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Exploring scenarios to facilitate the access to 3D printing technology through sustainable product-service systems in the Egyptian maker market

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Exploring Scenarios to Facilitate the Access to 3D Printing Technology through Sustainable Product-Service Systems in the Egyptian Maker Market

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List of Abbreviations

GEM – Global Entrepreneurship Monitor

PSS – Product Service System

S.PSS – Sustainable Product Service System

PO – Product-oriented

UO – Use-oriented

RO – Result-oriented

DE – Distributed Economies

DM – Distributed Manufacturing

AM – Additive Manufacturing

ICT – Information and Communication Technologies

NGO – Non-governmental Organization

CEO – Chief Executive Officer

UN – United Nations

EU – European Union

STL – Standard Triangle Language, Standard Tessellation Language

CRM – Customer Relationship Management

Abstract

The research aims to investigate two models: Sustainable Product Service System (S.PSS) applied to Distributed Manufacturing (DM). S.PSS aims to combine environmental with social and economic sustainability to achieve social equity in low and middle-income contexts through a system design of products and services satisfying the market demand. DM allows the organization of connected small scale and flexible production units to share various forms of resources (tangible or intangible), while using emerging technologies. The combined models aim to address the environmental, social and economic issues in low and middle-income contexts by offering new opportunities for young makers who wish to be entrepreneurs to develop sustainable local startups. The research started by covering past work about approaches, opportunities and barriers of the two models through literature review. Then, a collection of international cases of small-scale production were studied further and other case studies in the Egyptian context were formulated. The Egyptian case studies were based on qualitative methods (mainly in-depth interviews, observational research and reflective field notes) and investigated the operational tactics of PSS to fill research gap. Participatory workshops were held to discuss the possible scenarios for applying the coupled models in business, especially in the field of Additive Manufacturing. Later, experts were interviewed to discuss whether the scenarios are applicable in a low and middle-income market like Egypt. The outcome is a sustainable design-oriented scenario (from proposed near-future scenarios) that reflects the advantages of S.PSS applied to DM for the Sustainable Development in low and middle-income contexts; in addition to a set of guidelines for applying these scenarios to support makers' market. The scenarios and guidelines are to fill the research gaps found in previous studies discussing the mentioned models and to pave the way for future studies with same focus.

Introduction

In a developing country like the Arab Republic of Egypt, it is challenging for a local entrepreneur to start a business due to barriers enforced by governmental regulations or economic constraints. Reports from the world bank and Global Entrepreneurship Monitor GEM for the past years from 2016 to 2017, display low ranks in the indicators related to the business ecosystem in Egypt. As a consequence, the young generations are afraid of being involved in entrepreneurial activities due to these barriers, and the first four key factors mentioned in the GEM report that constrain entrepreneurship are: limited access to financial capital, bureaucracy to get permits in certain sectors, unsupportive regulations for entrepreneurship, and lack of education and entrepreneurial skills (GEM, 2017).

These obstacles need to be resolved in order to make an "enabling ecosystem" for entrepreneurship. Entrepreneurship has been identified as one of the main drivers for sustainable development, and the international research about entrepreneurship has become important when academics and policy makers identified how small, medium and micro-sized enterprises are actually playing an important role in the economy by decreasing unemployment rates and poverty which predominate the developing third world countries nowadays (GEM, 2017). In the latest conventions of the United Nations UN, 17 goals were formulated to address the development problems which today's world is facing. The 8th goal, in Figure 0-1, was to reach "Good Jobs and Economic Growth", and it aims to:

Figure 0-1 The 17 Goals of Sustainable Development (General Assembly, United Nations, 2015)

“Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services” (UN Economic and Social Council, 2016; General Assembly, United Nations, 2015).

Despite of this goal, the Egyptian population is still suffering from unemployment and poverty. The youth population has reached 26,8% in 2017 for age ranges of 15 to 29, which represents the quarter of the population (approximately 97 million) (CAPMAS, 2017). According to the world bank, Figure 0-2, the level of unemployment of youth (ages 15-24) in Egypt reached approximately 33% in 2016, and in 2017 it remains the same with a slight decrease (The World Bank , 2017). It is also important to mention that the percentage of population living in extreme monetary poverty (National Lower Poverty Line) in 2015 has reached 27.8% (CAPMAS and UNICEF, 2017), and 28% of this population are young people (CAPMAS, 2016).

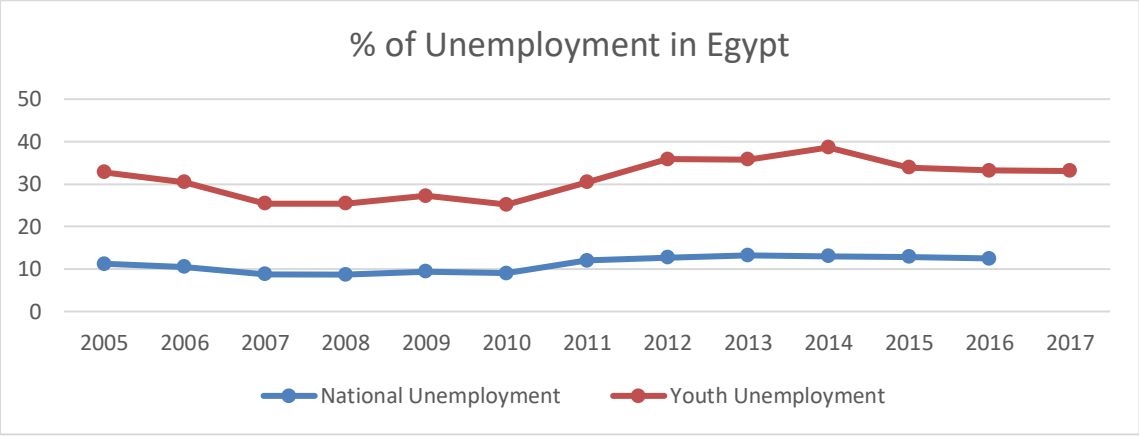

Figure 0-2 Comparison between unemployment on national level and youth (The World Bank , 2017)

These statistics show the lack of opportunities to sustain a reasonable economic and social status in the young population, and in consequence, Egypt can be referred to as low and middle-income country due to its socio-economic issues, mainly poverty and unemployment. Despite of this fact, the GEM Report of 2017 is mentioning these issues as promoters for Entrepreneurship; but the access to financial resources remains missing and is stated in the constraints. This contradiction shows that although unemployment and poverty look like features of low social and economic progress, they are good incentives for the Egyptians to

launch start-ups, and the access to the financial capital can be provided through other methods (loans from banks, angel investors, etc.). New network-based business models provide good insights of how to have access to resources without the need for an initial investment cost. This thesis will discuss two models that are tackling these approaches: Sustainable Product-Service System and Distributed Manufacturing.

Sustainable Product-Service System (S.PSS) applied to Distributed Manufacturing (DM) is a concept proposed to address environmental, social and economic issues, and offer opportunities for the youth to launch start-ups without the need for an initial capital by allowing access to resources. Distributed Manufacturing, one type of the Distributed Economies (DE), has been chosen due to limited past studies covering its coupling with S.PSS. The recommendation section in a recent study is stating the need to develop near-future scenarios and systematic guidelines for their application (Petrulaityte, Ceschina, Peia, and Harrisona, 2017).

The main barriers, discussed in this study, are: access to tangible and intangible resources (funds, skills, knowledge and technology), bureaucracy and regulative policies. Therefore, this research aims to find ways to overcome them and fill the research gap of developing near-future scenarios of S.PSS applied to DM and their application guidelines. The research questions proposed in this thesis are:

- How can S.PSS applied to DM tackle the barriers hindering Entrepreneurship in a country of a low and middle-income like Egypt?
- What other barriers exist in the ecosystem against access to technology and sustainable business practices like S.PSS?
- How can PSSs operate in a market like Egypt, and what are their impacts on the local market?
- What are the possible scenarios for S.PSS applied to DM, and their possible impacts on the three pillars of sustainability?

