary exchanges. But actually, there is a lot of value. And actually, that's part of the business model, too.*

Donations and public funding are a part of sustaining the business for many fablabs. The comparatively high percentage of "donations" in Table 5.4 highlights their ongoing financial requirements. It is a primary concern among all the surveyed labs except those hosted in universities and led by the government. I5 expressed this obstacle by saying,

> *We have to maintain the business through specific services, the rent of residents, and sometimes some rentals, machine rentals. As president, I cannot touch any money. The main salary should go to the Fabmanager actually. But today he can't have any money as the structure is not stable enough.*

I1 has mentioned they had the EU and other public funding opportunities in the initiation process and adding that: *"For the EU funds and public money, they were always asking for the good of taxpayers. Three years, five years, OK, we can sustain, but after that...we have to be self-sufficient".* I8 had the flowing comment on the issue:

> *Sometimes it works, sometimes it's hard to sustain. The difference from other fablabs is that we have a company. So, the company supports us. And sometimes when we have problems, they support us. Other fablabs need to find their funds…*

I12 mentioned the role of public funding on the establishment of fablab and implied the concerns and plans for the future as: *"Since the feder funding is finished we have because of the fit out and the financing to the finish now. So now we have to find another way".*

The qualitative analysis provided information on the legal status of the labs, and it was observed that fablabs could have different legal status for the legitimacy of operations as well as have different typologies. Even their legal status is a company; there are instances that those companies are working for non-profit. Quantitative data presented in Table 5.3 (purpose of activity) supports this observation, too. The data provides strong evidence on non-profit activity.

When I asked about the legal status of the place, this economic profit-making model is explained by I8 as, *"It's a company that works in the solidarity economy. Our*

activity is on solidarity and social, but we do profit, and reinvest profit in the "économie sociale et solidaire (Social and solidarity economy)[9][10]*".* Most of the university-hosted labs surveyed do not have legal status at all, since they have affiliated to an administrative unit an example for which is I3 said that: *"it has zero status by itself. It has no legal existence".*

During the interviews, a concept emerged "augmenting the fablabs" as part of a business model, which implies opening new nodes affiliated to the existing ones via personal networks. It is a practice for some fablabs to augment the business in a new neighborhood or collaborate with a network for opportunities. I6 gave an example for augmenting as:

> *In fact, the business has a little bit changed. So, there was … Montreuil, then they decided to open Marseille, and next Nantes... and then go on... So now we have a "réseau" (network). So, they (the executive board) are dealing with the spreading of the places.*

I3 highlighted the role of the international fablab network on augmenting as *"Many instructors of the Fab Academy system are now pioneering in another lab to build a new node for the Fab Academy. And according to the country where you are".* I9 said that it becomes a requirement to multiply the place due to physical conditions stating that: *"The fablab is totally full, we need more space. Our residents, after 1 or 2 years of prototyping and developing their business, they need more resources. At this point we need more space"* while he set forth the reasons for extending the place.

One example was given by I11, who wants to open a new fablab to reduce the financial burdens on the current one and create a mutual synergy between them:

> *So, I got the money for all this year. It's OK. But after we must find the money for my freedom and do some work for my children (the users). This will be a*

[9] Social and solidarity economy (SSE) : is a concept for organizations that produce goods, services, and knowledge while pursuing economic and social goals and promoting solidarity. These entities, called SSE organizations, generally include cooperatives, mutual societies, social enterprises, associations, and foundations.
Source: https://www.ilo.org/empent/areas/social-finance/WCMS_762264/lang--fr/index.htm

[10] Implemented by structures in diverse forms, the social and solidarity economy has acquired a legal status with the law of July 31, 2014, in France.
Source: https://www.economie.gouv.fr/cedef/economie-sociale-et-solidaire

lot of work. We will open a new fablab to. We will open a new facility, maybe not just the fabrics, it will be more. A lot of wood. And iron work, a micro factory. So, it's another way to find money. We will open another place to touch those people. And also, you would try to create a dynamic between these spaces….by finding money for here and to put a little peace here to make an equilibrium.

Whether by personal network or via the international fablab community, fablabs facilitate the opening of new branches. In some cases, it is only done for solidarity; for others, it is a way of having a financial balance between the sister nodes by common use of the human resources and equipment.

5.6.2. Collaborations

As presented throughout the thesis, the GI movement and fablabs are not market-oriented. However, there is significant entrepreneurial or research activity that takes place in them. This deviation from the dominant markets creates opportunities to diffuse into niche markets such as green technologies. Collaborations would play a vital role in this diffusion. Collaborations also enable fablabs to participate in joint projects or initiatives contributing to sustainability. One of the most salient examples of collaboration for sustainability is Fab City Grand Paris. The aim is to establish a local network of makers, designers, architects, urban farmers, and innovators engaged in the rise of the circular and collaborative economy in the Parisian metropolitan area. To better understand the dynamics of this relation, I utilized both quantitative and data. Firstly, the partner typology is gathered via questionnaire, which is shown in Figure 5.4 below.

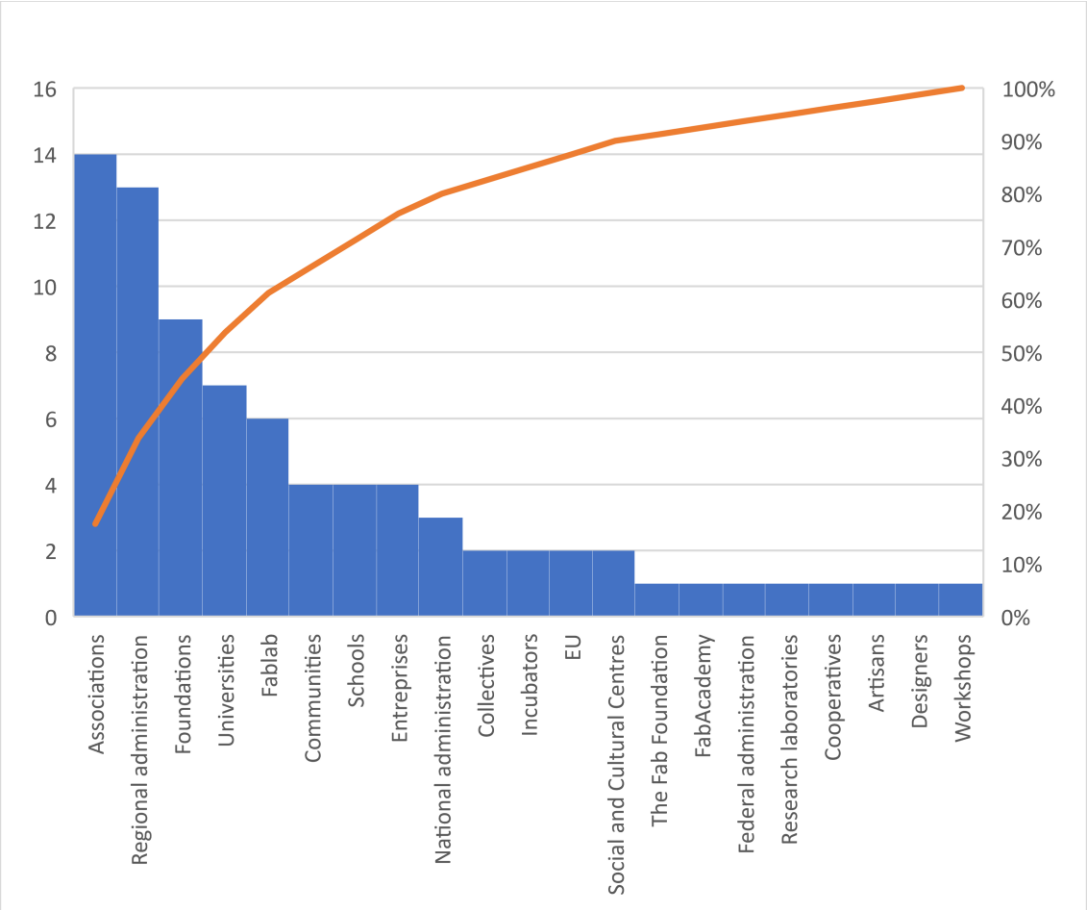

Figure 5. 4: Partner typology of the French fablabs

According to that data, the associations and regional administration institutions are the main partners of fablabs. Foundations, universities, and other fablabs are following the primary partners. This finding aligns with the previous findings in the sense of social and solidarity aspects adopted in fablabs. Enterprises have emerged as a partner as well, that would facilitate the market entries of niche innovations.

As the following question, the fablabs surveyed the essential type of relation with the most critical five partners. According to the results demonstrated in Figure 5.5 below, the essential type of relation among the preceding five partners is “joint projects” where they realize collaborative social work and artifacts for the planned purposes. Even the donation role is salient for the primary partners, the overall resource exchange type of relation is more significant in numbers. The resource exchange can be human resources, knowledge, equipment, and other available resources.

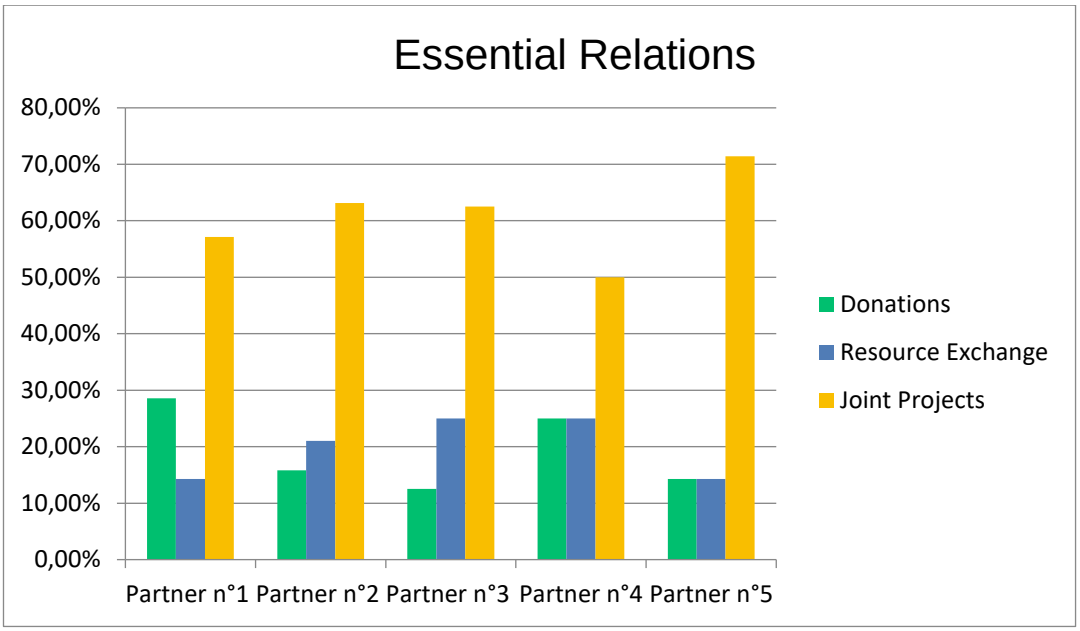

Figure 5. 5: Type of essential relations with primary partners

The qualitative data provides details on these partnership relations and the dynamics of the relations. I2 exemplifies the variety in partnership relations as such:

> *We have different kinds of partners, I would say. When we built the fablab, we had a big partnership with company X. A big company. It was a funded partnership. They give us like 150,000 euros, we have also some partnerships with company Y, that is a software company. We have also a partnership with company Z.*

When I asked him why they prefer to invest that funding into fablab and whether the investors benefit financial advantages, he reasoned it as:

> *They do not get public funding, but they pay less tax. And also, the image. Indeed, we were planning to build the fablab... We had already a big budget for that. They wanted to be associated with this project in particular. It is also social responsibility; it's also that image.*

Apart from this type of relation, he provided a partnership case with public institutions: *"Also we have partnerships with some scientific organizations, such as AVA, it is the National Centre for Research in Computer Sciences. We have been working with them a lot".* It is worth mentioning that I2's fablab is a public fablab operating under a well-known national institution affiliated with a French ministry.

I8, who is an active fablab manager on building networks gave the following commentary: *"For example, (Corporate Company X), we make the days of training. It is something like upskilling and reskilling for companies"*. He mentioned Orange Foundation, which is salient in interviews and questionnaires that supports the establishment of fablabs in the start-up stage:

> *There was a call from the Fondation Orange (Orange Foundation). A call for a 'Fablab solidaire'. They have financed a lot of fablabs in France. And in Africa and Asia. They have this program every year. Every year they make a call for a 'Fablab solidaire'. And they finance it. To open a new Fablab or to consolidate... It is not a partnership to make money. It's not possible for them, because they don't do business, they are financed by the state, and the public, so...*

I1 specified their partners as: *"Corporate company X, Region Ile de France, feder also, Orange Foundation, there's a program called 'Fablab Solidaire'. I get money there in Brussels".* As mentioned in the previous sections, public influence, whether via funding or regulating, is quite salient on fablabs. A previous example provided on recycling by I9 is also funded by public partnership funding as he says: *"It is not the government for this project, it is the regional authority. And there is also EU funding"*.

I3 has reservations on partnerships with corporate companies and set the following reasons forth when he challenged whether the market can push the fablabs to produce green solutions:

> *I will agree right away, but then I will ask for proofs. That it's going to be green for sure, and not "greenwashing". So, I would be more than disappointed, I would be very angry, if someone used us. To justify SDGs when they're not aligning with them, for example. I would denounce. This would have an impact. It's easy to say; it's harder to do.*

I4 provided a comprehensive example of collaborative partnership within university fablabs and explained how they could facilitate the different capabilities for their students mutually:

> *Yes. The decisions are made with the three schools (University X and University Y), and the persons that can access the fablab are all the students. We participate in fablab networks in …, that is Grand Paris Sud. Grand Paris Sud is a "communauté d'agglomérations" (community of local authorities). Bondoufle, Ris Orangis, Corbeil, Evry (different locations). There are many institutions, and in Grand Paris Sud we have many partners. We have partnered with Grand Paris Sud but with University X, too. We wanted to create a lab network in the local (area). And for example, we have some*

partners like Community X. Community X has no fablab, but there is a bio lab. It is not a fablab, but they have test tubes to make new technology etc. So, we have many partners, firstly ... partners and each fablab has its particularity.

As presented above, the joint projects implemented are a bridge between fablas and their partners, which creates the most considerable potential for their niche activities to diffuse. Even though they require donations or subsidies to sustain the place, community exchange or resource exchange is quite valuable for them. The utilization of the equipment poll for sharing is a common practice for the fablab network.

5.6.3. Personalized Production and Local Value Chains

The relocation of manufacturing is something desired by fablabs, and most of their efforts align with this projection. They work hard with small resources to build new competencies in order to achieve this goal. However, there are internal and external bottlenecks they still need to overcome. For their niche activities to diffuse faster, it is expected to harmonize their social and technical capital with niche markets and society. The commodification of knowledge can be a parameter to understand the extent to which they carry this diffusion potential. Therefore, within the online questionnaire, they have surveyed their utilization of Creative Commons licenses, giving us clues on their insights on the appropriation of their knowledge. The data shows us that mostly French fablabs do not apply for any Creative Commons Licence or traditional property rights protection. However, when they did, they mostly prepared 'ShareAlike' which one can share, copy and redistribute the material in any medium or format and make adaptations for any purpose, even commercially. On the other hand, they have serious efforts to document the projects they implement and share through common platforms such as "wikifactory" or on their web portals and social media. It means that the knowledge created by most French fablabs resides within the local circumstances.

Table 5. 5: Type of licenses demanded

Type of License	*Percentage (%)*
Attribution	14,58
Non-Commercial	12,50
No derivative works	0,00
Share alike	16,67
No licenses demanded	56,25

The qualitative analysis provides rich data on their worldview, goals, and desires for decentralization or localization of manufacturing. I9 commented on that as such:

> *On this one, we are all aligned, OK "responsible production and consumption", which is this idea to bring the production tools inside the city, to relocate all the production and consumption inside short circuits. About this we co-create the organization X in Paris. This goal to introduce the production idea inside the city and think about it.*

The traces of relocation of production are evident throughout this chapter. It is the desire and a goal for fablabs to reduce the environmental burden caused by the logistics and transportation of the mass production processes. I8 contributed with the similar views on the relocating the production by stating:

> *I think it's more ecological than buying Christmas decorations from China, in a little shop, and you know that this little object came from the other side of the world. So even if you produce a Christmas decoration, you don't really need a Christmas decoration; even in this case I think it's better to create your own mass reorder than to buy your mass reorder from a shop that is Chinese. I say Chinese but just to mean…*

The fablab managers are susceptible on the local dynamics and capabilities. A typical example was I14, a fablab manager from Brussels, mentioned that bringing the manufacturing capabilities back in the city is their primary goal by stating that:

> *Circular economy is not even a question as long as we do not produce anything. We can make prototypes of a circular economy, but we cannot really make the city walk like metabolism. If we don't make quantity… so we have to get back our hands-on producing things. And yes, they did so deepest, deepest motivation to do to the deepest motivation.*

He provided examples on the recent history of Brussels, how transferring the production capabilities overseas affected the local landscape, and he continued on his commentary mentioning on a paper he previously read as such:

> *It is a study which is called the City of Making. And one of the striking numbers in that study is that in Brussels in the 60s, it was one of the main research centers and 60 percent of the job were related to the industry. For the production and now it in 2000, 17 or 18. That's only three percent. And it was a third place in Europe.*

When I asked him whether Brussels tries to regain its skills back, he replied: *"The skills and the leverage and reveal the parameters like instruction and everything. Skills are leverage as well. And I would say that people involved in DIY or more craftsmen work for not neglectable part".* That was an important contribution for me to apprehend the relatedness of cultural meaning and user practices elements with personalized manufacturing. Another remarkable comment was given by I6:

> *That's sustainable communities and cities. That's more in my opinion, but I believe places like this, in case of a rupture - supply chain failure. If there is a crash or something, a catastrophic vision of our future... places like this are to me very important, because they are places of publication, creation, and so this is a workshop, and while we have been putting all our industrial products from faraway countries, having places to create things is essential for a city.*

I3 as an active fablab manager in the international community highlighted the potential and possibilities by relocating the production by enhancing the idea via different business models that would propose collaborative work with the mainstream actors, especially firms.

> *We could like start defining the position and getting involved. It is about bringing value to a network that is often perceived as a bunch of places where you do electronics or 3-D print something. But I think what you can do with the fablab network is a lot more than that. And if you connect this idea with the business model, an issue that many are going to be confronted with, the expertise could be sold to companies, for example. They could become part of the system, and it becomes able to make an expert assessment.*

He exemplified the business model he proposes as:

> *If a fablab acquires the machine or the equipment to change a chip in an I-phone, say, this is viable. It's probably 100 bucks, or euros, coming in, for a few, maybe one hour or less. So, you see what I mean. I'm trying to imagine a diversity. You know, monoculture is bad. Like diversity in interactions with the economic system around, might bring stability. Or not...*

A scale issue shows up between the lines of those quotes; that is, the production scale is determinant on the advantage of localized/personalized production over mass production. I1 explained it as:

> *That is the discussion we have about mass production. If you want to make 100 objects the same, do it with your 3-D printer. That is environmentally friendly. If you want to make 1 billion of them, do it with manufacture and now manufacturers are less in Europe, to make it in China. So, there is no one answer to that. But it's a possibility nowadays. It was impossible 20 years ago.*

He draws the line between mass production and localized production considering the customization requirements:

> *We do not do the same as mass production. When you are doing 3-D printing, you can do it for several hundred euros. One of them is that you want to customize it. You can't do it so industrially. Another one is to make it quicker all by yourself, it's possible here.*

Apart from the economy of scale, the local value chains are a parameter for localized production within a small circle. I found very little evidence on the existence of established local value chains; however, the fablab managers were aware of the importance of that fact. The following commentaries came from the same interviewee (I1) on the magnitude of the local value chains and networks as such:

> *You have to be in a network, that is another big issue. Reason to be in a network, because you can then discuss it over and, for example, if the CO2 tube is broken, by discussing with others I know where to buy it. It could I6 be quicker, or cheaper, that is a different choice.*

I6 said that it is their priority to utilize local value chains; however, he has concerns about the next circles in the chain:

> *Most of the companies we have been working with for material supplying, they are like neighbors, I mean in the region. But I don't know where the panels come from. The same is true for the plastic I use for the 3-D printers. OK, that's PLA, the company is a French one, but are they producing it?...*

This rhetorical question raised by him is followed by a concerning statement on the potential of fablabs for transition to better sustainability:

> *As an ecologist in my personal life, and a FabManager... I see different perceptions, what the market asks for, and mainly, if you ask around, most of the people are driven by the market. So, while the mass market has introduced certain processes... so as to put more things on the market, well you can't do*

much. I understand all the other aspects of sustainable development, such as caring for the poor, helping with food and stuff, but...

When I asked whether he thinks the market domination resides, he replied*: "Yes. That is how I felt. The way I had to work as a prototyper, to drive the community about this, all this makes me think that....."*. I4 gave an example for the dominance of the market dynamics:

> *Sometimes it is very complicated to... And I worked in a project on optics, about green products. But in optics, it is not the same domain. And it is clear in the business model. If you want the company to invest in green technology, you have to make the price sustainable too. Because if you say to the telecom industry: Ah, I send you a switch it is a very green switch, but the price is ten times the price of Huawei equipment, the company...*

As a final and concluding comment to that section is I3's contribution can be articulated here, which says:

> *The root of the fablab network is that we do not buy anymore... we will not be buying any more from vendors. Laser cutters, like that... Some of us, like me, but doing something else, are working on machines we can make in fablab that are the equivalent of that one. And for probably less than half of the price. … so, we could replace and minimize many things, meaning the data. Travels, the plans, the drawings, the codes. To make the machines, and not the machine travels from the US to here to be actually sold. So, there is a great deal. It's fablab 3.0. We are around 1.25. So, we are not there yet.*

The findings on the networks and markets element are provided in this section. The data shows that most of the fablabs in the sampling are acting for non-profit purposes. They usually utilize the income generated for reinvestment on the fablab facilities. Their social roles in the communities also appear as partners with social actors rather than economic actors. There is evidence that they have partnerships with the private sector, but it is not common in the sampling set. The collaborations can be established like a demonstration of social work they carry out. In general, the artifacts (i.e., knowledge and projects accumulated) are not commodified in the sample fablabs, which is a drawback for the diffusion of niche innovations. Localized manufacturing is acknowledged as a divine goal by many fablabs. The encountered best practices are presented in the findings combined with the current obstacles for personalized production to become dominant.

5.7. Concluding Remarks

The quantitative and qualitative analyses are compiled and presented in accordance with the theoretical framework. The findings are related to the concepts of elements to later establish an argument in the following chapter.

The data reveals that fablabs have a solid social and political stance regarding neighborhood communities and social inclusion. They have firm commitments to self-defined missions and harmonize with the expectations and desires of the communities. Those findings show that the C*ultural Meaning* element is vital and established in the relevant social context (e.g., region, community, country, faculty).

The findings on the *Technology* element demonstrate the dependence of the fablabs on the capabilities of the existing techniques and materials. The fablabs have concerns, especially on the ecological effects of digital printing technologies and responsibilities to minimize the potential harms on users.

The *Rules and Regulations* element is presented with the UN SDGs framework. SDG 12: Responsible production and consumption is the leading goal where French fablabs contribute the most. The qualitative data revealed that the social contribution is more substantial than the economic and ecological pillars. The majority of the surveyed fablabs align with the policy instruments whenever they need public funding, which causes contribution to sustainability via funded projects.

According to the analysis presented, one of the most enhanced pillars is the *User Practices* element. This element is where the skills-building takes place with hands-on learning and experiencing. There is significant evidence that responsible consumption and production practices occur within fablabs, and knowledge accumulation on these practices is achieved. These practices lead to better empowerment of fablabs in their social setting.

The ecological projects, environmentally friendly products, and processes are analyzed within the *Artifact* element. It is not a sole priority to produce “green” products for

fablabs, but indirectly they serve ecological responsibility. They demonstrate significant outcomes; however, they face economic and technical problems that hinder the impact's expansion.

The theoretical assumption is that fablabs -especially GI fablabs- are not market-oriented, yet there is evidence that they establish partnerships to become salient as a socially responsible actor in the landscape. The surveyed fablabs primarily operate for non-profit, and the generated income is invested in the further development of the environment. They have a firm commitment and desire for localized production; however, the data provide insights that this pillar is negatively affected by the bottlenecks presented in the technology and artifacts elements.

The following section will discuss the findings presented with a critical lens following the theoretical assumptions. The answer to the research question of the thesis is scrutinized with this lens. Relevant policy recommendations are discussed based on the findings and in line with the discussions.

CHAPTER 6

DISCUSSIONS

In the previous chapter, I presented the exploratory and descriptive analyses on fablabs and their potential for sustainable transitions. I associated my findings with the theoretical framework, which I adapted from the socio-technical systems approach. By conducting these analyses, I further explored the content of each element and contributed to the framed socio-technical system with my findings. In this chapter, I will discuss those findings to pose generalizations and answer the research question with the help of the literature. By discussing the trajectory of each element one by one in light of my findings, I will explore the possible pathways of transition and make future projections for the proposed system. Moreover, I will develop policy suggestions for fablabs and the personalized production system grounded on these discussions.

The themes I derived from qualitative and quantitative analysis are clustered under the concepts of the proposed socio-technical system of personal manufacturing. The summary of the derived themes with their assigned elements are provided in Table 6.1 below

Table 6. 1: Summary of the derived themes

Element 1: Cultural Meaning
– How do they define themselves?
– Governance
– Motivations of users to participate
– Missions and vision of fablabs
– Social Inclusion and Solidarity
– User Profiles

Element 2: Technology

- Field of Expertise
- 3D Printing Technologies and Sustainability

Element 3: Rules & Regulations

- Perception of Sustainability and UN SDG Agenda
- Contribution to SDGs
- Factors Affecting the Level of Contribution

Element 4: User Practices

- Skills Building
- Responsible Consumption and Production Practices (Repairing, Reuse, Recycling-Upcycling, Waste Management)

Element 5: Artifact

- Eco-Design and Ecological Projects
- Environmental-friendly materials and circular material flows

Element 6: Networks & Markets

- Business Model
- Collaborations
- Personalized Production and Local Value Chains

Each element of a socio-technical system is an outcome of the activities performed, interlinked, and reproduced by the system actors (Geels, 2004b). Those elements move in a trajectory of their own, paving the way for niche innovations to shift from micro-level niches to mezzo-level regimes and then to the macro-level landscapes. For a niche to become a stable socio-technical system, it needs to be aligned with the actors at the regime level. The trajectories of system elements are continuously developing until they gain a steady state within the regime or, otherwise, a failure occurs.

Existing systems are dominant at the regime level and stylized with lock-in mechanisms. The potential of niches is distinct to form a new socio-technical system at the regime level. The transition from traditional factories to mass production was a

change in the landscape level in the United States at the beginning of the 20th century, which happened as a result of sequential changes in the existing system's elements (Geels and Schot, 2007). There are slowly changing factors in the landscape level, such as political and normative values or economic developments and rapid changes such as wars, price shocks (Geels, 2004b), or a pandemic like Covid-19. These are external factors to the niche and regime elements. When these external factors are proper for a niche to break into the regime, windows of opportunity can open in the landscape. These opportunities would further lead an ongoing process for a niche to evolve with its interacting elements to build up a socio-technical system. During this process, knowledge accumulation in the niche is increased gradually and creates multiple trajectories (Geels, 2004b).

In order to explore the potential of personalized production as an alternative mode of production at the regime level, trajectories traced by each element of the proposed system will be discussed in light of the findings to conclude the research question and derive meaningful policy suggestions on the subject.

6.1. Element 1-Cultural Meaning

Before revealing the findings, I previously stated a set of propositions as part of the cultural meaning element depending on the literature survey. Those propositions were open innovation, desire for sustainability, localization, sharing, community spirit, social inclusion, and social justice. Those concepts are endogenous in fablabs which are part of grassroots movements. This research shows that Oldenburg's (2001) "third place" concept is at the forefront of French fablabs. It is evident that French fablabs and their communities see the lab environment as a social setting surrounded by their community instead of an innovation incubator or working environment. They participate in various solidarity projects with cooperatives, associations, or solidarity organizations.

Since the beginning of the millennium, a couple of steps have been taken in France to establish the legal basis of the third sector. The law of social and solidarity economy was enacted in 2014. This legal structure eases collaborative work between the actors and starts establishments of fablabs. Some of the fablabs have company status based

on this legislation and are active in the third sector, while some of them have private business status or have no legal status and exist as a unit under an institution. This finding can be supported by the mentions in the literature survey about the active roles of the National Council of Third Places and the Association France of Third Places on fablabs since 2018 (Garnier, 2020) and the underlined third-place concept in the white paper of RFF (Bosqué et al., 2018).

French fablabs' engagement with the international fablab community is relatively weak. A specific mention by Bottollier-Depois et al. (2014) was presented in the literature survey stating that French fablabs prefer to be free from the supervision of MIT in their operations. This fact is one of the reasons for the introversion of the French fablab community. In my research, I also observed that French fablabs prefer to be in contact with their own national, local or francophone network rather than other international networks. During the observation sessions, I witnessed the discussions of collaborations with Maghrib countries, where organizations like Orange Foundation provide subsidies for the establishment of fablabs with local economic development. The surveyed Belgian fablabs have contacts with the Quebec region of Canada, which is another francophone region. Speaking and writing in the French language is essential for francophone communities, which might hinder international communication in some instances. The French fablabs feel responsible for social issues and adopt political concerns such as solidarity economy and social justice. These are the essence of the meaning element for the surveyed fablabs, which are not that much underlined in the international fablab charter. Those nuances draw a specific worldview line between the French fablab community and the MIT-led international network, where technological innovation is the predominant concept in the latter. For the surveyed fablabs social innovation concept preponderates over technological innovation.

The governance mechanism is affected by the legal status of the fablab. For the private company cases in which a board of directors exists, the critical decisions are given in a more top-down fashion. For the grassroots fablabs, the community members can participate in the decision-making processes on a rotation-based system. In any case,

the community's demand is transmitted to the managing team and influences the direction of the fablab activities.

The fablab users have various motivations while becoming a member of the community. The community members are required to access and discover the means of digital fabrication technologies while seeking the collaboration opportunities offered by the social network of the fablabs. The fablab managers do not pose any priority to the members not to frustrate them and provide an openly shared environment. In the meantime, users appropriate the place for themselves with sharing, trials, and the work they develop. They enhance their knowledge via vocational training opportunities and find technical support for their research within the fablab.

On the other side of the user motivations, there stands the missions and visions of fablab. When the fablab managers express their primary missions, I observed that those missions are well-complemented user motivations. The management team feels responsible for establishing the social network to facilitate the interaction between the users and third parties. For specific fablabs with youth or school children in their target groups, the mission shifts to educational aspects such as increasing digital literacy and skills, spreading STEM education while caring for gender equality, and gaining scientific viewpoints.