In Figure 0-3, the research framework is illustrated to show the topics covered in the literature review, the methodology and the final outcome of this study. The methodology is qualitative and includes: a literature review about the Egyptian entrepreneurial ecosystem and the two models S.PSS and DM, web research to collect international case studies, workshops to generate near-future scenarios for the coupled models, in-depth interviews with stakeholders in the local market who have experience in relevant business models to adjust the scenarios generated and formulate case studies relevant to Egypt.

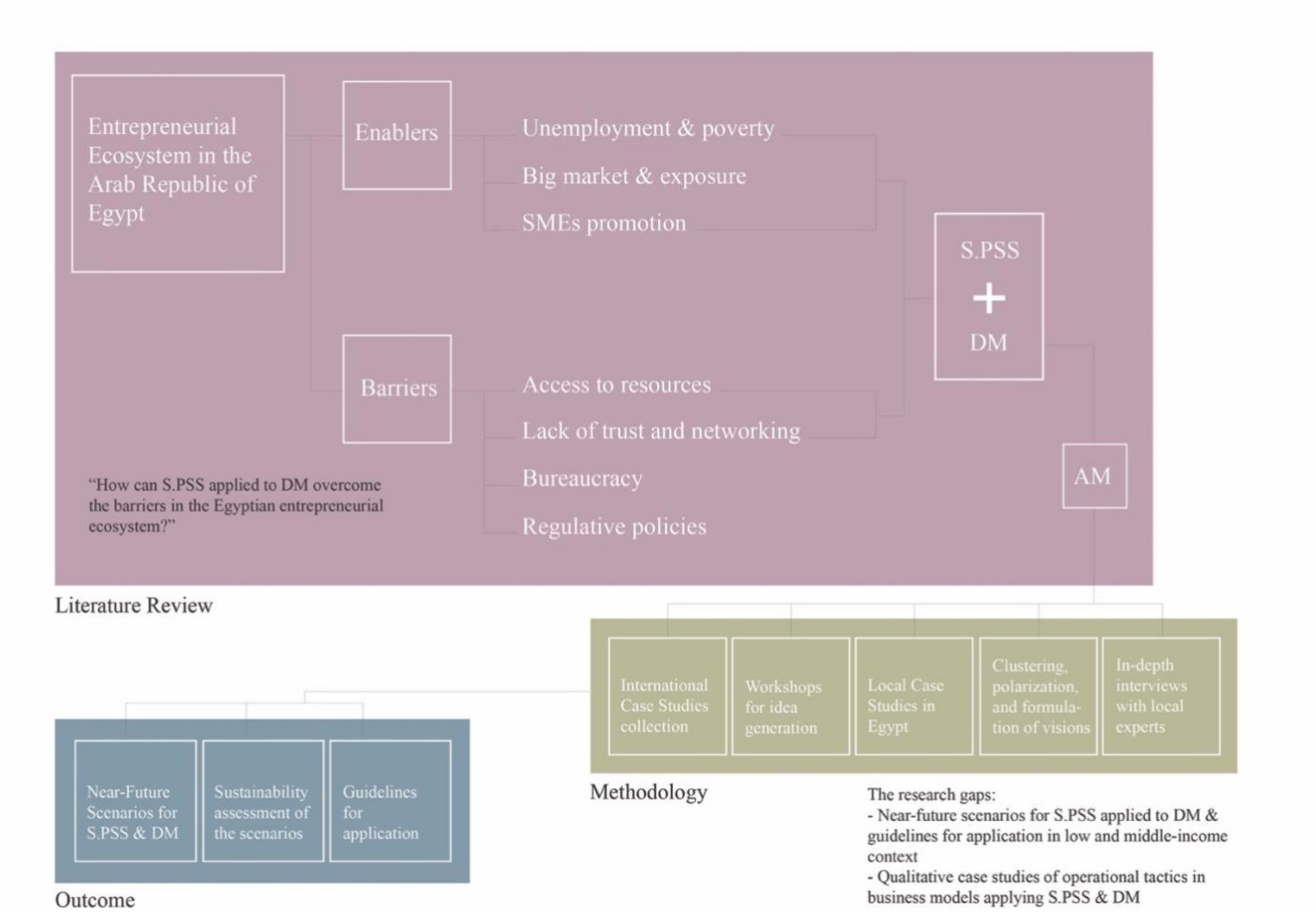

Figure 0-3 Research Framework for literature review and methodology

1. Literature Review

1.1. Description of Egyptian Entrepreneurial Ecosystem

The Global Entrepreneurship Monitor (GEM) reported in 2017 that entrepreneurship in Egypt is perceived as a positive activity and good choice for a career: 83.4% of the sample (individuals between the ages of 18 to 64) confirmed that entrepreneurship is a good career choice; this result ranks Egypt the 4th among GEM countries. From the social status perspective, it is considered as the right path to escape poverty and unemployment and have a good quality of life; so, the incentive for entrepreneurship exists and it is well perceived by the society (Placeholder1). However, the ease of doing business in Egypt is ranked 122 out of the 190 economies covered in the Doing Business Report of 2017, compared to the ranking of 126 for 2016 (World Bank, 2017). The entrepreneurial environment in Egypt is considered weak and not as enabling as it should be (Saeed, El-Aasser, and Wasfy, 2015). Hence, the ambition of Egyptians to be entrepreneurs exists but the ecosystem is still not encouraging strongly this ambition.

The economy of the country is identified as efficiency-driven (driven by necessity), while a percentage of 61.2 are encouraged to start businesses because of opportunity rather than necessity (Placeholder1). Such start-ups in a country like Egypt create a strong drive in the economy, help in decreasing the unemployment, have a good influence on enhancing international trade activity and improve the Gross National Product GNP (Saeed, El-Aasser, and Wasfy, 2015). The indicators of starting a business and access to credit have reached the ranks of 39th and 82nd respectively among 190 countries (World Bank, 2017). From these ranks, it is evident that Egypt is standing strongly among the countries that facilitate the process of starting a business, though the access to financial resources is not a strong feature of the ecosystem. The procedures of starting a business are developing when it, however getting credit (as securing funds) is still a quite complicated practice due to some limitation; these limitations are projected in the regulations and institutions that should facilitate the provision of loans and capital for borrowing (World Bank, 2017). It is worth to mention also that the political and economic situation in the country, and the limited access to finance has pushed the rank of Egypt in the perception of entrepreneurial opportunities from the 21st in 2010, to the 38th in 2016, which falls under the global average (Placeholder1).

To highlight what should be done to enhance the status quo, on one hand, the key factors that hinder starting business and that are going to be tackled in this study are: financial resources access, the lack of proper education about entrepreneurship and related skills, the missing culture of trust and taking risks, and the lack of networks that provide other resources (e.g. knowledge, expertise, markets, funds, etc.) that support the business operation (Placeholder1).

From the overview given about the ecosystem, it is evident that the Egypt market is still suffering from bureaucracy and hindering policies, lack of tangible and intangible resources (funds, skills, knowledge and technology), lack of trust and networking, and others. The factors mentioned should be tackled intensively and efficiently in order to promote entrepreneurship and encourage people to start their own business. Motivation to address these issues can come from the unemployment and high poverty rates, that push the entrepreneurs to take the risk and make initiatives. To help them overcome the barriers, new scenarios and business models should be proposed for low and middle-income contexts like Egypt. In the following sections, modern models in entrepreneurship will be discussed in order to come up with new concepts that overcome some of the obstacles that face the Egyptian entrepreneurs.

1.2. Frugal Innovation

Regarding sustainable business models, sustainability always focuses on the resilience of the created systems from the social, ecological and economic aspects; it puts in consideration the economy and the society while respecting the boundaries of the environment capability (Arnold, 2015). To have such resilient systems, sustainable innovations are developed to provide the necessary improvement that deals with the environmental, economic and social worries (Arnold and Barth, 2012; Arnold and Hockerts, 2011). Hence such innovations must deal with the environmental impacts by using tools like eco-design and eco-efficiency in order to optimize the use of resources and reduce pollution and waste per the production unit, without neglecting the usage stage in the lifetime of a product (Bocken, Short, Rana, and Evans, 2014). This goes without ignoring the socio-economic impact that represents a key challenge for any business, ensuring the quality of life for the customers, while tying it with the economic and environmental benefits (Rosca, Arnold, and Bendul, 2017). Socio-economic issues are summarized in limited capital, talent and technology, in addition to

limited resources with which entrepreneurs in such countries need to figure out ways to solve their problems (Hossain, Simula, and Halme, 2016).