The surveyed sample frequently highlights solidarity and social engagement with the neighborhood as a sole mission. Ensuring openness is aimed at by the surveyed fablabs while facilitating production and research as part of their mission. Those findings show that the grassroots notion is stronger in francophone fablabs than the digital fabrication notion of fablabs.

As shown in the literature by several scholars (e.g., Voigt et al., 2017; Carstensen, 2013; Guthrie, 2014), fablabs are male-dominant environments, a status which my findings validate in this research. Most of the fablabs surveyed are run by male teams, and male dominance is evident in the user population. Despite this being the fact, my observations align with the premise of Bean et al. (2015) that fablabs are a welcoming environment for women. There are no physical barriers for females to participate in

fablabs. Due to areas of interest, women participate more if they have tangible projects to implement, as it was with one case where textile and design were the core activities of the fablab and most of the participants (at the time of observation) were female.

Interaction with the vulnerable groups was not a salient issue in the fablab literature, yet traces existed in francophone literature (Roussel and Fillion, 2019), proposing that fablabs facilitate the independence of people with disabilities. The findings of this research verify this view, as well. There are numerous examples explicitly targeting disabled people and establishing social ties between youth and this group. Not only the handicaps also other vulnerabilities and minorities are addressed by the surveyed fablabs. Amongst the specifically targeted vulnerable groups, the findings revealed the elder people, low-income groups, refugees, and unemployed people as the target groups of fablabs. According to the observations, the social inclusion dimension is the most substantial aspect of the cultural meaning element. Different social classes encounter in the fablab environment to create a social value for the good of disadvantaged groups. Both France and Belgium have significant immigrant populations, and fablabs are cohesion agents of different social layers by facilitating peer production for the social good.

The richness and variety in the user profiles of the fablabs depend on their typology, as expected. For the grassroots fablabs, the target group is more diversified, while for the university-hosted labs, it is primarily the students, the Ph.D. fellows, or the university staff. Since the personal networks play a crucial role in the formation of the community, the profession or background of the fablab founders is determinant on the target group. For example, architects or landscape gardeners were the primary target group, where the founders were a group of architects. I came across the same situation where most of the users were designers in a fablab founded by professionals of the textile and fashion business.

Ensuring sustainability is not highlighted as a cultural value to the expected extent. This is due to fablabs' perception of sustainability from its environmental pillar only. When I surveyed the social and economic pillars via the UN SDGs framework and presented sustainability as an umbrella concept, they realized their contribution to

sustainability. Feeling responsible for social, economic, and environmental sustainability is a core value they adopt.

The strong emphasis on the above-mentioned social aspects is closely related to the socio-cultural specificities of the societies. Civil society is vital in the surveyed countries, and they have longstanding structures for starting initiatives in the different policy and interest fields. For example, in France, many organizations for co-creation, knowledge exchange, and collaboration existed long before the spread of the fablabs. These were the seeds of the physical establishment of fablabs that justifies the highest number of fablabs in France and their rapid organization around RFF.

As an overall conclusion to the Cultural Meaning element, with a strong emphasis on social responsibility and caring for the local community's desires, the fablabs symbolizes the catalyzation of the normative change in the making. That kind of "Making" in the fablabs is a new mode of production, which is more responsible, collaborative, thoughtful, accessible, and affordable. Those attributions form a moral solidity and stance, which would be an advantage for fablabs to gain legitimacy in society and increase their visibility in the meantime. Considering the education and formation aspect and the young population in their target group, we can expect that the rate of participation in the fablabs will increase in the mid-run with the inclusion of the new generations.

Grassroots fablabs have a diverse target group, reach vulnerable people, play a vital role in social cohesion, and stimulate DIY with less consumption, all constituting the cultural element. These values are firmly supported by the supranational development goals, EU's social cohesion schemes, and national and regional development initiatives. Therefore, this element follows an upward trajectory for sustainable transitions due to its comprehensive alignment with several aspects of the sustainable development agenda, thanks to the vast potential of fablabs being a change agent between the different layers of the social landscape.

6.2. Element 2-Technology

Technology is one of the major driving forces for a niche to enter into the landscape. The maturity level of the technology determines the transition pathway with the landscape pressures. Since the transition to more sustainable systems is the locus of this study, I examined the technologies utilized in the fablabs (i.e., additive manufacturing, digital printing, and other traditional techniques) from the sustainability point of view.

Any production impacts the environment, and it is both a matter of used technology, the process, and the material. As witnessed in this study, fablabs possess different workshops encapsulating different types of machines. Most processes are computer-controlled technologies; therefore, users virtually simulate and develop the final product and prototype before producing it. This reduces the production cycles and creates a positive impact on material consumption. This way, the machines in the fablabs enable economic savings on manufacturing costs, too. The most encountered machines were desktop 3-D printers, laser cutters, CNC milling machines, vinyl cutters, and PCB circuit makers in the sample fablabs. These machines process different types of materials, from plastics to wood, vinyl, or textiles. It is the machine and the material that determine the production process in fablabs as it is the same for any production line.

As previous discussions in the literature show, there is an ongoing debate on digital printing technologies and additive manufacturing and to what extent they are ecological-friendly. Although Kreiger and Pearce (2013) claimed better energy efficiency and lower carbon emissions for the 3-D printers (RepRap), Faludi (2013) objected to that claim. Multi-users using fewer printers is a crucial fact for environmental benefits, according to him. Many other potentials for sustainability have been mentioned in the literature, primarily relying on the small scales of manufacturing, and few of them touch the technical aspects relating to environmental impacts as done for the RepRap case.

The observations and findings of this research reveal a gap between the expectations from digital printing technologies and their current capabilities regarding environmental sustainability. First of all, special attention needs to be given to the utilization of materials. Plastics -including vinyl- and other materials such as industrial wood having chemical ingredients might cause severe damage to human health in case of misuse. This is a tension for fablab managers whose customers are ordinary people or even children. Protection instructions are strict for machines such as laser cutters which would burn the eye retina if not adequately shielded. Industrial wood or MDF used in the laser cutters or CNC milling machines diffuses petrochemicals. The vapors and micro-particles of plastic materials such as ABS (which is a plastic filament for 3-D printers) spread around, which negatively affects the air quality in the environment.

ABS and PLA are the two main types of filaments used in 3-D printing. ABS is preferred in cases where better material resistance is needed due to its polymer structure. On the other hand, most of the fablabs purchase and utilize PLA as it is a plant-derived plastic made from corn starch and labeled as biodegradable as a better alternative to typical polymers. It reduces the usage of fossil fuels, yet its decomposition requires special industrial facilities, which is an economic burden for fablabs. As stated by Peng, et al. (2018), there is relatively little research on the impact of additive manufacturing relying on the primary life cycle assessments, and the full potential of AM can only be assessed by integrating the energy and material aspects into consideration.

In conclusion to the discussions on the Technology element, the findings reveal that the strength of this element for socio-technical transition lies in its future potential rather than current capabilities. Fablabs tend to change their preferences to more environmentally friendly materials as these materials and technologies are supplied to the market. In addition, they experiment with putting the used materials in a circular flow of production with the equipment, skills, and knowledge they possess. The private sector initiated additive manufacturing first, and MIT's inkjet printing technology accelerated the evolution. All around the globe, market actors and research institutes are working on different materials and techniques to enhance the capabilities and borders of this technology. Cutting-edge solutions on digital printing technologies may

emerge either from fablabs/grassroots innovators or mainstream innovation channels. It is possible that the grassroots innovators would seek environmental benefits rather than cost-effectiveness, where mainstream innovators would prioritize the latter.

6.3. Element 3-Rules & Regulations

The rules and regulations element has significant importance for the sustainability transitions. The legislation set forth by the supranational, international, national, or regional organizations plays a crucial role in the transformation of sectors hence the landscape. Combating the climate crisis is irrecusable for the states, and day by day, a social and environmental paradigm shift is witnessed in the governments' policy agendas. A series of initiatives were started by supranational organizations such as United Nations Framework Convention on Climate Change (UNFCCC) -the 'Rio Convention'- (1994), Kyoto Protocol (1997), EU Lisbon Treaty (2009), OECD Green Growth Strategy (OECD, 2010), Paris Agreement (2015), the UN 2030 Agenda for Sustainable Development Goals (2015), EU Green Deal (2019) all of which are mentioning the hazards of climate change, urgent need for reducing carbon emissions and calling for a paradigm change for sustainable growth. The realization of this paradigm shift requires an overarching approach covering all the policy fields to catalyze a change in the locked-in, unsustainable systems and regimes.

In this study, I employed the UN 2030 Agenda as a global framework to examine the effect of regulations on fablabs due to its convenience and comprehensive structure. The survey results on SDG contribution of fablabs show that with the highest share of "SDG No.12-Responsible Production and Consumption" fablabs contribute to economic sustainability with 41,67 %. Social sustainability follows the economic pillar with 39,4 %, including the significant share of "SDG No.4-Quality Education" and "SDG No.11- Sustainable cities and communities". The environmental pillar lags behind with a percentage of 15,16 % for the fablabs' contribution to SDGs.

Although the surveyed fablabs are very sensitive to sustainability, their awareness on the agenda is relatively low. They welcome the sustainability concept; however, do not see the UN SDG agenda as a critical path to follow. They find the goals ambiguous and mention that the SDGs framework has weaknesses for impact assessment. They

naturally contribute to that agenda; however, they do not strictly want to align themselves with the 17 goals. This situation is also due to their perception of *freedom* from any top-down policy agenda and the desire to seek democratic ways of innovation and existence. Even though they need public funding for financial sustainability, searching for public funds is not the primary motivation for their contribution to sustainability. These facts cause the lack of set routines within the fablab and complicate their contribution's impact assessment. A group within the French fablab community claims that aligning with UN SDGs is helpful to progress and present the results better, yet the great majority do not have time or willingness to deal with a policy framework as long as tangible interests are not at the front.

The global indicator framework consisting of 230 items is too broad for fablabs to comprehend, as the indicator framework mainly covers national-level indicators (and fablabs operate on local and community levels). Nevertheless, there are many indicators related to fablabs' achievement, if extracted to assess the performance of fablabs, will probably ease them to align themselves with the agenda. For the time being, the SDG goal "itself" is more meaningful than its indicator set for a fablab.

The public funds provided through the national, regional, or EU level policy schemes support the establishment of new fablabs and positively affect the sustainability contributions for the existing ones. These schemes inherently forward the supported bodies into socially responsible actions and accelerate the collaboration between the actors in the regime. Consortiums from the private sector, research institutions, and third places like fablabs implement regular or ad-hoc projects with the leverage of public funding. However, according to my observations and survey, in France mostly the regional funding schemes and civil society help fablabs sustain. Grassroots digital fabrication workshops are not salient in central policies at the national and EU level policy papers to the desired extent.

The surveyed fablabs have more awareness of the national or EU level legislation related to their specialization, such as agricultural legislation or law on circular economy and the obligations they should obey for the manufacturing environment.

Overall, the regulations have a slow but solid impact on the grassroots actors' better contribution to sustainability, hence paving the way for a radical change in the landscape. The EU Common Agricultural Policy, EU Strategy on Climate Action, The Low-Emission Mobility Strategy, Fluorinated Greenhouse Gases (F-GHG) Policy, The Energy Efficiency Policy, Renewable Energy Policy, EU Strategies on Eco-Innovation are among the recent relevant legislation adopted at the EU level which is being diffused to the Member States and daily lives of EU citizens in the meantime. The situation in the EU is that there is a significant landscape pressure over the existing regimes to force them to transform into more sustainable systems. The regulations at the regime level are also aligning with the landscape level due to coercion of top-down policy as well as the urging call of local actors from the bottom-up. Therefore, communication channels need to be established to harmonize this bilateral pressure of the top and bottom levels to encourage fablabs as agents of transformation.

6.4. Element 4-User Practices

User practices element signals the core strengths of the socio-technical systems. Cognitive routines, institutional setup, competencies, and skills form the "organizational capital" (Geels, 2005). This organizational capital evolves with social interactions of niche actors by forming associations and sharing knowledge via conferences, events, or even journals in specific fields. The whole process leads a technological trajectory by accumulating knowledge and best practices (Geels, 2004b). This is the same trajectory followed by fablabs. I investigated the substance of user practices in fablabs by surveying the custom user patterns, routine behaviors, and primary competencies established by building skills.

According to the findings of this study, many fablabs are quite competent in assembling 3-D printers, improving the quality of the final products by trials on new techniques and materials, which reduces their dependency on the market actors. Day by day, they enhance the intervention and maintenance skills on the machines hence decreasing the economic burden of after-sales services put by the manufacturers. Self-maintenance and self-manufacturing are natural ways of learning by playing in the fablabs. Specific programs such as Fab Academy serves these skills with the comprehensive curriculum it provides for six months. However, there are quite a few

numbers of nodes in the surveyed sample. Many fablab managers expressed that the program is beneficial but not a must to become a highly skilled fablab. According to my observations, the two Fab Academy nodes were the ones that are more open to the idea of international collaboration rather than the national closed-circuit network. These nodes can be the bridges between the francophone fablab community and the international network.

The responsible consumption and production practices require special attention due to the firm commitment of the surveyed fablabs. I witnessed that fablabs practice the 3-R principle (reuse, recycle, and repair) by any means they possess. During the interviews, it was mentioned to me out loud that recycling is a costly, time-consuming, and technically complicated process. This complexity is primarily due to the substance of the objects to be recycled, such as plastics or used wood, including harmful chemicals. It is more convenient and practical to repair or reuse things and make long-lasting, durable objects rather than recycle heterogeneous materials. Nevertheless, evidence shows that recycling and upcycling are particular areas of interest in the fablab community despite these obstacles. Recycling plastics is a common concern as polymers are mainly used raw materials for personalized production. An open-source commons project, “Precious Plastics” is widely developed in many fablabs that enable the recycling of plastics of many types. The firm will of the communities for sustainability incline them to recycle the multi-iterations and experiment with combinations of new materials.

Reparation is a fundamental skill to be transmitted to fablab users via regular repair events where people bring their broken staff and repair them with the support of the fablab community. Paris is a vibrant city where these kinds of organizations are made with high participation of residents. Brussels has various repair cafes, as well. Reusing is an inseparable side of this picture. Fablabs collect reusable materials in reserved spaces and organize them for creating new objects. These materials can be collected from donors or even from streets and supermarkets by hand. The issue is to separate and manage the waste to be reused, as the amount gets enormous. The users are mostly not interested in the separation process, and the fablab managers may not have the time

and proper resources to do that. Electronic waste, scrap materials, and computer parts are the most reused materials in fablabs.

Those skills are shared within the fablab and through the social network. I observed that many fablabs try similar practices and share experiences on their trials and errors. The skills mentioned above are all contributing to environmental sustainability, and a valuable service fablabs provide. As is the case with the cultural meaning element, there is a normative position fablabs have by practicing their sustainability-related skills in a daily routine. The FabX events, both conducted physically and virtually due to the Covid-19 pandemic, become an exhibition ground where all fablabs around the globe present their projects, explain how they improve skills on materials and environment-friendly substances they explore. This sharing increases and accelerates the possible trajectories derived from "User Practices" element and mobilizes the shift of niche innovation. In conclusion, the user practices element draws fast trajectories and becomes the main carriage element of the system during its transition to regime level by forming the "organizational capital" as Geels (2005) mentioned.

6.5. Element 5-Artifact

Kline and Pinch (1996) argued the role of artifact and its close relatedness with social groups during the evolution of technology. The cultural meaning, which social groups shape, leads to the transfiguration of artifacts, and newly supplied artifacts alter the social relations. The predominant cultural meaning signaled by fablabs is being socially responsible, and the artifacts are shaped in line with this meaning and user motivations. In this study, I presumed the artifact as an encapsulating element of the tangible outcomes produced by the fablabs. The open-source projects, collaboration work for social responsibility, and solidarity can all be counted as artifacts. However, in the findings section of this element, I focused on the environmental-related products and processes to understand the extent to which they realize prototyping and production of goods and materials rather than formation, organization, or collaboration activities. Here the environmental-related product and processes refer to the definition of "Environmental Technologies" which is "a technology that advances sustainable development by reducing risk, enhancing cost-effectiveness, improving process

efficiency, and creating products and processes that are environmentally beneficial" (NSTC,1997).

In that sense, I presented the essential findings derived from the questionnaire on the artifacts created with the fablabs. Various environmental technology products are produced as projects where renewable energy resources are utilized, energy efficiency is ensured, low-carbon mobility is achieved, and pollution in the oceans and soil is decreased or even prevented. Virtual reality tools for environmental education in schools are also regarded as environmental technology within the study. Usage of organic or biodegradable materials, experiencing material recovery via circular flows, becomes inseparable production process phases for many fablabs surveyed. Apart from these examples, there is significant evidence of artifacts on human health targeting the improvement of conditions for disabled people by producing custom-made implants or vehicles for their mobility.

The study reveals that fablabs are productive on the artifact element and provide a large spectrum of product and process innovations for environmental and social benefit. When we consider the ecological weaknesses of current technologies, the outcomes of the fablabs can be regarded as overachievement. Those findings disclose that fablabs are active in so-called "eco-innovation" which is:

> Any form of innovation resulting in or aiming at significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment, enhancing resilience to environmental pressures, or achieving a more efficient and responsible use of natural resources (EU Community Guidelines on State Aid for Environmental Protection, 2008/C 82/01).

Eco-design is frequently mentioned during the interviews, which is "the integration of environmental aspects into product design to improve the environmental performance of the product throughout its whole life cycle[11]." Those concepts are essential to

[11] Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products.

mention due to their becoming more visible in the policy agendas. Overall, the artifact element follows an upward trajectory as part of the niche innovations in fablabs and has a crucial impact on opening windows of opportunities.

6.6. Element 6-Networks & Markets

The final element is the Networks and Markets element, where I elaborated the interaction of fablabs with the social groups such as their partners and the market/non-market actors in their networks. Various product and process innovations may occur in fablab. The occurrence of these niche innovations in the market depends on facts such as the performance of the innovation, alignment of the innovation with the expectations of users, public or private subsidies/investments on innovation, and the niche's establishment of a market presence in the local context (Geels2004a, 2004b, 2005). Informal networks are crucial in technical change (Hamel et al., 1989).

The primary findings on this element verified that fablabs are not market-oriented; most of the surveyed fablabs are acting non-profit. A small portion of the surveyed fablabs is working entirely for profit. Legislative regulations on the third sector positively affect the fablabs to operate in the social and solidarity economy and increase the non-profit, socially responsible activities. There is a significant share for the "others" type where the profit is re-invested in the space as part of the business model. Most fablabs provide memberships, services, and equipment for reasonable prices, which signals that fablab is an affordable place for any social group or class. To my understanding, this affordability notion aligns with user expectations where the profile is heterogeneous in terms of social class. Both a new immigrant and a professional expert can afford fablab and be equally treated. The profit-making fablabs mostly have professional residents who utilize the labs as a coworking space. My findings and observations align with Osunyomi et al. (2016), mentioning that European fablabs are generally funded by public or private actors where fablabs in North America are more "business-oriented".

The French fablabs' main income line is providing services, such as making designs, providing consultancy, and prototyping on demand. Voluntary work and contributions are crucial for business sustainability. Most of the fablabs suffer financial burdens and

are in search of public subsidies from time to time. Self-sufficiency is something desired, however not achieved to the full extent. Some fablab managers initiate the opening of the new fablabs as an extension node of the existing ones. They try different membership modalities in the augmented branch and balance the financial figures with the income generated from the "sister" fablab(s).

Partners are the most important social actors for fablabs with whom they implement joint projects, exchange resources (know-how, equipment, or personnel), or receive donations (in-kind or monetary). The preliminary partner typology identified in this study are organizations such as associations, foundations, and public institutions. This finding corresponds to the significant non-profit activity and solidarity work carried out by the surveyed fablabs. Enterprises and incubators are amongst the partner typology as well, who are actors of mainstream innovations and opening windows to the niche markets such as environmental technologies or eco-labeled products. The fablabs establish essential relationships with the partners in joint projects to network, do social work, and demonstrate collaborative achievements. Gaining the "socially responsible" image is a reason for corporate companies to collaborate with the fablabs. They can benefit from tax reductions for such collaborations in France. For the university-hosted fablabs, it is also convenient to collaborate with the national research institutes. The fablabs collaborate rather than compete, and what shapes this collaboration is the particularity of each fablab with its resources.

For more than half of their work, fablabs do not apply for creative commons licenses. There is a significant tacitness for the knowledge produced in the fablabs. The tacit knowledge is uncodified, differs for every individual, but spreads between the colleagues as a shared common experience (Dosi, 1988). Although formal appropriation of knowledge is weak, this tacitness aspect through informal international networking draws its stylized pattern for reciprocal knowledge sharing (Rip and Kemp, 1998).

It is rather a desire and worldview than an achievement for fablabs to bring back the production tools inside the city and relocate all the production and consumption inside short circuits. The importance of relocation of production would be lifesaving in case

of a failure. This is the case at the global outbreak due to the Covid-19 pandemic in 2020, when makerspaces and fablabs quickly responded to the lack of medical supplies by locally producing open-source healthcare products, especially face shields (Kieslinger et al., 2021).

The scale of production is a crucial fact determining the price of a product. In this regard, developing environmentally friendly technologies might be costly compared to the traditional products supplied in the market. That is why such new technologies need protection from the dominant regime because, at the time of their emergence, they are mostly expensive and have low technical performance (Mokyr, 1990). The diffusion rate of the new technology depends not only on its competition with the dominant systems but also on the costs and availability of the complementary technologies with the changes of the behavior of the system actors (Rip and Kemp, 1998). In order to sustain the collaborations, established tangible objectives need to be set; otherwise, networks established under the emergency cases become inactive by the time (Kieslinger et al., 2021).

As a conclusion for the networks and markets element, the surveyed fablabs establish alliances with various actors, including market actors, institutions, professionals, and social organizations that form a collective organizational capital around the fablab ecosystem. Those collaborations are primarily due to joint projects which facilitate technological and artifact development and knowledge accumulation. The spirit of personal production within fablabs is alive and fresh for the social groups involved. Although codification of knowledge is comparatively less than expected, the tacit knowledge is generated and shared via partnerships. Still, the low rates in the commodification of knowledge may negatively affect the diffusion of innovation within fablabs. Currently, the niche innovations developed in fablabs are not always cost-effective compared to the large-scale produced alternatives or suffer from low adoption rates in the early phases of the invention due to immaturity.

6.7. The Transition patterns and pathways for personalized production within Fablabs

Throughout the thesis, the elements of the proposed system are examined one by one. Each element has its dynamics, hence draws a different trajectory. According to that, the C*ultural Meaning* element follows a rapid path by constructing values around the personalized production, such as being socially responsible and environmentally friendly. Moreover, these meanings are taken as moral stances by all parties affiliated with the system. Whether market-oriented or not, producing personally desired artifacts that meet the self-requirements instead of buying a best-fit alternative is the essence of the meaning element.

The *Technology* element follows a relatively weak trajectory with regards to the expectations on environmental-friendliness and larger-scale productions. For a novel technology to become stable, it needs to find new application domains and benefit from scaling (Rip and Kemp, 1998). Certain technology is not always selected due to its efficiency but becomes effective and efficient as it spreads. This is called increasing returns to adoption (OECD, 1992). Combating climate change requires replacing multi technologies and the social system in connection (Rip and Kemp, 1998). Additive manufacturing, which stands at the core of 3-D printing technologies, can be used in many sectors and create various artifacts. In that sense, AM is an enabling or general-purpose technology. Enabling technologies such as ICT, biotechnology, nanotechnology have broad application domains and trace rapid internal growth paths as techno-economic trajectories (OECD, 2015). A similar course is expected for Additive Manufacturing; the more it is adopted, the returns to the technology will increase, and fablabs can be important actors in accelerating this technological trajectory.

The *Rules and Regulations* element flows stable but intense trajectories by initiating various policy instruments for sustainable transitions. Today there is more policy determination than ever for sustainability transitions in all sectors. It is a moment in history that the coercion from the landscape firmly forces the existing locked-in unsustainable systems to transform into sustainable alternatives. It is primarily the regional development and cohesion policies that support the establishment and the

activities of fablabs. Market actors do not hesitate to collaborate with them for new windows of opportunities, as well. However, there is a policy communication gap between the fablabs and central policies. In theory, the agenda of bottom-up initiatives and top-down policy aligns well around the same cultural values to promote sustainable systems. Nevertheless, there is a need for explicit mentions of central policy interest for encouraging and promoting fablabs as the pioneers of responsible production and consumption.

The *User Practices* element follows multi trajectories with various techniques, materials, and accumulated experience. Accumulating the knowledge and skills, practicing with old and new materials, shaping the artifacts to address the social issues, and learning the latest technology by doing will increase the return to adoption for personalized manufacturing. This would be realized by a "seamless web" (Hughes, 1986) that stands for the interactions between elements (such as networks, regulations, artifact, meaning) affecting technological developments. Fablabs are important actors in that seamless web by their knowledge, technique, and artifact contributions.

The *Artifact* element has the potential to align with the fast trajectories followed by cultural meaning, rules and regulations, and user practices. This potential lies within the commitment of fablabs for producing environmental technologies, realizing eco-design, and creating gadgets for improving the quality of life. A growing niche market on green technologies and artifacts produced in fablabs can shape that market by influencing user requirements and expectations as a channel of force and change.

Trajectories of *Markets and Networks* are versatile. Fablabs establish purposeful partnerships for knowledge accumulation, skills building, value sharing, and artifact development. The partner typology is quite inclusive; hence fablabs are in contact with many relevant actors in the socio-technical landscape. However, due mainly to the cost burdens of the current technology, the niche-market and alliances are still fragile and follow up and down cycles during the timeframe. There is little evidence on the established local value chains, which is a weakness for the Markets and Networks element.

As a conclusion of alignment of the trajectories followed by each element of the personalized production system within fablabs, the Cultural Meaning, Rules and Regulations, and User Practices elements have well established and aligned trajectories. Artifacts signal the potential of rapid trajectories for sustainable transitions however have dependencies on the technology element, which has current weaknesses and needs time to be enhanced. Depending on the developments in *Technology* and improvements on *User practices* and *Artifacts; Markets and Networks* element is expected to have an aligned trajectory with the other leading elements. Figure 6. 1 below demonstrates the alignment of trajectories of the examined elements:

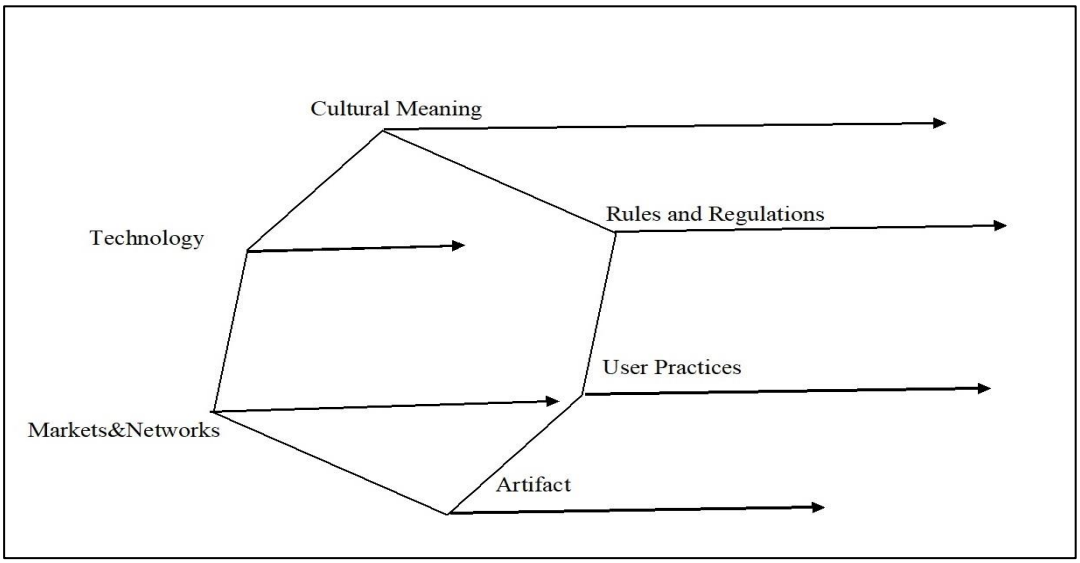

Figure 6. 1: The aligned trajectories of the elements of personalized production
Source: Author

Four types of transition pathways were explained in Chapter 3: transformation, reconfiguration, technological substitution, and de-alignment and re-alignment pathway as part of patterns of transitions (Geels and Kemp, 2012; Geels and Schot, 2007). In order to conclude on the transition pathway of a socio-technical system precisely, the transition should be realized, and only then an analysis of the historical evolution can be conducted. However, this thesis aims to make projections for the future alignments of the proposed systems relying on the findings of this study.
According to the demonstrated alignment of trajectories in Figure 6.1, it is possible to presume that the personalized production within fablabs is a rapidly developing socio-

technical system with vital elements. However, the primary determinant for the regime shift is the technological developments in digital printing and additive manufacturing technologies. Fablabs have close collaborations with the market and non-market actors for developing sustainable solutions with sustainable practices. Considering this determination with other well-developed elements and the significant landscape pressure for sustainable regimes, the expected pathway to be followed by the proposed system is the "reconfiguration pathway" where niche innovations are welcomed in the regime within a specified local context and further followed by broader adoption in the regime. In this pathway, the niches characterized by symbiotic innovations as an add-on to the existing regime and dominant system actors can also adapt them to address specific issues, as demonstrated in Figure 6.2.