Unlike developed countries, technological discoveries are not the main focus when it comes to innovations in developing countries (Zeschky, Winterhalter, and Gassmann, 2014; Soni and Krishnan, 2014; Brem and Wolfram, 2014), because usually these innovations include new patterns that combine knowledge and technology that already exist (Govindarajan and Ramamurti, 2011). Therefore, these innovations are usually solutions of low-cost that target people from low-income contexts, and that explains why they usually are spreading in countries with the same socio-economic circumstances (Hossain et al., 2016). Frugal innovations work exactly in such contexts and it is easily to detect frugal innovations in emerging markets with low-income feature (Luo, Sun, and Wang, 2011), hence the great attention given to the emerging markets responding to their potential in growing and the availability of business opportunities (Hossain et al., 2016). Explaining frugal innovation, it is a process where customers' needs become the main target that products and their manufacturing aim for (Colledani et al., 2016); so, developing new business models are necessary to adapt to this process. A business model is a way to explain how a company creates value through opportunities utilization in business (Zott and Amit, 2010), and "Business model innovations for sustainability are defined as: innovations that create significant positive and/or significantly reduced negative impacts for the environment and/or society, through changes in the way the organization and its value network create, deliver value and capture value (i.e. create economic value) or change their value propositions" (Bocken et al., 2014, p. 44). In light of this definition, new business models are developed in order to restructure the value chain and redesign goods for efficient and smart usage of resources and industrial processes (Berger, 2013).

The process of frugal includes not just the product: frugal innovation includes the product, service or a mix of both that should remain affordable, friendly to use, sustainable, and efficient in using resources (Hossain et al., 2016). It is necessary to highlight the customer position in such business models: frugal innovation is considered a customer-centric approach and the value is co-created with the target group through the long-term collaboration of providers with users in the process of designing products and services, and their delivery (Jha and Krishnan, 2013), which in its turn relate to the product-service

patterns from the point of restructuring the value chain and business models (Colledani et al., 2016). From a holistic view, designers now are shifting from product to service focused approach in design (Rodriguez and Peralta, 2014), and this shift is due to the economic change of perspective to focus on systems and services rather than designing products only, changing the whole paradigm in design thinking (Young, 2008). In fact, the method has changed from problem solving, which is centered on product design, to system thinking that include the service design as well (Jonas, 1996; Rodriguez and Peralta, 2014).

In such context, focusing only on the product becomes an outdated approach and should be exchanged with an approach that is based on service to deliver the added value and build long-term relationships (Zeschky, Widenmayer, and Gassmann, 2011). These collaborations need some enablers as technical and innovative solutions for better operation of the business models; these enablers can be advanced information and communications technology ICT, production intelligence and internet of things (Jha and Krishnan, 2013), to set a collaboration on a network level in production. From the product-service perspective in doing business and building long-term relationships with customer for better value delivery, new systems are developed to redesign business models where the product and the service are combined to satisfy the needs. Product-service systems (PSS) have been proposed by researchers as a way to endorse sustainability and develop strategic business model (Manzini and Vezzoli, 2003; Tukker, 2015). In the next chapter, PSSs are defined, discussed and reviewed in literature for a better understanding of its mechanism and offered opportunities.

1.3.Product-Service System Design as A Business Approach

Today's business is not based just on delivering products that satisfy the customer, people now care also about the quality of service they receive while acquiring their satisfaction. With globalization and the increasing competition in the international markets, many companies seek to differentiate themselves. In many cases, they try to adopt new marketing strategies and decrease prices of products; however, what the market really needs is to identify how the customers perceive the offering of the company (Tan, McAloone, and Gall, 2007). Therefore, developing more convenient services became part of the business models that exist in today's world. Business models are now relying on services, dematerializing their processes and delivering the satisfaction required through intangible services. Therefore Product-Service System PSS appeared, and it "consists of a mix of tangible products and

intangible services designed and combined so that they jointly are capable of fulfilling final customer needs" (Tukker and Tischner, 2006). The definition identifies the importance of the customer satisfaction as the starting point of creating the system. PSS was developed initially when design researchers wanted to better identify environmental sustainability: Life Cycle Assessment LCA and Eco-design tools were not practical in the context of business and products' sale, therefore PSS was promoted to open the door for innovation to go beyond what the product can offer alone, and to combine it with an intangible offering like service (Vezzoli et al., 2014). In the light of this, industries became more open minded to the idea of PSS and adopting services in their business models to build long-term relationships with their customers and enhance their value proposition.

This change in how business approaches new systems is derived from some motivations: the high competitiveness (as mentioned earlier due to what PSS can offer), less expenses, better customer experience "convenience and flexibility", and the enhanced corporate identity (Pigosso and McAloone, 2016). In addition to these economic benefits, the environmental qualities of PSS: reduced material and energy during the production and consumption/usage, extended responsibility of the manufacturer over the product's life cycle, developing more enduring and efficient products, enhanced quality of the end-stock and avoiding down-cycling, optimized products for better performance in their essential function (fulfilling products' requirements), encouraging re-use of the products/components, and using more advance and ecological technologies (Beuren, Ferreira, and Miguel, 2013; Tukker and Tischner, 2006). Hence, the relationship between the company and the customer does not end by transferring the ownership of the product but also include post-purchase activities (monitoring usage, maintenance and disposal). Adding on this, the responsibility of the company assumes for the social and environmental impacts of its offer. Especially after the appearance of Circular Economy CE concept; it is a social and industrial approach that aims for the goals of sustainability by adopting the notion of waste-free processes (Rios and Charnley, 2016). Usually the benefits of adopting CE in business are: saving materials, lowering issues in supply, enhancing the loyalty of customers, and developing new sources of revenues (Winkler, 2011; Ellen MacArthur Foundation, 2014; Schenkel, Caniëls, Krikke, and Laan, 2015). Therefore, new models have been introduced where the ownership has new forms and the company strategy is not only focused on the technicality of sustainable design, but also the whole corporate sustainability (Rios and Charnley, 2016).

Table 1-1 Comparison between business-as-usual and S.PSS offering (Tan, McAloone, and Gall, 2007)

	Business-as-usual	S.PSS
Involvement in customer activity	No	Yes
Value	Extraction Process	Creation Process
	Delivering Activity	Co-creation Activity
	Through offering a product that satisfies the demand	Through interaction with the customer during usage to develop insights about the product and customer
Operation	Process ends with production description or production realization and sales	Process includes use phase to ensure constant development associated with customer's activities
	Company sells ownership of products and provide maintenance	Company takes responsibility of products during usage, maintain and dispose them
Responsibility	No responsibility of the social and environmental impacts	Responsibility of total social and environmental impacts of their product
	No responsibility of developing further relationships	Responsibility in partnering with other companies and their mission in the process
Knowledge and competencies	Directed to be included in the product	Directed to the customer's activities (training, educating, etc.)
Development Activities	Are Top down from strategies put by the company and its market position	Uncover possible relationships and organize the network of partners
Market Positioning	Based on comparison with others according to specific parameters	Based on the development of new networks
Market Stability	Field configurations are stable	Markets are not stable due to following emerging opportunities

In Table 1-1, the differences between the business-as-usual (traditional offering) and S.PSS offering are further concluded from the study of (Tan, McAloone, and Gall, 2007) and explained. The level of interaction between the customer and the company varies in the two models, where in PSS the level of interaction is higher than in the business-as-usual. Also, the level of interaction is not just depending on the customer-company relationship, but also the interaction on a network level for service and product providers, therefore we can call it a "co-dependent" relationship in the aim of delivering a final satisfaction for the customer's demand. Moreover, from the comparison we see that PSS is paying attention to the sustainability aspects of the business itself and the offering, shedding the light on the impacts of the product provided from environmental and social perspectives. However, PSS has developed further to be Sustainable PSS, referred to as S.PSS, because it has been discussed that although its potential to offer more sustainable systems PSS is not fundamentally sustainable and some cases reported a higher environmental impact than business-as-usual. Yet with the right design process for the system, the environmental performance is significantly better due to the efficiency of the business' infrastructure and networks, along with the well-designed products and services (Pigosso and McAloone, 2016).