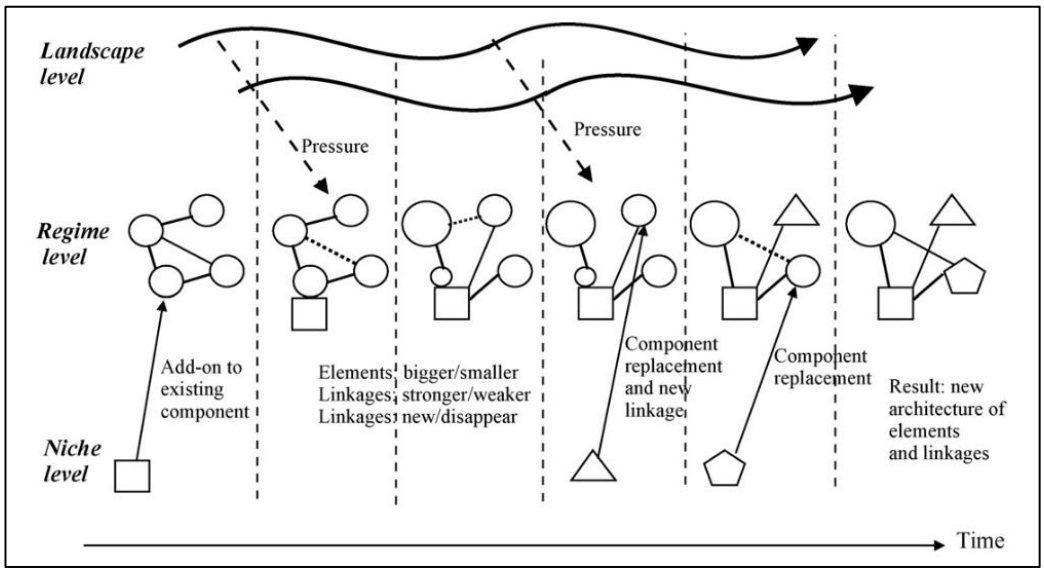

Figure 6. 2: The expected pathway for the transition of personalized production within fablabs: Reconfiguration pathway
Source: Geels and Schot (2007)

However, if an unpredictable and major collapse occurs in the mass production system and fablabs can respond with sound solutions, the transition may also follow de-alignment and re-alignment pathway where the sudden pressures cause disintegration in the regime and with opened windows of opportunities, multiple niche innovations occur and compete until an acknowledged one(s) become stable. In this scenario, the

"h*ype-disappointment cycles pattern"* is expected to be observed, referring to ups and downs during the acknowledgment process of the niche innovations. Though, it is not expected for a niche to become dominant in the regime level in a short period (e.g., less than ten years) (Rip and Kemp, 1998; Belz, 2004), which would be the case for personalized production.

6.8. Policy Implications

According to the evolutionary perspective, policymakers intervene whenever there is a failure in the system (Nelson, 1959; Arrow, 1962; Chaminade and Edquist, 2010). The notion of system failure has its theoretical foundations on the market failure proposition in the neo-classical economy (Akçomak, 2016). The underperformance in the production of knowledge is a rationale for the government intervention for evolutionary economists. Today most of the public policies rely on the principles of neo-classical and evolutionary economics. Although those principles are still valid, there is a paradigm shift in reasoning the policy interventions. Addressing societal challenges is at the forefront of public policy as a recent trend, rather than sustaining the economic growth in the government's agendas (Weber and Rochracher, 2012). Sustainability transitions may require determined interventions from the policymakers to break the resistance of incumbents of the locked-in systems (Markard, 2011).

A new policy framing for transformative change is proposed in order to address the outcomes of sustainability transitions by scholars (Weber and Rochracher, 2012). This policy framing claims to analyze the characteristics of failures and offer solutions with a well-justified policy. It is proposed to examine the shortcomings and failures of the system and justify the rationales for policy intervention. These are market failures (including information asymmetries, knowledge spill-over, externalization of costs, over-exploitation of commons), structural system failures (including infrastructure failures, institutional failures, interaction, and network failure, capabilities failure), or transformational system failure (directionality failure, demand articulation failure, policy coordination failure, reflexivity failure). Schot and Steinmueller (2018a) further contributed to this framing and named it "third framing" assuming that socio-technical change does not necessarily emerge in developed countries and instead of a catch-up

strategy, developing countries are well in a position to experience regime change at first hand.

The mission-oriented policy development approach addressing "well-defined objectives related to a societal challenge, in a defined timeframe with its specific targets on the application domain" (Larrue, 2021) is also positioned alongside this third framing (Schot and Steinmueller, 2018b). With its strong emphasis on citizen engagement, missions are expected to include citizens as innovators in the innovation process and monitor the evolution towards realizing the mission's objectives (Mazzucato, 2018, 2019).

Relying on the traditional and recent policy trends and discussions on the elements of personalized production within fablabs, we can trace the system's failures. While discussing each element, I mentioned the systemic failures and where and how they occur. According to that, there need to be enhancements in technology regarding environment-friendliness, local value chains need to be established to gain legitimacy as niche markets, communication gaps need to be eliminated with the policymakers, durable collaborations between system's actors need to be established for the socio-technical system to become a rival to the set regime. Following these arguments, I propose the following policy tools for fablabs to become a legitimate actor in the science, technology, and innovation policy landscape

Table 6. 2: The policy recommendations for transitions of personalized production as a socio-technical system within fablabs

The failing aspect	***Policy Aim***	***Policy Tool***	***Primary Responsible Actors***
Technology	Accelerating the technological development in AM and 3-D printing technologies by supporting basic and applied research	Thematic funding for Grassroots and Mainstream Actors for technological enhancement in AM	• International Funding Agencies/Organizations (e.g., EU[12], UN Organizations, OECD, World Bank) • Governments • Ministries • National Science and Research Institutions/Councils

[12] EU has a key funding program for research and innovation with a budget of €95.5 billion called Horizon Europe

Table 6. 2 (cont'd)

Technology	Boosting ecological innovation by incorporating grassroots movements	Organizing interdisciplinary conferences/meetings to foster sustainable options for the technology, the raw materials, and the artifacts	• National Science and Research Institutions/Councils • Academia • Public and Private R&D Centers
	Steering the technology market actors to sustainable solutions and collaboration with grassroots innovators	Organizing information meetings with vendors/suppliers of the equipment/materials and fablab representatives to discuss the aspects of sustainability, including Product Life Cycle Assessments	• Ministries • Regional Authorities • Industry and Trade Unions/Chambers • Professional Communities • Grassroots Representatives
Artifact	Accelerating the diffusion of niche innovations by supporting fablabs	Facilitate public procurement for eco-designed artifacts produced by fablabs (e.g., educational digital artifacts, solutions addressing urban life)	• Governments • Ministries • Regional Authorities (Municipalities)
		Providing financial and legislative support for application and verification processes of relevant accreditations/databases/certificates of environmental technologies.	• EU Horizon Program • Ministries
Markets	Supporting the niche market via partnerships with the mainstream actors (the ones sharing the social values with fablabs)	Thematic call for proposals for collaboration between grassroots innovations and mainstream innovations	• EU Horizon Program • Ministries • Regional Authorities
	Supporting the niche market by establishing local value chains	Designing mission-oriented policies, including diagnostic studies and establishment of context-based local value chains within a specified location and duration	• Ministries • Regional Authorities

Table 6. 2 (cont'd)

Markets	Supporting knowledge accumulation in the niches	Providing human resources/consultancy support to fablabs for the appropriation of the knowledge via the Creative Commons License regime	• Ministries • National Science and Research Institutions/Councils • International Funding Agencies
Partnerships	Establishment of solid partnerships for sustainability transitions	Soft policies such as consultancy and organization support for enabling the preparation of roadmaps for determined mission partnerships (e.g., for sustaining the medical supplies production partnerships established during Covid-19)	• Ministries • Regional Authorities • National Science and Research Institutions/Councils
Rules and Regulations	Eliminating the communicatio n gap between policymakers and fablabs and increasing citizen engagement	Establishing communication committees (working on a regular basis) of policymakers and representatives of fablabs and other grassroots movements (especially for sustainable cities and local solutions)	• Ministries • Regional Authorities • Grassroots Representatives • NGOs
	Boosting the circular economy via fablabs	Privileging fablabs via legislations for them to reach and manage the electronic and other proper types of waste and reuse material easily and at a lower cost	• EU • Ministries • Regional Authorities
	Alignment of the supranational and national regulations on eco-design, circular economy, and environmental technologies	Establishing expert committees for designing and revising the interrelated regulations	• Supranational and International Organizations • Governments • Ministries • Academia

Table 6. 2 (cont'd)

Cultural Meaning	Cultivating the socially responsible production and consumption through the society	Awareness-raising activities for the public on the responsible production and consumption within fablabs/makerspaces	• Governments • Ministries • Regional Authorities • NGOs
		Updating the curriculum of K12 level education to promote responsible consumption from childhood and utilize digital fabrication tools for daily purposes	• Governments • Ministries •
User Practices	Promoting the niche innovations at the regime level	Selection of best collaborative work practices and promote them to incumbent firms as an organizational or process innovation.	• Ministries • National Science and Research Institutions/Councils • International Funding Agencies

Source: Author

The policy implications presented above would vary in terms of context and the responsible actors. For the developed countries with already built infrastructure on R&D institutions, the funding schemes would focus on frontrunner projects based on the predefined selection criteria. On the other hand, it would be the priority to establish national and thematic R&D facilities working with enabling technologies like AM. For developing countries, the legal framework may be insufficient for the third sector to be operational; in that case, preliminary steps should be taken to fortify the civil society and the NGOs to enable networking and market activities.

Contrary to many innovations support schemes, policymakers should be careful not to push commercialization as a sole objective for the fablabs. The policy intervention to fablabs may not have an economic rationale. Fablabs are primarily non-profit organizations; many operate in the solidarity economy, making them key contributors to sustainable transformation. Grassroots fablabs' target audience is wider than the commercially fablabs. Grassroots communities resist the mainstream regime and are

always in a desire for democratic ways of existence. Therefore, the policy tools should be designed and implemented in continuous dialogue with the representatives of fablabs. Adaptation into niche markets should not hamper the sustainability aspect of the possible developments that originated in fablabs. Robust communication channels should be established with the local communities, and local priorities should be cared for designing the context of missions. It is vital to keep the civil society and its organizations alive for these channels to be sustained. Soft policy schemes such as providing expertise would make a massive difference in a fablab, and they would be open to this kind of support if they are convinced of the benefits to their community. It is not their primary desire to receive monetary support for purchasing new equipment but to utilize financial resources to increase the inclusivity in the fablab.

Finally, it is worth mentioning that the fablabs who specifically target children are essential change agents for the future's moral stance of production and consumption. This aspect is not only a concern of innovation policy but also education policy as well.

6.9. Limitations of the Study and Suggestions for Future Research

The main limitation of the study is comparatively low response rates to the online questionnaire. There were three parts to the questionnaire, and some respondents skipped particular questions. This may be because fablabs receive attention from researchers of multi-disciplines and frequent requests of filling questionnaires. Since they have scarce human resources, they would prefer to take a little time. This deficiency is attempted to be mitigated via interviews by elaborating more on the surveyed topics.

Fablab networks' being an active global platform enables it to be a tool that amplifies and diffuses innovation between different countries and territories. There are cases in the literature showing the role of the international fablab network in collaboration projects between developed and developing countries. The fablabs in Norway, Afghanistan, and Kenya collaborated in an open-source tool to enhance wi-fi networks in developing countries (Stacey, 2014). Literature and the actual figures of the fablab network show that the international network spreads to developing countries such as

India and African countries, allowing the more fragile zones to appropriate the same technology and skills with the developed world. (Radjou and Prabhu, 2015; Liotard, 2017). Fablab-like digital fabrication workshops are pointed out as a development pathway for developing countries (World Bank Report, 2014). Although fablabs were born in the United States and then spread to Europe, their appearance in developing countries and the regions where access to technology is limited is quite significant (Garnier, 2020). On the other hand, there are countries that host a relatively low number of fablabs compared to their size and population. Turkey is an example of that case, with having 15 fablabs established up to now. There is not an established national or regional network within the country, and to the current knowledge, there is not any policy paper conducted on the Turkish fablab community, which signals the little interest from the policy side.

The sampling in this study is selected from developed countries, members of the European Union, where grassroots movements have acknowledged, civil society is long-established, and the third sector is already regulated. The findings presented are specific to that context and may not be relevant for other countries, especially developing ones. Further research is required to understand the transition potential of fablabs in developing countries, and specialized policy suggestions need to be provided regarding the country-specific factors.

Fablabs are rapidly growing in number worldwide, and the evolution in the timeframe is quite unstable. The fablab network is a dynamic social network where relations are in continuous change and evolution. Therefore, the research agenda on fablab needs regular updates and extensions on different country or territory cases.

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APPENDICES

A. APPROVAL OF METU HUMAN SUBJECTS ETHICS COMMITTEE

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
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ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

Sayı: 28620816 /

21 ARALIK 2020

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Arsev Umur AYDINOĞLU

Danışmanlığını yaptığınız Beyza ÇOŞKUN'un ***"FABLAB'lar ve Sürdürülebilirliğe Katkıları"*** başlıklı araştırmanız İnsan Araştırmaları Etik Kurulu tarafından uygun görülmüş ve **348-ODTU-2020** protokol numarası ile onaylanmıştır.

Saygılarımızla bilgilerinize sunarız.

Prof.Dr. Mine MISIRLISOY
İAEK Başkanı

B. OUTLINE OF THE ONLINE QUESTIONNAIRE

QUESTIONNAIRE FABLABS and SUSTAINABILITY

General Questions

* 1. Name of the Fab Lab

* 2. Do you have any particular specilization(s) ? (If yes, precise : agriculture, handicapped, digitalization etc.)

1-

2-

3-

* 3. How would you define your Fab Lab?

	Definition
First of all it is a	
At the same time it is	
It is also	

Other : please specify...

* 4. Are you an organization :

- for profit
- non-profit
- other : please specify...

QUESTIONNAIRE FABLABS and SUSTAINABILITY

Your projects and SDGs

- **In 2015,the United Nations has adopted 17 Objectives for Sustainable Development(https://en.wikipedia.org/wiki/Sustainable_Development_Goals)**
- **We would like to know 3 projects carried out by or in your Fab Lab that have contributed to the SDGs.**
- **Please answer the following questions for 3 projects completed in the past 3 years(finished or not)**

Projet n°1

1. Name of the project ?

2. Web link of the project (if possible)

3. Has the project been completed?

- ◯ Yes
- ◯ No

4. For this project, did you collaborate with external partners or fablabs? If yes, mention the 3 main.

1 -

2 -

3 -

5. In your opinion, to which SDG (s) did this project contribute? (3 choices maximum)

6. Explain in a few sentences how this project contributed to the SDGs. (can be either in terms of process or the final result(s))

7. Has a Creative Commons license been obtained for this project?

QUESTIONNAIRE FABLABS and SUSTAINABILITY

Your projects and SDGs

Projet n°2

1. Name of the project?

2. Web link of the project (if possible)

3. Has the project been completed?

- Yes
- No

4. For this project, did you collaborate with external partners or fablabs? If yes, mention the 3 main.

1 -

2 -

3 -

5. In your opinion, to which SDG (s) did this project contribute? (3 choices maximum)

6. Explain in a few sentences how this project contributed to the SDGs. (can be either in terms of process or the final result(s))

7. Has a Creative Commons license been obtained for this project?

QUESTIONNAIRE FABLABS and SUSTAINABILITY

Your projects and SDGs

Projet n°3

1. Name of the project ?

2. Web link of the project (if possible)

3. Has the project been completed?

- Yes
- No

4. For this project, did you collaborate with external partners or fablabs? If yes, mention the 3 main.

1 -

2 -

3 -

5. In your opinion, to which SDG (s) did this project contribute? (3 choices maximum)

6. Explain in a few sentences how this project contributed to the SDGs. (can be either in terms of process or the final result(s))

7. Has a Creative Commons license been obtained for this project?

QUESTIONNAIRE FABLABS and SUSTAINABILITY

To conclude, we would have a few questions regarding your collaborations.

This part will allow us to better understand who your privileged partners have been over the past 3 years.

"Partner" means actors outside the fablab:
who make you donations (philanthropy, sponsorship, ...)
with whom you exchange resources (information, knowledge, materials, spaces, skills, ...)
with whom you carry out common projects (scientific, commercial, social, ...)

1. In your opinion, what are the two main advantages of engaging in a new partnership?

1-

2-

2. Who have been your privileged partners in the past 3 years?

Partner n°1 :

Partner n°2 :

Partner n°3 :

Partner n°4 :

Partner n°5 :

3. For each partner, please specify the type and importance of the relationship

	1. Vital	2. Very important	3. Important
Partner n°1 :			
Partner n°2 :			
Partner n°3 :			
Partner n°4 :			
Partner n°5 :			

4. What are the two most important sources of income for your fablab?

- [ ] Contributions
- [ ] Donations
- [ ] Machine access fees
- [ ] Space rental fees
- [ ] Services
- [ ] Other:

C. INTERVIEW GUIDELINE WITH FABLAB MANAGERS

Organization

1. Please tell me about your Fablab? When and how was it established?

2. What is the vision and mission of the Fablab?

3. What are the organizational structures?

   Decision making processes

   Business Model

   Governance Modality

   Of your Fablab?

4. How many users do you have? (just approximately)

5. What are the profiles of the users of your Fablab?

6. What are the motivations of these people?

7. What are the most prominent activities that take place in your Fablab?

Positioning on SDGs

1. Are you aware of UN SDG goals?

2. What do you think of them? (Positive/Negative Comments and Concerns)

3. Do you think there is a relation with your vision and UN SDG agenda? If yes, how?

4. Are you currently targeting the vulnerable groups) how?

5. In your opinion what is the social value created by your Fablab?

6. Which of the following three SDGs do you think that you may contribute?

7. How do you contribute? (In terms of materials, processes, practices etc.) Can you give examples from the finished/ongoing projects?
   For example:
   - Circular material flows, repairing, recycling, upcyling
   - Environmental-friendly materials
   - Environmental-friendly production processes
   - Localized/Decentralized production and supply chains
   - The value of the awareness of maker community on environmental issues

   Etc.

8. Is there significant difference in SDG perception between the commercial work and social/solidarity work that you execute? How and why?

9. According to you, what would be the factors to affect the willingness/achievements of a Fablab in terms of contribution to SDGs?

Example:

- Level of awareness of the users
- Level of awareness of the Fablab Management team
- The willingness to benefit the public funds
- Partner influence (Positive/negative?)
- Specialization area

Etc.

10. How do you see the level of fablab community in your country in terms SDG awareness and tendency?

Partner and Collaboration Behaviors

1. Who are your main partners?

2. What is the type of relation you establish with them?

3. What is the role of openness and sharing in these collaborations?

4. How do you see the level of fablab community in your country in terms of sharing and collaboration?

Other comments you would like to share?

D. CODEBOOK

1-CULTURAL MEANING

Accessibility
Animateur
Awareness Of Maker Community On Environmental Issues
Decision Making Process
Matter of legitimacy
Fabmanager's Background
Business
Guidance
Personal Choices
Free Access
French Specifities
French Specifities
Inclusivity
Gender Diversity
Variety-Diversity
Mission and vision
Being Professional
Democratise Fabrication Tools
Digital Literacy
Economic Development
Free Access
Knowledge-Sharing
Match-Making
Prototyping
Scientific Culture
Social Inclusion
Motivations
Access To Fabrication Tools
Community Spirit
Discover Digital Fabrication
Have A Desk
Knowledge Sharing
Place To Work
Research
Vocational Training
Neighbourhood
Obstacles

Openness-Openlab
Open-Source
Overwhelmed
Self-Assessment
Sharing
Mutual Responsibilities
Social Innovation
Social Relations
User Profile
Architects
Artists
Craftsmen
Designers
Doctoral Students
Engineers
Enterpreneurs
Farmers
Graphists
Paysagists
School Children
School Children (2)
Start-Up
Students
User Number
Youth
Vulnerable Groups
Elderly People
Handicapped
Homeless
Refugees
School Children
Underschlorarised
Unemployed

2-TECHNOLOGY

3-D Printing Technologies
Devices
Cnc
Ink Printer
Laser Cut
Miling Machine
Textile Machines
Traditional Equipment
Vinly Cutter
DIY

Field Of Expertise
Self-Made 3-D Printers
Themes
Agriculture
Farmers
Reduce Pesticide
Astronomy
Electronics
PCBs
Embroidery
Formation Center
Logistics And Mechanics
Pedagogy
Robotics
SW Programming
Textiles-Design
Wood Work
Urban Agriculture
Workshops

3- RULES&REGULATIONS

Effect Of Typology On Sustainability
Global Warming
Government Funding
Public Procurement
Perceptions
Policy
EU Leadership
Feder
SDG Contribution
UN SDGs
SDG 1
SDG 10
SDG 11
SDG 12
SDG 13
SDG 14
SDG 15
SDG 16
SDG 17
SDG 2
SDG 3
SDG 4
SDG 5
SDG 6

SDG 7
SDG 8
SDG 9

4-USER PRACTICES

Obstacles For Re-Use
Principals Of Fablab
Recycling
Repairing
Re-Use
Skills
Fabacademy
Mainteanance
Self-Made 3-D Printers
Tacit Auto Control
Upcycling
Waste Management
Wikifactory

5-ARTIFACT

Circular Material Flows
Ecology
Eco-Design
Environmental Friendly Materials
Environmental Friendly Production Processes
Green Investment
Precious Plastic
Sustainable Design

6-MARKETS &NETWORKS

Affordability
Reasonable Fee
Augmenting
Business Model
Governance
Hybrid
Non-Profit
Association
Volunteers

E. TURKISH SUMMARY / TÜRKÇE ÖZET

Azalan ve kirlenen kaynaklar, iklim değişikliği, ekonomik daralma, sosyal ve kültürel problemler, düzensiz göç, hatta Covid-19 pandemisi gibi birçok mesele, devletleri ve toplumları, kamu hayatı ve politikalarını yenilikçi ve dönüşümcü bir bakışla ele almaya zorluyor. Günümüz dünyasının istikrarlı kalkınması ve gelecek kuşakların refahını sağlayabilmek için ortaya atılan sürdürülebilirlik kavramı (Birleşmiş Milletler Brundtland Komisyonu, 1987), 2015 yılında kabul edilen sürdürülebilir kalkınma hedefleri doğrultusunda; çevresel, ekonomik ve sosyal boyutları olan kapsamlı sistem revizyonları yapılmasını öngörüyor. Sürdürülebilirlik açısından zayıflıkları olan mevcut sistemlerin yerini alabilecek daha sürdürülebilir ve çevre dostu alternatif arayışları, pek çok sektör ve politika alanında öne çıkıyor. Taban örgütü inovasyonları (Grassroots innovations) bu noktada yerel meselelere yenilikçi ve sürdürülebilir çözümler arayan ve toplumsal tabandan yukarı doğru bir halk hareketi olarak örgütlenen bir inovasyon modeli olarak karşımıza çıkmaktadır. Bu tezin ana fikri bir taban örgütlenme inovasyon modeli olarak kabul edilen "maker" hareketi ve köklerini bu harekete dayandıran fablab'ların (Fabrication Laboratories-Fabrikasyon Laboratuvarları) sürdürülebilirlik ile olan ilişkilerini incelemek üzerine oluştu. Bireysel olarak ulaşılması şimdilik maliyetli ve zor olan üç boyutlu tasarım ve üretim teknolojilerinin yanı sıra geleneksel atölye ekipmanlarını da bünyesinde barındıran bu yapılar her yaştan ve sosyo-kültürel düzeyden kişilere; kendi ihtiyaç ve arzularına göre tasarım, modelleme, prototip ve üretim yapabileceği bir ortam sağlamakta.

2001 yılında ilk kez Amerika Birleşik Devletleri'nde Massachusetts Institute of Technology'de (MIT) laboratuvarlarında kamu fonuyla kurulmasından bu yana fablab'lar, son yirmi yılda hızla yayıldı ve sayıları dünya çapında 1800'e ulaştı (fablabs.io). Fablab, fonksiyonel tanımı itibarıyla, bireyler için maliyetli ve ulaşılması zor olan üç boyutlu dijital baskı teknolojilerini (üç boyutlu yazıcı, lazer kesici, tarayıcı) sunan küçük-orta ölçekte atölye alanlarıdır. Fablab'ın kuruluş felsefesi, dijital imalat teknolojilerinin sağladığı yeteneklerle oyun-deneme odaklı yaratıcı çalışmalar yapmak

ve bunlar açık kaynak olarak paylaşmaktır. İmalat teknolojisinde devrimsel değişiklere olanak sağlayan eklemeli imalat tekniği (Additive Manufacturing), geleneksel imalat tekniği olan, malzemenin eksiltme yolu ile üretilmesi (talaşlı imalat) karşısına bir dizi avantaj ile çıkmaktadır. Fablab'ların fikir babası olarak kabul edilen Neil Gershenfeld ünlü manifestosu "Bitlerden Atomlara: (Neredeyse) her şey nasıl yapılır?" (2012), bir referans kılavuz kitap olarak dijital prototip üretiminin temel ilkelerini sunar. Genel olarak bir fablab'da olması beklenen ekipman(lar) aşağı yukarı şu şekildedir: 3-D yazıcılar, lazer kesiciler, nakış makineleri, devre yapıcılar, tasarım yazılımları, CNC makineleri ile geleneksel ahşap veya metal işleme makineleri. Geçen yirmi yıllık süre zarfında gerek gelişmiş gerekse de gelişmekte olan ülkelerde açılan fablab'lar yine MIT'nin öncülük ettiği uluslararası bir ağa dönüştü. Fablab'lar giderek artan sayıları, yetkinlikleri ve bölgelerinde edindikleri meşruiyet ile kitlesel üretim rejiminin karşısına bireysel tasarım ve üretimi koyarak; bir alternatif üretme arayışında benzersiz yerlerini alıyorlar. Bu ağın üyeleri sahip oldukları mütevazi imkanlarla pek çok yenilikçi hatta radikal nitelikli ürün ve hizmetin üretimini gerçekleştiriyorlar.

Bu noktada radikal yeniliklerin yerleşik rejimin egemenliğinden sıyrılarak gelişebileceği "korunaklı alanlar" demek olan "niş" kavramı (Kemp ve diğerleri, 1998), fablab'ların tanımı ve faaliyetleri ile örtüşmekte. Niş(ler) kavramı, sürdürülebilir kalkınma için dönüşüm çalışmaları literatürünün (sustainability transition studies) sosyo-teknik sistemler yaklaşımının yapı taşlarından biridir. Bu literatür temel olarak ulaşım, enerji ve tarım-gıda gibi büyük sistemlerdeki önemli değişiklikleri incelemesine rağmen (Elzen ve diğerleri, 2004, 2011; Geels, 2011), nişlerdeki inovasyonların sistem oyuncularını değişime zorladığı durumları da incelemeye elverişlidir. Bir teorik çerçeve olan "çok-katmanlı yaklaşım" (Multi-Level Perspective) (Geels, 2002), nişlerin tabandan yukarı doğru yarattığı arz-talep ilişkisi ile en üst düzeyden gelen politik karar ve zorlamaların uyuşması durumunda; daha sürdürülebilir olan yeni sosyo-teknik sistemlerin mevcut sistemler ile olan etkileşimlerini ve bunun sonucunda ortaya çıkabilecek dönüşüm türlerini tanımlayan bir kuramdır.

Söz konusu kuramda üç katman bulunmaktadır. Bunlar niş, rejim ve genel görünüm katmanlarıdır (niche-regime-landscape). Orta katman olan rejim seviyesinde kurumsal

düzenlemeler, bilişsel rutinler, beceriler ve yetkinlikleri içeren bir örgütsel sermaye birikimi vardır. Bu katmanda yer alan sosyo-teknik sistemler, pazarın dinamiklerini belirler ve kilitlenme mekanizması (lock-in mechanism) doğrultusunda stabil hale gelen bir seyir izlerler. En alt katmanda yer alan nişler pazar dinamiklerinden ve baskın rejim etkilerinden saparak yukarı doğru zorlayıcı bir rol oynarlar. Genel görünüm, en üst katman olup; nişlerin ve rejim aktörlerinin doğrudan müdahalesinin ötesindeki siyasi ve ekonomik manzarayı betimler. Birbirleriyle sürekli etkileşim halinde olan bu üç katmanda iç içe geçen hiyerarşiler mevcuttur. Genel görünüm düzeyi, niş inovasyonları normatif baskı veya dışsal gelişmelerle desteklediğinde; niş kaynaklı yeni bir sosyo-teknik sistem için fırsat pencereleri açılır ve bu yeni sistem rejim katmanında yer edinebilir.

Fablab'lar bünyesinde kişisel üretim teknikleri kullanılarak; kişilerin bireysel ve yerel taleplerini karşılayan, uzun ömürlü ve dayanıklı ürünler yaratmak mümkündür. Bununla beraber fablab'lar, onarım-tamirat ve geri dönüşüm pratikleri, döngüsel malzeme akışları, yerel tedarik zincirleri oluşturmaları ve üretici topluluklarında farkındalığın arttırılması sayesinde sürdürülebilir bir ortama sayısız katkılar sunmaktadırlar. Yerelde yapılandırılmış sorumlu üretim ve tüketime dayalı iş birlikleri, sürdürülemez hale gelen kitlesel üretim ve tüketimin karşısında bir rakip olarak belirgin hale gelmektedir. Fablab' lar bünyesindeki kişiselleştirilmiş üretimi, kitlesel üretim rejiminin karşısında yer alan bir sosyo-teknik sistem olarak ele aldığımızda; bu yeni sistemin yerleşik katmanlarda ne ölçüde bir yer edinebileceğini incelemek mümkündür.

Bu çalışma fablab'ların yukarıda iddia edildiği gibi sürdürülebilir üretim dönüşümüne katkı sunup sunmadıklarını, sunuyorlar ise bunu ne düzeyde başarabildiklerini araştırmaya odaklanmıştır. Bu sorulara cevap verebilmek için, yukarıda anlatılan teorik çerçevenin sunduğu kavramlar ile fablab'lar ve taban örgütü inovasyonların kendine has özellikleri göz önünde bulundurularak yazar tarafından bir sosyo-teknik sistem önerisi getirilmiştir. Buna göre baskın kitlesel (seri) üretim rejimine alternatif olarak ortaya çıkan fablab'lar içindeki kişisel üretim sistemine ilişkin teorik çerçeveye uygun olarak altı bileşen belirlenmiştir. Bu bileşenler bazında fablab'ların öngörülen

dönüşüm için mevcut durumları incelenmiştir. Belirlenen altı bileşen ve bileşen bazında cevap aranan alt araştırma soruları şu şekildedir:

1) Kültürel Anlam: Fablab'lar sürdürülebilik kavramını nasıl algılıyor ve bu anlama kültürel açıdan ne şekilde katkı sunuyor?
2) Teknoloji: Sürdürülebilir üretimde fablab'larda kullanılan teknolojilerin yetenekleri ne düzeydedir?
3) Kural ve Düzenlemeler: Fablab'lar, mevcut düzenlemeleri ve Birleşmiş Milletler Sürdürülebilir Kalkınma Hedeflerini (SKH), ajandalarına nasıl entegre ediyor?
4) Kullanıcı Yöntemleri: Fablab'lar sürdürülebilirliğe katkıda bulunmak için hangi örgütsel uygulamaları ve kullanıcı pratiklerini hayata geçiriyorlar?
5) Eser: Fablab'lar ne tür sürdürülebilir eserler yaratıyor ve kullanıma sunuyorlar?
6) Pazarlar ve Ağlar: Fablab topluluğuyla birlikte pazarlar ve ağlar nasıl gelişiyor; niş pazarların evrimi nasıl bir seyir izliyor?