1.3.1. Sustainable Product Service Systems Offer Model

Sustainable Product Service System (S.PSS) is "an offer model providing an integrated mix of products and services that are together able to fulfil a particular customer demand (to deliver a 'unit of satisfaction'), based on innovative interactions between the stakeholders of the value production system (satisfaction system), where the economic and competitive interest of the providers continuously seeks environmentally and socio-ethically beneficial new solutions" (Vezzoli et al., 2014, p. 31). The step of adding "Sustainable" to "PSS" is to highlight the responsibility of the business towards the customer, where the value offered must be socio-ethical and environmental. But how exactly does S.PSS work?

In a S.PSS model, the provider of the product, who is the business owner, can retain its ownership and in consequence, there is always an incentive to increase the lifetime of this product to avoid extra costs of maintenance, replacement and disposal. With retaining the ownership comes an economic incentive which is represented in the resources reduction,

because the profit is always dependent on the unit of satisfaction delivered to the customer, also the managerial costs are streamlined (Vezzoli, Ceschin, Diehl, and Kohtala, 2015). At the end of the product's life, the provider can still benefit from some components by re-use or recycling (re-manufacturing) instead of manufacturing new ones from scratch; as for the material used, the owner in such systems is keen on preserving the material through upgrading, recycling, fixing, remanufacturing, recovering energy, or composting (Vezzoli et al., 2015). This is when it comes to the business owner. As for the customer, S.PSS offers the benefit of cutting the costs of the initial investment (capital) and of running the business by allowing access to goods and services in return of only paying per unit of satisfaction (Vezzoli et al., 2014). Therefore, the system is focused on the usage context because the products are not sold to the end user, and the relationship between the provider and customer is lengthened; this is what makes such a system socio-ethical as well as economic.

To simplify the concept behind this system, we can say that S.PSS is based on the approach of providing access to resources through paying per the satisfaction acquired and getting rid of the incentive behind ownership. In consequence, a wider range of people have access to the same products and/or services without the need to have a big capital to acquire them and satisfy their needs. Also, the running costs are covered in the amount paid for the satisfaction obtained, and in consequence the customer is no need to maintain the products and the provider makes sure of their longevity. Therefore, S.PSS is described as a promising model, because of the benefits it provides by putting the customer in the center of its operation, encouraging the local participation instead of involving global stakeholders, increasing local employment and skills spreading due to the intense relationship and labor that characterize such systems, and in consequence boosting the whole local economy. In addition, the marginal costs of operating PSSs when associated with the innovation of the business model are quite low, that is because of their presence in a market that is based on having access to and exchanging of products and services instead of a market that is based on ownership (Rifkin, 2014), this in turn promotes the sustainable behavior through the stewardship of products by implementing contracted services, and efficient use of resources as part of the product-service system (Mont, 2002; Maxwell, Sheate, and Vorst, 2006; Tukker, 2015). The competition advantage in such market usually goes to the business models who can incorporate advanced ICT for accessibility and improved performance in services with less intermediates (França, Bromana, Robèrt, Basile, and Trygg, 2017).

Despite of these advantages, S.PSS is not implemented in business broadly due to barriers that include the structure of both the companies and regulations in the ecosystem, however Distributed Manufacturing DM is proposed by one study to address some of these barriers (Petrulaityte et al., 2017). On the other hand, researchers highlight the opportunities S.PSS offers, which can in turn support the presence of the three pillars of Sustainability (social, economic, and environmental) in the designing process of S.PSS.

The barriers and opportunities of S.PSS will be reviewed in literature to provide a complete picture about this model and areas that need to be worked further during its application, especially when applied to DM.

1.3.2. Opportunities of S.PSS

Some of the opportunities mentioned were how the model cuts the need for initial investment and running costs by providing access to resources instead of individual ownership, offers more customization option and high-quality products/services for customers, increases local employment, and creating long-term relationship with the customer (Vezzoli et al., 2015). One major opportunity offered by S.PSS is the ability of launching startups more easily due to limited requirements of the system and its low cost. This advantage is the perfect scenario for low and middle-income contexts that suffer from limited access to resources (tangible or intangible). The benefits of S.PSS in creating Startups are categorized under each pillar of sustainability:

- for the environmental, PSS supports the dematerialization of offerings switching from products to services, and in consequence material and energy consumption will drop significantly; also designing life cycles of products to be longer will in return decrease the amount of waste generated and promote the efficient use of these products (Mont, 2002; Tukker and Tischner, 2006)
- For the social, in PSS is based on the network of stakeholders that the system is built upon and which creates a set of benefits that include: the integration of diverse markets, the increase in stakeholder's awareness about their roles in the network, and the provision of access to services for people with low income through the implementation of shared systems (Omann, 2007; Ness, 2007)

- For the economic pillar benefits have been emphasized as: the opportunities of incorporating new markets, a significant increase of competitiveness, adaption of operations that are more efficient, and introduction of new technologies and innovation into the processes (Omann, 2007).

1.3.3. Barriers of S.PSS

PSS implementation barriers have been discussed in many studies, and in a recent study done in 2017, barriers are categorized in three groups: "barriers for companies, barriers for customers and regulative barriers" (Petrulaityte et al., 2017). The barriers mentioned on a company level are: lack of knowledge about designing PSS (Mont, 2004; Maurizio Catulli, 2013) and fear of consequences of partnership e.g. co-dependence, core competencies decrease, confidential information spreading, complications in the purchase of the customers, and customer's complicated behaviour when it comes to purchasing and accepting the service (Vezzoli et al., 2015; UNEP, 2002; Mont, 2004). The barriers for customers are: also lack of knowledge and uncertainty about the system, the ownership as a representation of the social status (Catulli, 2012; Rexfelt and Ornäs, 2009), their need for independence, fear from using unhygienic parts (Catulli, 2012) and the costs that might be hidden in the initial price of the service (Rexfelt and Ornäs, 2009). Finally, on Context level, the two studies of Vezzoli (2015) and Petrulaityte (2017) argued that the government should interfere to support S.PSS businesses, against business-as-usual practices, through providing policies, infrastructure and technologies to make them more appealing for the local market.

1.3.4. The categories and Tactics of S.PSS Business Models

S.PSS is classified into three categories of application: Product-oriented (PO), Use-Oriented (UO) and result-oriented (RO) (Tukker, 2004): PO is adding services to the product offered within the system, UO is based on services to increase the use intensity of the products (e.g. renting, sharing, or leasing), and RO is the most concentrated on fulfilling customers' demands by creating an original system to deliver a result without their interference (Tukker and Tischner, 2006; Reim, Parida, and Ortqvist, 2014). There are two approaches for building successful business models: 1) a radical transformation is required in the value-chain and the industrial process, therefore the business model should be developed carefully to avoid negative impacts on the social, economic and environmental aspects (Martinez, Bastl, Kingston, and Evans, 2010), 2) adopting some tactics in building S.PSS models to get the

value expected from their implementation (Reim et al., 2014). The tactics needed in S.PSS implementation have been concluded by the authors Reim, Parida, and Ortqvist (2014) in their literature review, which include five main tactics: contracts, marketing, product/service design, sustainability, and networks in the operation of the business to maintain long-term relationships with customers, see Figure 1-1.