Bu çalışmada yukarıdaki soruların cevapları araştırılarak; fablab'lar bünyesinde gerçekleştirilen kişiselleştirilmiş imalatın, hâkim sistemlerin bulunduğu rejim katmanına geçişte nasıl bir yol izleyebileceği ve ne ölçüde hâkim sistemlerin yerini alabileceği keşfedilerek; kısa ve orta vade için bir projeksiyon yapılmıştır. Ayrıca bu analizlere dayanarak başarılı bir sosyo-teknik geçiş için politika çıkarımları yapılmıştır.

Nicel ve nitel yaklaşımların ikisinin de kullanıldığı bu çalışma, AB Jean Monnet araştırma bursu ile Fransa ve Belçika'da gerçekleştirilmiştir. Fransa, Avrupa kıtasında en fazla fablab barındıran ülkesidir. Kültürel benzerlikler ve erişim elverişliliği sebebiyle, örneklem grubuna Belçika'nın frankofon bölgesinden fablab'lar da dahil edilerek nitel analizler zenginleştirilmiştir. Fablab'ın kendisini bir analiz birimi olarak alan bu araştırmada yakınsak karma yöntem tasarımı (Creswell ve Creswell, 2018) kullanılmıştır. Çalışmanın eksenini belirlerken yazara araştırma sorularına odaklanma ve bilgi elde etmek için çoklu yöntemleri kullanabilme imkânı veren pragmatik bakış açısı (Morgan, 2007; Patton, 1990) benimsenmiştir. Bahsedilen bu karma yöntem

kapsamında öncelikle sahada gözlem ziyaretleri ile başlatılan araştırma, bu gözlemlerde edinilen birikimler ile oluşturulan bir anket çalışması ile devam etmiştir. Fransız fablab'larına gönderilen bu ankette fablab'ların sürdürülebilirliğe katkıları, Birleşmiş Milletler SKH'leri kapsamında sorgulanmıştır. Anket, "Genel sorular", "SKH'lere ilişkin projeler" ve "Ortaklıklar" olmak üzere üç bölüm altında 29 sorudan oluşmaktadır. 294 alıcı ile paylaşılan çevrimiçi bu anket sonucunda, 65 yanıt alınmıştır. Bu anketten elde edilen veriler, çalışmanın ağırlıklı bulgularını sağlayan nitel veriyle yan yana sunularak analizler zenginleştirilmiştir. Anket ile eşzamanlı olarak başlatılan nitel veri toplama sürecinde; Fransa'da 10, Belçika'da beş adet olmak üzere toplam 15 fablab yöneticisi ile birebir mülakatlar yapılmıştır. Yine bu süreçte iki adet gözlem daha yapılarak toplamda dört gözlem oturumu ile veri elde etme çalışmaları tamamlanmıştır.

Veri toplama safhasının tamamlanmasını müteakip, öncelikle çevrimiçi anket uygulamasında yer alan gelişmiş araçlar yoluyla nicel analiz yapılmış; görsel grafikler, istatistiki tablolar ve açık uçlu cevapların işlendiği formlar oluşturulmuştur. Nitel analiz içinse araştırma günlüklerinde yer alan notlar ile mülakat görüşmelerinin deşifrelerinin yer aldığı transkripsiyon dokümanları kullanılmıştır. Bu dokümanlar, nitel ve karma yöntem araştırmalarında kullanılan bir analiz yazılımına aktarılarak anlamsal kodlama işlemine tabi tutulmuştur. Bu işlemin ilk aşamasında teorik çerçeveden bağımsız olarak yapılan analizler sonucu elde edilen temalar, teorik çerçeve ışığında belirlenmiş altı bileşen ile ilişkilendirilerek tekrar yorumlanmış ve bulgular bölümündeki altı başlık içerisinde sunulmuştur. Söz konusu temalar ve ilişkili olduğu başlıklar aşağıdaki özet tabloda görülmektedir.

Tablo 1: Temalar ve ilişkilendirildikleri bileşenler

Bileşen 1: Kültürel Anlam
– Kendilerini nasıl tanımlıyorlar?
– Yönetişim
– Kullanıcıların motivasyonu
– Misyon ve vizyon
– Toplumsal kapsayıcılık ve dayanışma
– Kullanıcı Profilleri

Bileşen 2: Teknoloji

- Uzmanlık Alanları
- 3D imalat teknolojileri ve sürdürülebilirlik

Bileşen 3: Kural & Düzenlemeler

- BM SKH Ajandasını nasıl algılıyorlar
- SKH'lere katkıları
- Katkı düzeyini etkileyen faktörler

Bileşen 4: Kullanıcı Yöntemleri

- Becerilerin geliştirilmesi
- Sorumlu Tüketim ve Üretim uygulamaları (Tamirat-onarım, tekrar kullanım, geri-ileri dönüşüm, atık madde yönetimi)

Bileşen 5: Eser

- Eco-tasarım ve ekolojik projeler
- Çevre dostu malzemeler, döngüsel malzemeler

Bileşen 6: Pazarlar ve Ağlar

- İş modelleri
- İş birlikleri
- Kişiselleştirilmiş üretim ve yerel tedarik zincirleri

Sosyo-teknik sistemlerin bileşenleri, zaman içinde farklı süreçlerden geçerek değişik yörüngeler izleyebilir. Nişlerin açılan fırsat pencerelerinden orta katmana doğru geçişlerinde, bileşenlerin izlediği yörüngeler birbirleriyle ne kadar uyumlu ve eşzamanlı ise sistemin bir bütün olarak orta katmanda yerleşik hale geçmesi o denli elverişli olacaktır. Bu elverişliliğe genel görünüm katmanının destekleyici unsurlarla eşlik etmesi de beklenir. Bu tezde önerilen "Fablab'larda Kişiselleştirilmiş Üretim Sistemi"nin rejim katmanında ne düzeyde yer edinebileceğini anlayabilmek için bileşenlere ilişkin bulgular, literatür ve araştırmacının kendi izlenimleri doğrultusunda değerlendirilmiştir. Bu değerlendirmenin sonucunda her bileşenin izlediği yörüngeye ilişkin öngörülerde bulunulmuştur. Bu kapsamda; bulgular, değerlendirmeler ve araştırmacının yörüngelere ilişkin projeksiyonları aşağıda sunulmaktadır.

Kültürel Anlam: Mevcut literatür, fablab'ların öncelikle dijital prototipleme atölyeleri olma özelliğine vurgu yapmaktadır. Ne var ki örneklemimizde yer alan fablab'lar, kendilerini öncelikle "üçüncü yer[13]" (Oldenburg, 2001) olarak tanımlamaktadır. Buna göre fablab'lar, gücünü içinde bulundukları mahalle ve parçası oldukları komünitenin oluşturduğu sosyal sermayeden almakta ve bu toplulukların karşılaştığı sorunların çözümüne katkı sunmaktadır. Kadınlar, kız çocukları, göçmen-mülteci toplulukları, evsizler, yaşlılar, işsizler ve engelliler gibi çeşitli dezavantajlı gruplarla yürüttükleri atölye çalışmaları, sosyal açıdan gösterdikleri sorumlu tutumun bir göstergesidir. Fablab yöneticileri, kullanıcıların ihtiyaç ve motivasyonlarına kulak vermekte; misyon ve vizyon anlayışlarını bu doğrultuda tanımlamaktadırlar. Ayrıca fablab'lar her sosyal sınıftan bireye; atölye alanına, ekipmanlara ve uzmanlığa erişimi makul fiyatlardan sağlamaktadır. Ayrıca iş birliği ve örgütlenmeyi destekleyerek sosyal uyum ve dayanışmanın sağlanmasında önemli bir rol oynamaktadır. Fablab'larda beyaz yakalı eğitimli profesyonellerden, görece yoksul ve yüksek öğretim alma imkânı olmayan kimselere; doktora öğrencilerinden, girişimcilere; okul çocuklarından, yaşlılara kadar birçok farklı gruptan insan bir arada yaratım yapabilmektedir.

Yukarıda bahsedildiği gibi kültürel anlam bileşeni, sürdürülebilirlik kavramının ağırlıklı olarak sosyal niteliklerine işaret etmektedir. Bu güçlü sosyal vurgu, çalışmanın yapıldığı toplumların sosyo-kültürel özellikleriyle yakından ilgilidir. İnceleme yapılan ülkelerde sivil toplum yapısı oldukça güçlü olup; fablab ulusal ağının nüvesini oluşturan sivil toplum örgütleri, fablab kavramının ortaya çıkmasından önce de faaldir. Ayrıca üçüncü sektör olarak nitelenen sivil toplum sektörünün gelişip serpilmesi için elverişli ve destekleyici yasal ve mali bir mali ortam mevcuttur.

Öte yandan örneklem grubundaki fablab'ların uluslararası fablab ağından ziyade ulusal veya bölgesel ağlar ile daha yakın bağları olduğu görülmüştür. Bunun sebepleri özellikle Fransız fablab'larının MIT'den bağımsız hareket etme eğiliminde olmaları; uluslararası ağdaki trendlerden ziyade kendi kültürel özelliklerini önceliklendirmeleri ve Fransızca dilinin baskın etkisidir.

[13] Üçüncü yer: İnsanların ev ve çalışma ortamından sonra gelen sosyal çevre.

Genel olarak bakıldığında fablab'lar üretimin daha işbirlikçi, erişilebilir, dayanışmaya açık ve sorumlu bir türünü sembolize etmektedir. Bu sembol, fablab'ların bulundukları toplumda meşruiyet kazanmaları ve görünürlüklerini artırmaları için avantaj sağlayacak sağlam bir ideolojik-kültürel duruş oluşturmaktadır. Sahip oldukları eğitim-formasyon boyutu ve hedef kitlesindeki genç nüfus dikkate alındığında; orta vadede yeni jenerasyon arasında fablab'lara katılım oranının artmasını beklemek mümkündür. Sosyal çeşitlilik ve ulusal/uluslararası düzeydeki sosyal politikaların (örneğin, AB sosyal uyum fonları, AB bölgesel kalkınma fonları, federasyon kaynakları) bu yöndeki desteği göz önünde bulundurularak, kültürel anlam bileşeninin yukarı doğru bir yörünge izlediğini söylemek mümkündür.

Teknoloji: Masaüstü üç boyutlu yazıcıların ortaya çıkmasıyla kişiselleştirilmiş üretim imkânı tanıyan en önemli teknolojik gelişme, eklemeli imalatın ortaya çıkmasıdır. Hammadde kütlesini keserek üretim yapan talaşlı imalatın aksine, eklemeli imalatta dijital olarak tasarlanan karmaşık obje, ince bir şerit halindeki hammaddenin üst üste eklenmesiyle elde edilir. Eklemeli imalat; havacılık, sağlık gibi pek çok farklı sektörde kullanım olanağı bulunan kolaylaştırıcı bir teknoloji olma niteliği taşır. Teknolojinin sunduğu farklı kullanım alanları, fablab'larda da uzmanlaşma olarak gözlemlenebilmektedir. Temelde dijitalleşme, eğitim ve formasyon gibi daha genel amaçlı olarak faaliyet gösterseler de spesifik alanlarda projeler yürüten fablab'lara da rastlamak mümkündür. Örneğin mekatronik, robotik, tekstil-tasarım, astronomi, gıda-tarım gibi birçok farklı alanın bulgu olarak tespit edilmesi; eklemeli imalatın sunduğu imkanların çeşitliliğinin sağlamasını yapmıştır.

Eklemeli imalat, tekniği itibarıyla dijital tasarım ve prototipleme sayesinde malzeme sarfiyatını azaltmaktadır. Öte yandan çevreye etkisi bakımından teknolojinin malzeme boyutu da, en az kullanılan teknik kadar önemlidir. Bu noktada bulgular, pazarda hazır bulunan sarf malzemelerinin halen yeteri kadar çevre dostu olmadığını ortaya koymaktadır. Biyolojik çözünme özelliği olan hammaddeler tercih edilse dahi, bu çözünmenin özel endüstriyel tesislerde gerçekleştiği ve maliyetli olduğu kaydedilmiştir. Bunun haricinde kullanıcılar ve çevre için olası zararlı etkilerinden dolayı, ekipman ve teknolojinin gerekli önlemler sağlanarak kullanılması zaruridir.

Sonuç olarak; teknoloji bileşeninin sürdürülebilirlik çerçevesindeki gücü, mevcut yeteneklerinden ziyade gelecekteki potansiyelindedir. Fablab'lar sürekli olarak döngüsel üretimi deneyimlemekte ve farklı malzemelerle üretimdeki çevresel etkiyi azaltmaya çabalamaktadır. Fablab'lar, tedarikçiler tarafından makul fiyatlarla arz edildiği takdirde çevre dostu malzemeleri diğer malzemeler yerine tercih etme eğilimindedir. Bu bakımdan eklemeli imalatta kullanılan hammaddenin daha çevre dostu hale gelebilmesi için temel araştırma ve ürün geliştirmeye ihtiyaç duyulmaktadır. Bu ihtiyaca yönelik çözümler, piyasa aktörleri veya kamu/akademi araştırma enstitüleri olarak nitelendirilen ana akım inovasyon oyuncuları tarafından geliştirilebileceği gibi; fablab'larda bir niş inovasyon olarak ortaya çıkma potansiyeline de sahiptir.

Kural & Düzenlemeler: Bu bileşen kapsamında ulusal ve uluslararası kural ve düzenlemelerin fablab'lar üzerindeki etkisi, özellikle BM SKH'leri kapsamında incelenmiştir. Görüşme yapılan tüm fablab'lar, sürdürülebilirlik kavramına sıkı bir bağlılıkları olduğunu ifade ederken; birçoğu SKH ajandası kapsamında bir öz değerlendirme veya uyumlama çalışması yapmamıştır. Yine de bu durum, BM SKH'lerine önem vermedikleri anlamına gelmemektedir. Zira halihazırda yaptıkları projeler ve günlük rutinlerindeki uygulamaları ile sürdürülebilirliğe katkı sunmaktadırlar. Anket çalışmasının ortaya koyduğu analizlere göre bu katkı en fazla "SKH 12: Sorumlu üretim ve tüketim" amacına yoğunlaşmaktadır. Bunu "SKH 8: Kaliteli Eğitim" ve "SKH 11: Sürdürülebilir şehirler ve topluluklar" takip etmektedir. Anket verileri sürdürülebilirliğin üç boyutuna (ekonomik, çevresel ve sosyal) dağıtıldığında en fazla katkının ekonomik sürdürülebilirliğe yapıldığı anlaşılmakta ve bunu sosyal sürdürülebilirlik katkısı izlemektedir. Ekolojik sürdürülebilirlik ile ilgili katkı ise görece düşüktür. Mülakat sonucundaki nitel analizler ise "SKH 8: İnsana yakışır iş ve ekonomik büyüme" ve "SKH 10: Eşitsizliklerin giderilmesi" amaçlarının sıklıkla vurgulandığını ortaya koymaktadır. Öte yandan öncelikleri olmasa bile fablab yöneticileri, mekânın işlerliğinin devamı için sıklıkla kamu fonlarından yararlanmakta; proje teklif çağrılarına başvurular yapmaktadırlar. Bu çağrıların çerçevesi de fablab'ların sürdürülebilirliğe katkılarına olumlu yönde etki etmektedir. Her ne kadar politika gündemleri bazı fablab yöneticilerine uzak ve belirsiz gelse de somut bir fayda görülen durumlarda politika içerikleriyle uyumlu hareket

edilmektedir. Sonuç olarak; kural ve düzenlemeler bileşeni, fablab'ların sürdürülebilirliğe daha fazla katkı sunmaları üzerinde yavaş ancak kalıcı bir etkiye sahiptir. Günümüzde politika yapıcılar, sürdürülebilirliği her zamankinden daha fazla desteklemekte; ulusal ve uluslararası düzeyde yürürlüğe konan pek çok mekanizma ile (AB Yeşil Mutabakatı, AB Ortak Tarım Politikası, AB İklim Eylemi Stratejisi, Düşük Emisyonlu Hareketlilik Stratejisi, Florlu Sera Gazları (F-GHG) Politikası, Enerji Verimliliği Politikası, Yenilenebilir Enerji Politikası, Eko-İnovasyona İlişkin AB Stratejileri vb.) orta katman rejim üzerinde baskısını giderek artırmakta ve rejim aktörlerini değişime zorlamaktadırlar. Yukarıdan gelen bu zorlama, tabandan gelen talepler ile uyum göstermektedir. Bu bakımdan kural ve düzenlemeler bileşeni ani etkilere açık bir yörüngede hızlı ilerlemektedir. Yine de arzu edilen sürdürülebilir dönüşümün gerçekleştirilmesinde fablab'ların daha fazla teşvik edilmesine ihtiyaç duyulmaktadır. Bu bakımdan fablab'lar ve merkezi kurumlar arasında iletişim kanallarının kurulması gereklidir.

Kullanıcı Yöntemleri: Bu bileşen sistemin en güçlü bileşenlerinden biri olarak karşımıza çıkmaktadır. Oluşturdukları bilişsel rutinler, yetkinlik ve beceri birikimleri ile fablab'ların örgütsel sermayesi, geçiş literatüründe öngörüldüğü şekliyle seyretmektedir. Bulgular, fablab'lar içerisinde sorumlu tüketim ve üretim uygulamalarının yoğun olarak gerçekleştiğine ve artan bilgi birikimine ulaşıldığına dair önemli kanıtlar sunmaktadır. Bu uygulamalar, yeniden kullanım-geri dönüşüm-atık yönetimi ve onarım pratiklerini içermektedir. Fablab'lar, bir yandan bu uygulamalarla yeni teknik ve malzeme döngülerini deneyimlerken; bir yandan da yasal engellerin üstesinden gelmeye çalışmaktadır. Mülakatlarda fablab yöneticileri tarafından geri dönüşümün maliyeti ve teknik zorlukları ifade edilmiş; üretimin ilk aşamasından itibaren çevre dostu malzemelerle dayanıklı ürünler üretmenin önemine vurgu yapılmıştır. Bu zorluklara rağmen geri dönüşüm konusu, fablab topluluğu için özel bir ilgi alanıdır.

Bu çalışmanın bulguları, pek çok fablab'ın kendi bünyesinde üç boyutlu yazıcı üretebildiğini veya montajını gerçekleştirebildiğini göstermiştir. Yine pek çok fablab, makine ve ekipmana yönelik müdahaleleri kendi imkanları ile yapmakta ve bu sayede satış sonrası mali yükleri ve üreticiye olan bağımlılıkları azaltmaktadır. Bu

yeteneklerin artırılmasında uluslararası fablab ağı tarafından geliştirilen Fab Academy programlarının da faydası olmakla birlikte görüşülen fablab'ların çoğu, bu programların tecrübe edinmede zorunlu olmadığını; birçok tekniği el becerisi ve deneme-yanılma yöntemleri ile edindiklerini belirtmiştir. Fablab'ların temel felsefesi olan açık paylaşım ve iş birliğinin etkisiyle bu tecrübeler fablab'lar arasında paylaşılmakta ve yaygınlaşmaktadır. Yılda bir kez gerçekleştirilen FabX etkinliklerinde, tüm fablab'lar fiziksel veya sanal olarak bir araya gelip; projelerini, keşfettikleri çevre dostu malzeme ve teknikleri birbirleriyle paylaşarak; bilginin ve becerinin hızla yayılmasına katkı sunmaktadır. Sonuç olarak, kullanıcı uygulamaları bileşeni yukarı yönlü ve hızlı bir yörünge çizmekte ve orta katmana geçişte örgütsel sermayeyi oluşturarak sistemin ana taşıma öğesi haline gelmektedir.

Eser: Teknolojinin yarattığı kültürel anlam, zamanla eserin başkalaşımına yol açar ve yeni haline bürünen eser de beşerî ilişkileri etkiler. Bu anlamda sistem bileşenleri sürekli etkileşim ve devinim halindedir. Fablab'lar söz konusu olduğunda; açık kaynak projeleri ve sosyal sorumluluk için yapılan iş birliği çalışmaları birer eser sayılabilir. Ancak bu çalışmada, özellikle fablab'larda üretilen ve çevre dostu olarak nitelendirilebilecek ürün ve hizmetlere odaklanılmıştır.

Gerek nicel gerekse nitel veriden sağlanan bulgulara göre fablab'lar bünyesinde üretilen ve pazara sunulan pek çok somut proje ve eser bulunmaktadır. Yenilenebilir enerji ekipmanları üretiminden, enerji verimliliği sağlanmasına; ulaşımda karbon salınımının azaltılmasından, okyanus ve toprak kirliliğinin önlenmesine; okullarda çevre bilinci eğitimi için artırılmış sanal gerçeklik uygulamalarından, engelli bireylerin spesifik ihtiyaçlarına cevap veren implantlara kadar çok çeşitli projeler hayata geçirilmektedir. Ayrıca döngüsel malzeme kullanımı, biyolojik olarak parçalanabilen malzemelere yönelim ve ekolojik temelli tasarım gibi unsurlar da eser bileşeni kapsamında göz önünde bulundurulmuştur.

Söz konusu bulgular, fablab'ların çevresel ve sosyal fayda için geniş bir ürün ve süreç inovasyonu yelpazesine sahip olduğunu ortaya koymaktadır. Mevcut teknolojilerin ekolojik zayıflıkları düşünüldüğünde, bu çıktılar üstün bir başarı olarak kabul edilebilir. Genel olarak eser bileşeni, teknoloji bileşenine bağımlı olmakla birlikte

fablab’lardaki niş yeniliklerin bir parçası olarak yukarı doğru bir yörünge izler ve fırsat pencerelerinin açılması üzerinde çok önemli bir etkiye sahiptir.

Pazarlar ve Ağlar: Çalışmanın bulgularına göre, fablab'lar genellikle pazar odaklı değildir ve örneklemdeki fablab’ların çoğu kâr amacı gütmeyen örgütlerdir. Elde edilen gelir genellikle atölyeye yeni yatırım için kullanılmaktadır. Anket verilerine göre çok küçük bir yüzde tamamen kâr amaçlı faaliyet göstermektedir. Gelir elde edilen durumlarda ana gelir kalemleri tasarım-danışmanlık hizmetleri ile prototip üretiminden oluşmaktadır. Fablab’ların faaliyetlerini sürdürmelerinde gönüllü çalışan katkısı önemlidir. Başarılı modellerini yaygınlaştırmak isteyen fablab’lar, kardeş şubeler açarak mali sürdürülebilirliği sağlayabilmektedir.

Fablab’ların en önemli partnerleri dernekler, vakıflar ve kamu kurumları gibi kuruluşlar olmakla birlikte piyasa ve ana-akım inovasyon aktörleri de bu partnerler arasında yer almaktadır. Bulgulara göre partnerlerle geliştirilen en önemli ilişkiler ortak projeler vasıtasıyla kurulmaktadır. Bunu kaynakların değişimi ve bağışlar takip etmektedir. Ayrıca kurumsal şirketler vergi indirimlerinden faydalanmak ve sosyal sorumluluk imajını kazanmak için fablab'larla iş birliği yapabilmektedirler. Üniversitelerde bulunan fablab’ların ulusal araştırma enstitüleri ile iş birliği yapması ise yaygın bir durumdur. Özetle fablab’ların birbiriyle rekabet etmek yerine iş birliği yaptığı bir ekosistem mevcuttur.

Fablab’lar, yerelleştirilmiş ve kişisel üretimi bir hedef olarak görmekte ve üretim becerilerini global piyasalardan, yerele geri kazandırmak idealine sıkı bir biçimde bağlıdır. Örneğin, Covid-19 pandemisinde, global pazarın cevap veremediği bir dönemde, fablab’lar tıbbi malzeme ve yüz siperlikleri gibi ürünleri hızlıca üreterek ihtiyaç sahiplerine ulaştırmışlardır.

Bu bileşen altında karşımıza çıkan bir diğer kavram ölçek ekonomisidir. Üretimin ölçeği, bir ürünün fiyatını belirleyen en önemli etkenlerin başında gelmektedir. Bu bağlamda, çevre dostu teknolojiler geliştirmek diğer teknolojilere kıyasla maliyetli olabilmektedir. Belirli bir sayının üzerindeki imalat söz konusu olduğunda; ulaşım, lojistik gibi ekstra maliyetlere rağmen kitlesel üretim ekonomik olarak

kişiselleştirilmiş üretime göre halihazırda daha avantajlıdır. Kişiselleştirilmiş üretimin avantajı, tüketim alışkanlıklarını değiştirerek; uzun ömürlü, dayanıklı ve kişisel zevk ve tasarıma yönelik ürünler üreterek, kitlesel üretime olan talebi azaltma potansiyelidir.

Nicel analizler, fablab'larda üretilen eserlerin yarıdan fazlası için lisanslama yapılmadığını göstermiştir. Bu bulgu, örtük bilginin, yazılı bilgiye dönüşmesi bakımından bir yetersizliğe işaret etmekte ve bilginin yayılımında olumsuz bir faktör olmaktadır. Örtük bilgi, genel olarak ortaklıklar yoluyla paylaşılmakta ve yayılmaktadır.

Netice itibarıyla bu bileşen ortaklılar yönüyle güçlü nitelikler barındırsa da mevcut teknolojik imkanlar ve maliyetler sebebiyle değişken bir seyirde ilerleyebilir. Niş pazarların güçlendirilmesi için gerekli olan yerel tedarik zincirlerinin oluşturulduğuna dair pek az bulguya rastlanmıştır ve bu pazarlarda yer edinmek için kurulan ittifaklar halen kırılgandır.

Sonuç ve Politika Önerileri

Önerilen sistemin bileşenleri birbirleriyle sürekli etkileşim halindedir. Mevcut bulgular önerilen sistemin, "kültürel anlam", "kullanıcı yöntemleri" ve "kural ve düzenlemeler" bileşenlerinin sağlam temeller üzerine tesis edilmiş olduğunu ve birbiriyle uyumlu yörüngeler izlediğini göstermektedir. "Eser" bileşeni hızlı bir yörüngede ilerlemekle birlikte, şimdilik zayıflıkları bulunan teknoloji bileşenine bağımlılığı vardır. Şu anda değişken ve tutarsız bir seyir izleyen "pazarlar ve ağlar" bileşeni ise öncelikle "teknoloji" bileşenindeki ilerlemelerin "kullanıcı yöntemleri" bileşenindeki birikimle beraber "eser" bileşeni üzerinde yaratacakları olumlu etkiyle ivme kazanacaktır. Üretilen somut ürünlerin niş pazarlarda yerel tedarikçiler vasıtasıyla erişilebilir fiyatlara sunulması bu sayede mümkün olacaktır.

Bu tartışmalar ışığında sürdürülebilir sistemin orta katmana geçişinde izleyeceği yol, literatürde "yeniden yapılandırma yolu" olarak isimlendirilmektedir (Geels ve Schot, 2007). Buna göre niş inovasyon, rejim katmanında öncelikle yerel veya spesifik bir

bağlamda kabul görür, yetkinlik kazanır ve zamanla daha geniş bir perspektifte benimsenir. Yeniden yapılandırma yolunu izleyen nişler, mevcut rejime simbiyotik eklentiler olarak giriş yapar ve sistem aktörleri tarafından uyarlanarak kalıcı hale gelir.

İkinci bir ihtimal ise uyumsuzluk-yeniden uyumlanma yolu olabilir. Bu yolun izlenmesi kitlesel üretim sisteminde, öngörülemeyen büyük bir çöküş meydana gelmesi ve fablab'ların bu duruma sağlam çözümlerle yanıt verebilmesi halinde gerçekleşebilir. Her iki durumda da rejim katmanına giriş yapan yeni sistemin kısa vadede stabil hale gelmesi beklenemez.

Günümüzde kamu politikalarının çoğu neo-klasik ve evrimsel iktisadın ilkelerine dayanmaktadır. Hükümetin politika müdahalesinin temel gerekçesi piyasa başarısızlığıdır. Bu ilkeler geçerliliğini korumakla beraber sürdürülebilirlikle ilgili sorunlara müdahale eden yeni bir politika yaklaşımı da ortaya çıkmakta ve misyon-odaklı politika tasarımları da bu yaklaşıma eşlik etmektedir. Klasik politika yaklaşımının yanında, sürdürülebilirlik çerçevesinde sistemin aksayan unsurlarına müdahaleyi öngören yaklaşımlar da dikkate alınarak; tezin son bölümünde bir dizi politika önerisi sunulmuştur. Bu öneriler:

- Eklemeli imalat ve üç boyutlu baskı teknolojilerindeki gelişmeyi hızlandırmak için tematik temel ve uygulamalı araştırma fonları sağlanması,
- Disiplinler arası iş birliğini teşvik eden ve taban örgütü inovasyonların da dahil olduğu konferanslar düzenlenmesi,
- Hammadde üreticileri ve fablab temsilcilerini bir araya getirerek daha sürdürülebilir malzemeler için iş birliği yapılmasını sağlayan organizasyonlar düzenlenmesi,
- Üretilen çevre-dostu eserlerin kamu tarafından satın alımının kolaylaştırılması,
- Üretilen çevre-dostu eserler için akreditasyon ve sertifikasyon başvurularının özendirilmesi amacıyla mali destek ve mevzuat desteği sağlanması,
- Sınırları belirlenmiş biçimde (misyon) yerel değer zincirleri kurulması,
- Nişlerde bilgi birikiminin desteklenmesi için lisanslama faaliyetlerine yönelik insan kaynağı ve danışmanlık desteği sunulması,
- Belirlenen misyonlar bazında kurulan ortaklıklar için yol haritalarının hazırlanmasını,

- Politika yapıcılar ve fablab'lar arasındaki iletişim boşluğunu ortadan kaldırmak ve vatandaş katılımını artırmak için iletişim komiteleri kurulması,
- Elektronik atıklara erişimde kolaylaştırıcı mevzuat geliştirmek,
- Sorumlu tüketimin teşvik edilmesi için K12 düzeyinde eğitim müfredatının güncellenmesi ve halk nezdinde bilinçlendirme faaliyetleri yapılması,
- İyi uygulamaların seçilerek yerleşik firmalara özendirilmesi

olarak özetlenebilir.

Bu politikalar uygulanırken dikkat edilmesi gereken husus, fablab'lar üzerinde ticarileştirme zorlamasının olmamasıdır. Tabanın onayı alınmadan tasarlanacak politikalar bu örgütler üzerinde başarısız olacaktır. Niş pazarlar oluşturma hedefi, sürdürülebilirlik amacı gözetilerek izlenmelidir. Fablab'lar ile olan iletişim kanallarının açık tutulması ve ihtiyaç duyulan konularda danışmanlık desteği sağlanması gibi müdahaleler fark yaratacaktır. Son olarak, hedef kitlesinde genç jenerasyon olan fablab'lar, sürdürülebilir yarınlar için birer değişim ajanı olarak görülmeli ve sadece teknoloji politikasının değil, eğitim politikasının da bir unsuru olarak ele alınmalıdır.

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