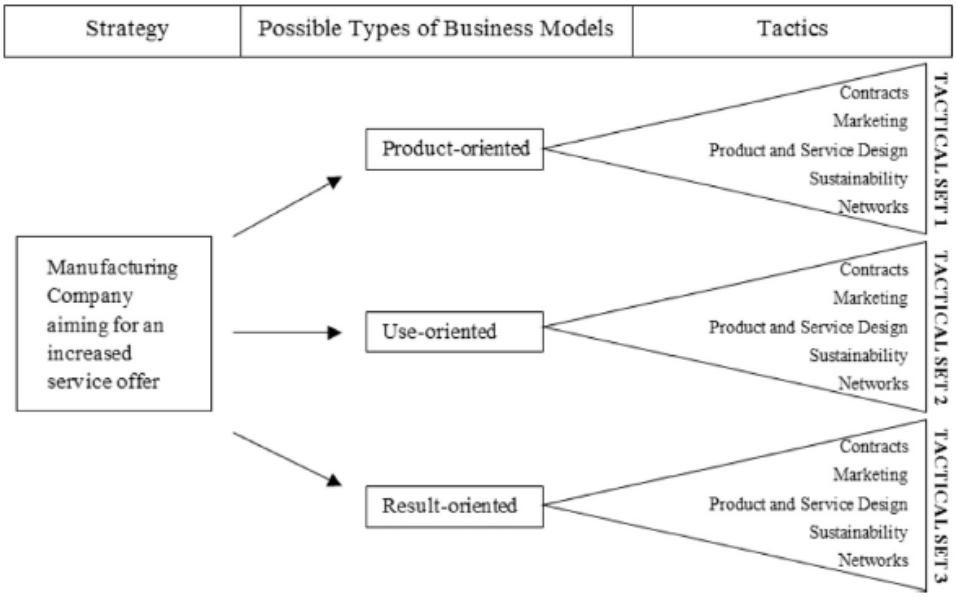

Figure 1-1 Relationships among strategy, business models and tactics for PSS (Reim, Parida, and Ortqvist, 2014, p. 67)

These operational tactics and their main aspects are discussed further in the methodology chapter.

1.4. Distributed Manufacturing Systems

The first time "Distributed" was used in the study of Paul Baran in 1964, see Figure 1-2.

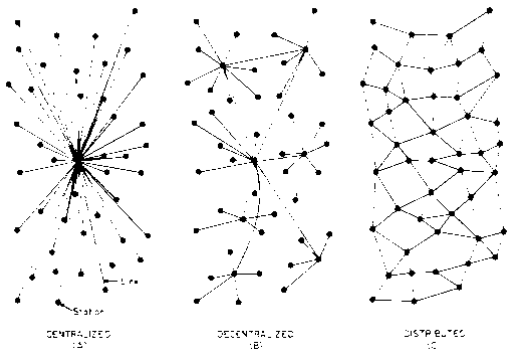

Figure 1-2 Centralized, Decentralized and Distributed Networks (Baran, 1964)

The study classified communication networks into three forms centralized, decentralized, and distributed. The classification is related to where the decision making happens in the network. The centralized network is built upon a single node in the center on which the whole network is depending; unlike the decentralized that is constituted of set of stars connected to a centralized node forming a network that does not rely on a single point for operation (Baran, 1964). As for distributed, all nodes are connected to form a network that relying on several points for operation and processing, and accordingly the decision making is not centralized but distributed over the network. The form of distributed networks developed further to include not only communication, but also manufacturing systems that are relying on small units connected to divide the production over the network.

Over the last two decades the research on Distributed Manufacturing Systems (DMS) have been evolving; and the term is defined usually by the main characteristic, which is the geographical distribution of its components (Rauch, Dallinger, Dallasega, and Matt, 2015). Twenty years ago, in the beginning of globalization, DMS is described by splitting the value chain and the product into what is called "sub-parts or sub-processes" with manufacturing at diverse locations (Gyires and Muthuswamy, 1993; Magretta, 1998). It is claimed that the reason behind this shift is the low cost of production in some countries, thus the planning and scheduling of the production process was necessary due to dispersion of units geographically (Landier, Nair, and Wulf, 2009). DM is believed to be the future of industrial operations due to the increased need for customization, proximity to the customers, and less delivery time and cost. DM is defined as "*modern organizational models for small, flexible and scalable manufacturing units in distributed production networks are needed to fulfil actual requirements such as individual customer needs and a sustainable supply chain*" (Matt, Rauch, and Dallasega, 2014, p. p.185). And in another study, it is defined as "*a production system made of small-scale manufacturing units equipped with physical and digital technologies, which enable localization of manufacturing facilities and comprehensive communication between all supply chain actors in order to facilitate customer oriented on-demand production"* (Petrulaityte et al., 2017, p. 376). From the two definitions we conclude that DM:

- Is about small units of production that are local, small, flexible and possibly scalable
- Is usually working in networks where communication is a basic infrastructure for its success

- Facilities should be equipped with two types of technologies: the physical and the digital
- Supply chain is divided on many actors in the system
- Aim is to fulfill customer demand, and on-demand production, therefore it is a customer-focused system.

The resources planning is adjusted accordingly, and decision making should be decentralized through multi-agent systems (Tang, Li, and Hu, 2007). DMS is benefiting from the advance ICT, as a result software integration is necessary in the area of information system for company's divisions (Misra et al., 1999). Rauch and the other scholars (2015) have stated the importance to investigate small and medium enterprises (SMEs) in the research of DMS because of their independence that represents a value to the network. DMS is a result of: sustainability, high logistic costs, mass customization, democratization of design, customer/market proximity, resources efficient utilization, localization and authenticity (Matt, Rauch, and Dallasega, 2014).

1.4.1. Types of Distributed Manufacturing

In the following Figure 1-3, the authors (Matt, Rauch, and Dallasega, 2014) included a detailed description of DM forms and their characteristics. They have categorized them in eight forms: four that represent existing models and their evolution, and the other four are future visionary forms, which appear among distributed manufacturing systems nowadays.

Evolution stages of distributed model factories			Special forms of decentralized production		
Type	Classification	Description and characteristics	Type	Classification	Description and characteristics
1	**Standardized and replicable model factory**	Replicable and standardized model factories for geographically distributed production of defined products with a defined number of units.	5	**Service model of industrial contract manufacturing**	Production service providers and intermediaries ("Production Provider") for distributed industrial contract manufacturing of different products with similar manufacturing steps and varying quantities on behalf of diverse clients.
2	**Modular and scalable model factory**	Modular model factories for geographically distributed production of defined products with flexibility in relation to item quantity and thus scalability of the manufacturing system.	6	**Mobile and non-location-bound model factories**	Mobile non-location-bound and highly flexible as well as scalable model factories for temporary production requirements reducing procurement and/or distribution transports.
3	**Flexible und reconfigurable model factory**	Flexible and rapidly reconfigurable model factories for geographically distributed manufacturing of products in different variants (product flexibility) and various quantities (quantity flexibility).	7	**Production-Franchise**	Model factories, operated independently by franchisees, with more or less flexible and adaptable production units for geographically distributed production of products in a franchise network.
4	**Changeable and „smart" model factory**	Intelligent and self-optimizing model factories with a high degree of adaptability to geographically distributed production of different products with similar manufacturing steps and varying quantities.	8	**Additive manufacturing in production laboratories (Cloud Production)**	Highly flexible and geographically capillary distributed laboratories for the production of various products with generative manufacturing processes (3D printing) by means of digital transmitted CAD data from the "Cloud".

Figure 1-3 Classification of modern forms of distributed manufacturing (Matt, Rauch, and Dallasega, 2014, p. 189)

This research will focus on the latest form of DM, which is the Additive Manufacturing AM. It implies a highly flexible kind of production and usually based on cloud networks; AM represents a modern manufacturing technique "3D printing" that allows production anywhere around the world using digital CAD files through cloud interfaces (Matt, Rauch, and Dallasega, 2014).

1.4.2. Additive Manufacturing (AM)

The decentralized production is referred to as "glocal" is a trend that has been spreading to satisfy the local needs while developing the global market (Schmid and Grosche, 2008). DM is derived by such a trend to grow as it is focused on micro-production facilities that are spread in different countries, allowing localization and proximity. With the newest form of DM, Additive Manufacturing (3D printing), the subject of cloud production is being discussed widely in research; such systems and technologies offer many benefits when it comes to sustainability: precise manufacturing saving materials, efficient use of energy, limited transportation, greener supply chain, promotion of localized production, production on demand avoiding waste and inventory, on-site recycling of waste, recycled and reused materials, and reduction in toxicity of material processing (Ford and Despeisse, 2016).

AM represents the technologies that build objects by adding layer on another of material. It has started as a technology for prototyping, but now even final parts can be produced using it (Spath et al., 2013). AM technologies now exist in many genres that differ in its process and the materials used during production; technologies include: Stereolithography SLA, Selective Laser Sintering SLS, Fused Deposition Modelling FDM (Upcraft and Fletcher, 2003), and digital light processing (DLP) (Monzón, Ortega, Hernández, Paz, and Ortega, 2017). This layering technique in production helps in making whatever complex shape is required and in various sizes, even the very small ones (Gebhardt, 2011). It also helps in decreasing the time of production and materials used, and in consequence quicker "time-to-market" (Filipovic et al., 2011; Durão, Christ, Anderl, Schützer, and Zancul, 2016).

However, there is a concern about health safety because of the heating process in AM. Epoxy resins and powder materials might cause irritation of skin and eyes, and allergy to skin just by being in contact or inhaling these materials (Kellens et al., 2017). Especially, when using Acrylonitrile Butadiene Styrene ABS material in desktop 3D printing there are ultrafine

particles released, and so they are considered high emitters (Stephens, Azimi, El Orch, and Ramos, 2013; Merlo and Mazzoni, 2015; Denga, Cao, Chen, and Guo, 2016). Photopolymers are also very toxic because of antimony (a heavy metal which is highly toxic) and they are used by many AM machines; most of the polymers existing in market for commercial use are highly toxic and have dangerous effects on embryos (Kellens et al., 2017). Polylactic acid PLA has proven to be better because it is biodegradable, ecological, and a good alternative for other polymers (Scaffaro, Morreale, Mirabella, and Mantia, 2011). Nevertheless, some procedures need to be taken in order to avoid health problems: collection of dust, air ventilation, wearing masks, glasses and gloves, suitable space, and a clear plan to follow (Deak, 1999; Kellens et al., 2017).

With the increasing implementation of AM and 3D printing technologies, cloud production became possible because of data transfer. Some studies present conceptual models of how cloud-based factories can operate and the possible opportunities that will appear on the long run (Rauch, Dallasega, and Matt, 2016). One of the many opportunities is Do-It-Yourself DIY manufacturing where customers are able to interact directly with the machines in stores (shopping malls) and deliver products and services according to the expectations of the customers from quality, cost, and time of delivery (Zanetti, Seregni, Bianchini, and Taisch, 2015).

1.4.3. Distributed Manufacturing in Emerging Markets

In a study by (Arnold and Quelch, 1998), they characterize these markets by two main criteria: countries with fast economic development, and policies that favor a liberal economy (e.g. Middle East, South Africa, China and India, Brazil and Mexico). Then, Kvint published in his book “The Global Emerging Market: Strategic Management and Economics” a definition for the Emerging Market, in 2009, as "Emerging market country is a society transitioning from a dictatorship to a free-market-oriented-economy, with increasing economic freedom, gradual integration with the Global Marketplace and with other members of the GEM (Global Emerging Market), an expanding middle class, improving standards of living, social stability and tolerance, as well as an increase in cooperation with multilateral institutions". Later, the Morgan Stanley Capital International indexes (MSCI, 2014) has also defined an Emerging Market as a country that has the developed countries’ characteristics for development but does not meet their standards. In simpler words, an emerging market can be

identified as a country that has the potential for economic growth, but it has not yet met the standards of developed countries' markets and their free economies.

Moreover, Rauch, Dallasega and Matt (2016) state in their study that the emerging markets have experienced 7% of growth a year starting from the middle of last decade, and they have continued to grow even after the economic crisis of the world in 2008 but with a lower rate, to reach 4% in 2013 (Sharma R. , 2014). The four largest of these emerging economies are the BRIC countries, which are Brazil, Russia, India and China (Wang and He, 2014), see Figure 1-4. In the same figure, Egypt is highlighted as one of the emerging countries in the Middle-East and Africa.

Figure 1-4 The 23 emerging countries listed in the MSCI index (MSCI, 2015)

Egypt has been identified in two sets of countries that are considered emerging: Next Eleven (Bangladesh, Egypt, Indonesia, Iran, Korea, Mexico, Nigeria, Pakistan, Philippines, Turkey, Vietnam) (O'Neill, Wilson, Purushothaman, and Stupnytska, 2005), and CIVETS (Colombia, Indonesia, Vietnam, Egypt, Turkey and South Africa) (Reuters , 2010). The International Monetary fund IMF in 2008 has announced a growth in Egyptian GDP by 7% after 4% growth in 2004/2005, and a higher GDP per capita reporting 5% after being 2% (International Monetary Fund, 2009). This rate signaled the presence of investment activity happening in Egypt during this period, and consequently Egypt was included in the emerging markets' list.

A lot of companies with industrial activity have relocated their manufacturing facilities to emerging markets to insure enough distribution of products, localize their brand and compete strongly with their low prices in the potential market's needs (Matt, Rauch, and Dallasega, 2014). Because of the mass customization trend, companies now are seeking to provide more personalized products at lower prices, by giving attention to important factors like: time, cost,

energy, quality and the CO2 resulting from the production (Mourtzis and Doukas, 2014). The presence of such emerging economies opens the doors for manufacturers to adopt the distributed production approach on one side, and on the other side these countries manage to fight poverty and meeting people's basic. The localization is a strong advantage for the small-scale units to change in their production to satisfy local demands fast in case that the needs change (demand production); along with the application of information and digital technology that facilitate the communication between the different units for monitoring, regulating and optimizing the material's stock and flow (Srai, 2016).

In consequence, DM is able to tackle the issues resulting from mass production on a social and environmental levels (Kohtala, 2015; Petrulaityte et al., 2017). Furthermore, emerging markets are vulnerable in developing sustainable patterns in production and consumption, to avoid exhausting natural resources in the process of providing a good standard of life for the people (Bouton, Lindsay, and Woetzel, 2012). DM is introduced in such markets for them to take advantage from its economic, social and environmental benefits. Localization and mass customization are from these main advantages to satisfy customer needs without increasing the burden on the environment, limiting waste and CO_2 emissions (limited transportation). Not forgetting that such localized model in manufacturing can encourage the entrepreneurial and manufacturing activity in emerging markets (Rauch, Dallasega, and Matt, 2016). Thus, DM is a win-win model for both companies and emerging markets, allowing the expansion of economic activities to new market places.

1.5.S.PSS applied to DM

Petrulaityte, Ceschina, Peia, and Harrisona, in 2017 have conducted the first study about DM and how it can enable PSS companies to perform better and tackle the barriers they face. The literature review in this research has proved positively that DM with PSSs may satisfy customers' demands through customization, which is enabled by localization of manufacturing units and the involvement of the customer in the product's development. In addition to that, DM proved its ability to extend the life cycle of the products offered by the PSS through simple product maintenance and re-manufacturing in the case of using AM.

The methodology in this paper is focused on literature review, expert interviews and research seminar that contributed in developing the scenarios of applying DM to PSS. The main focus

of the investigation is how PSS barriers can be addressed positively by DM opportunities; this happened by pairing the opportunities with the barriers in logical and feasible way. From this pairing, 6 scenarios were generated representing near-future scenarios that should be developed further in future research.

In these scenarios on one hand, problems faced in PSS are addressed, for example: lack of fund, customers preferences and behavior identification, know-how of design, hygiene of shared products, privacy of personal information, and end-of-life treatment. On the other hand, DM advantages are stated as solutions for these issues. From these solutions (Petrulaityte et al., 2017):

- Lack of fund: digital file transfer, on demand production, and limited transportation
- Identifying customers preferences: digital design tools, open workshops, and in-store production to
- Know-how of designing: Knowledge about AM, product design optimization and open source libraries
- Hygiene: Using 3D printing to produce products or parts for personal use
- Privacy of usage and personal information: Sensors in machines, open libraries, self-manufacturing of parts and community-sharing spaces
- End-of-life treatment: development of small units for maintenance and spare parts production, and remanufacturing through AM for.

Continuing on these findings, this research aims to fill the gap left by this study through developing more detailed scenarios with guidelines for the application of DM to PSS companies. The methodology section will explain further the methods used to develop these near-future scenarios.

1.6. Summary

The literature review started by identifying the barriers of entrepreneurship in the Egyptian ecosystem and investigating what should be done in order to tackle them. Barriers like bureaucracy and doing business policies were proven to be hindering the process of launching start-ups in Egypt, however a governmental reform was recommended in literature in order to ease the procedures required from entrepreneurs and promote entrepreneurship as a getaway from poverty and unemployment. Researchers in business and design have been investigating new business models to overcome the barrier of access to recourses - whether tangible or intangible - without the need for a big capital through networks of service

providers and establishing trust between the different stakeholders. In low and middle-income contexts, such models are more likely to succeed because of limited funds and the need of efficient use of resources. Frugal innovation is one of the first approaches that put the customers' needs in the center of business operation and suggested that delivering value should happen without putting extra burden on the environment and society. Also, the content of value was stated as a mix of products and services that should remain affordable, user friendly, sustainable and using resources efficiently. Hence, the investigation focused on product-service systems as a proposal to promote the environmental and social sustainability in designing new business models where the value is co-created with the final users, encouraging localization and limited transportation and avoiding waste and inventory costs. In such systems the ownership was discussed in several studies suggesting that it should stay with the provider as an incentive to elongate the product lifetime and avoid costs of maintenance and disposal. With this approach, the offerings were dematerialized through the provision of more services than products limiting the environmental impacts. On a social level, the idea of depending on a network of stakeholders was the right base to create a win-win model for all who were involved increasing diversity, awareness, and access to services with low costs. It is without a doubt that such systems have positive impact on energizing competitiveness by including new markets, adapting more efficient processes and introducing new technologies.

However, with every new approach in doing business, concerns appear about its operation. Barriers of implementing S.PSSs for companies and customers mainly revolved around lack of knowledge and trust; co-dependence on other providers and third-parties to deliver value triggered a fear of consequences for each stakeholder. DM was then proposed to address these barriers and the proposed scenarios in literature showed great potentials in solving the problems of: limited fund, identification of customers preferences, design know-how, hygiene of shared products and privacy of personal information and end-of-life treatment. AM, as a form of DM, was introduced to solve these issues effectively through the opportunities offered by this modern technology, cloud production and ICT. Nevertheless, certain safety procedures were mentioned to be taken in consideration while operating on 3D printers to prevent health problems. In conclusion, the implementation of S.PSS paired with DM is able to offer great opportunities in emerging markets (e.g. Egypt) and tackle the barriers in the entrepreneurial ecosystem through networks of stakeholders, and

inconsequence access to resources. The next chapter will discuss the methods used in filling the gaps found in literature and investigating further how S.PSS business models, with a focus of AM, operate in the local context of Egypt and their impact on sustainability. In addition, near-future scenarios are developed through a design thinking process, and later discussed with stakeholders to highlight the potentials that may result from their application.

2. Methods

How and why questions are still missing in the research about S.PSS and DM as a consequence to the absence of qualitative research in studies done on the paired models, and their recommendations to further investigate them qualitatively. While reviewing the literature a number of gaps are found that qualitative research about PSSs' operation, potentials and barriers are largely absent. Qualitative methods allow the researcher to define, analyze, and better understand realities, activities, players and decisions in a certain context to illustrate it better, and they have been qualified for research about entrepreneurship while developing the proper tools and theories (Hindle, 2004). In this study, qualitative methods were used to collect data from business owners, academics, and other stakeholders in the entrepreneurial scene, especially those who came across the two models and understood the advantages of such systems. This chapter explains the research methods and gives the reasons behind using each method. From a broad perspective to a narrow one, the research was based on the double diamond approach that helped in drawing the research phases and the needed steps to fill the gaps. As mentioned earlier in the introduction, qualitative case studies of S.PSS applied to DM were absent in the previous studies, in addition to near-future scenarios about the combined models and guidelines of their application.

2.1.Research Methodology

Qualitative presented more advantages than quantitative relating to the fact that latter's methods tend to overlook social patterns in the ecosystem where the entrepreneurial activity is happening. In most cases quantitative research hinders the ability to ask intuitive questions, unlike qualitative research's methods that are enabling researchers to further investigate interesting data that comes across (Gartner and Birley, 2002). The research aims to answer through actual facts on the ability of S.PSS applied to DM, both when combined, to allow the access of young entrepreneurs to an emerging technology like 3D printing. It also tackles the barriers in the entrepreneurial scene from poor access to resources (finds, technology, knowledge, etc.) and lack of networking and trust. The investigation also aims to detect other barriers in the ecosystem against the dissemination of technology and sustainable business practices. It is assumed that such practices can have positive impacts on the environmental, social and economic sustainability in the local market. Entrepreneurship has been described

as complex processes where different actors need to be interlinked, and these processes only show how entrepreneurship starts with inconsistent and nonlinear event that demands a motivated analyzing logic (Bygrave, 2007). This is where the role of qualitative methods comes handy in deepening the understanding of intertwined processes, untangling and analyzing them to reach conclusions about a certain phenomenon (Hindle, 2004).

Research gaps were highlighted in literature and two were chosen to be the focus in this thesis: qualitative case studies about operational tactics in PSS business models were mentioned in the study of (Reim, Parida, and Ortqvist, 2014); in addition to developing near-future scenarios of S.PSS applied to DM and application guidelines in the study of (Petrulaityte et al., 2017). To fill these gaps, the qualitative research followed the approach of Double Diamond with the conversion and diversion journey across four phases, see Figure 2-1: discover, define, develop and deliver. It was developed by the British Design Council to map out the creative process that most of Designers used; the tool is a visual map, as described by the council, starting with potential ideas that solve an issue or fill a gap, referred to as 'divergent thinking', and then narrowing down to one idea that represents the best potential, referred to as 'convergent thinking'. This is where the diamond shape comes from, and it is doubled because one diamond to define the problem and the other is to define the right solution; both diamonds are necessary for the design process to avoid making wrong conclusions/solutions (British Design Council, 2018).

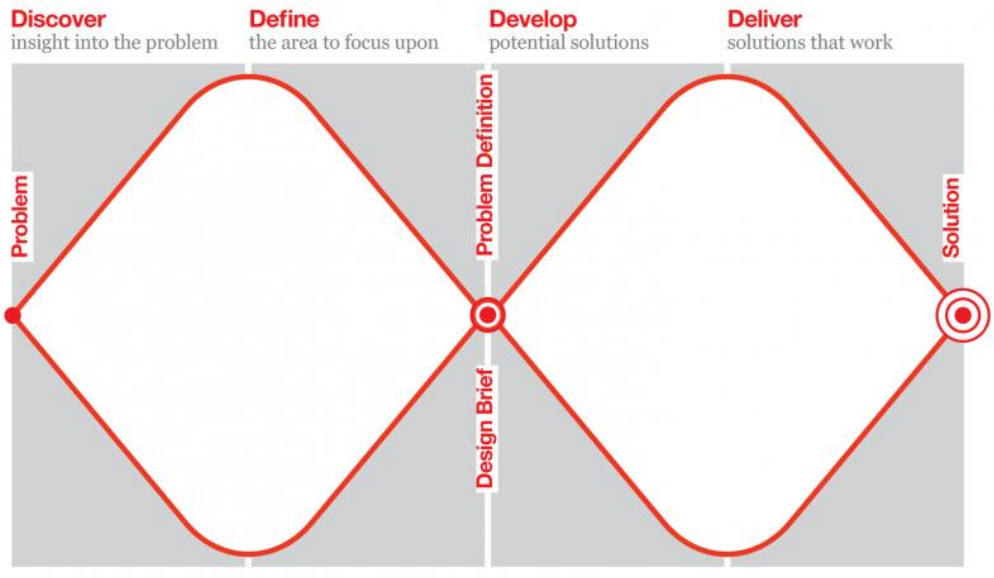

Figure 2-1 Double Diamond Process (British Design Council, 2018)

Discover phase began at an early stage with literature review and a desk research through collecting international case studies about DM from the internet, especially those which contained features of SPSS. Followed by workshops, in the define phase, where participants from product and service design fields were invited and acquainted about the research topic to discuss the two models, case studies, identify the gaps and points of weakness in such cases and generate new ideas. At this point, research questions were put clearly, and the gap was identified, to start the third phase of Develop where two local case studies were developed to investigate the operational tactics in Use-oriented and Result-oriented business models of S.PSS in Egypt. The Product-oriented category was excluded from case studies due to the fact that it has the lowest level of servitization among the three categories, which in another sense depends more on materialization than dematerialization. Still, it remained as a necessary feature in the Use and Result-oriented scenarios since the product was the base of operation, but it needed to be equipped with more intangible services for the dematerialization purpose. After the case studies, the collected data was further analyzed to come up with near-future scenarios. Scenarios were presented afterwards to local stakeholders during in-depth interviews to give their opinions about the possibility of their application, opportunities they could present and barriers they could face. Finally, at the Deliver stage, four visions were developed with a set of guidelines about how to start a business S.PSS oriented, see Figure 2-2.

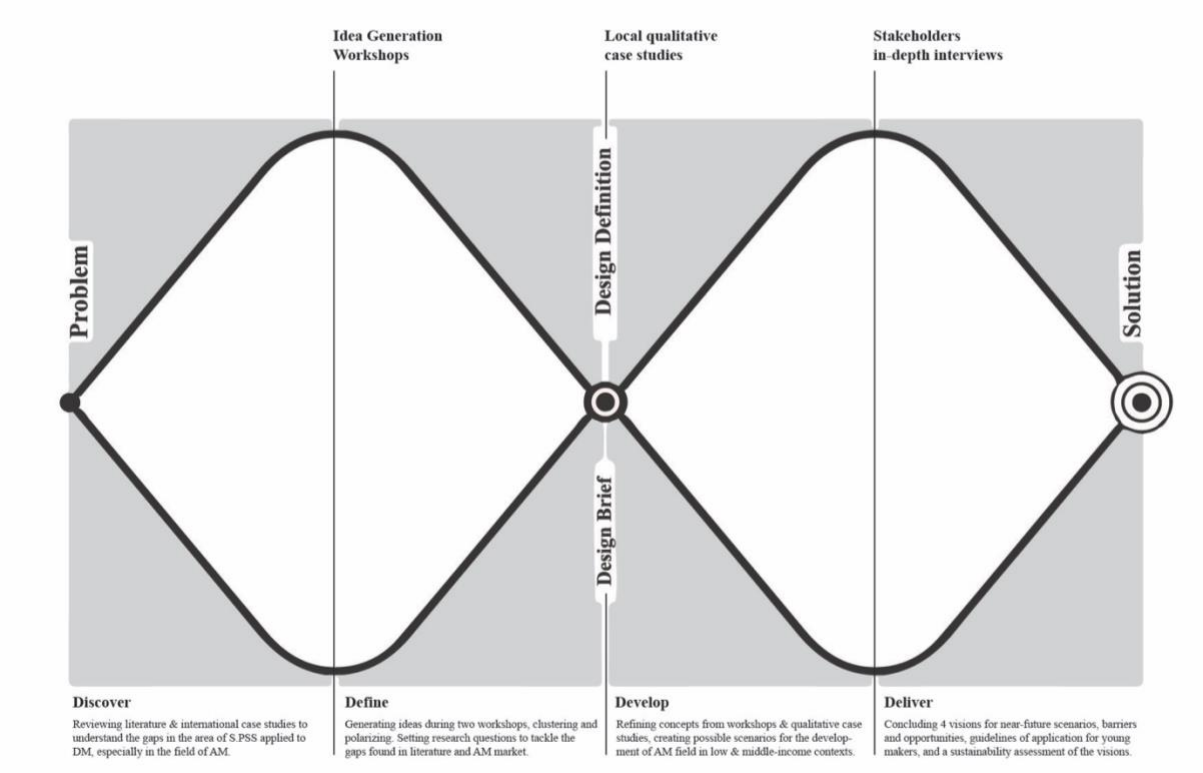

Figure 2-2 Double diamond adapted to the research framework

2.2. International Case Studies (Best Practices)

A case study is "the empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, (especially when) the boundaries between the phenomenon and the context are not clearly evident" (Yin, 1989, p. 13). Secondary research was the first phase to highlight the areas where there were still gaps to be filled by researchers. The data collected by others not by the investigator, but not necessarily for the same purpose of the study conducted (Stewart, 1984). After the literature review was complete, an desk research was done to study the business models of AM companies and service providers internationally. Researchers recently started to design case studies from secondary resources e.g. media (TV, publishing or internet) to collect information about companies, especially when relating to a country or a certain industry; these case studies helped in understanding the transactions in international business and the inconsistency in customers preferences, specifically the comprehension of models, concepts and theories related to management through actual practices (Reddy and Agrawal, 2012). Extracting the best practices from the internet and their success stories in sustaining an S.PSS business model, while focusing on smart offerings that included easy access to 3D printing services whether through use-

oriented model, or result-oriented model. Seven cases were found similar to the criteria put and were presented in the idea generation workshops that took place afterwards. See Appendix 1.

2.3. Case Studies from The Egyptian Context

In this research qualitative case studies were used. In reference to Patton in 2002, a case study is usually suitable to investigate complex issues hard to quantify; in addition to the need to identify topics, patterns, insights and concepts required for the understanding of such issues. When "how" and "why" questions are being asked, case studies are the most effective method to generate rich data especially when the researcher has limited control over the events (Yin, 1989). The case studies were formulated through in-depth interviews with managers of the two entities (Please refer to Appendix 2 to review the questions). Two main entities were chosen to study their operational tactics, and the challenges they faced and opportunities they pursued while operating in the Egyptian ecosystem of AM market. Digital fabrication service provider was also included, as digital fabrication presented the bigger umbrella that covered Additive Manufacturing, and Subtractive Manufacturing as Computer numerical control (CNC) machining and laser cutting. Once again, the focus was on use-oriented and result-oriented categories of S.PSS, while product-oriented services were investigated within the in-depth interviews. The operational tactics studied in the cases and their related aspects were the base on which the qualitative case studies were built, and they were extracted from the study of Reim, Parida, and Ortqvist, published in 2014:

- **Design of services**, two aspects to cover: functionality and customization of the offerings, which are the main advantages of cooperating with a PSS, in contrast with business-as-usual.
- **Contracts**, two aspects to cover: their complexity and formalization as they differ from one category to the other.
- on the value given, and the insights of customer/market through collecting data.
- **Network**, three aspects to cover: identify the type of partners the business needs to provide the product/service, decide the type of relationship and cooperation with these partners, and finally the activities should be shared and coordinated in the network to insure the delivery of the value to the end user.

- **Marketing**, three aspects to cover: communication of the value proposed by the business model, the level of interaction with the customers depending
- **Sustainability**, two aspects to cover: resource utilization to avoid waste and overconsumption, and level of innovation used to reduce possible harmful environmental impacts.

The two businesses' representatives (a total of four persons) were interviewed, for 90 to 120 minutes, each separately to discuss their opinions, fears, visions and aspirations in running the operation and managing these models in the Egyptian ecosystem. The in-depth interview questions covered the operational tactics and gave the opportunity to the interviewees to express themselves in an open discussion of the topic. They were asked about the aspects mentioned to cover the variables explained in the study of Reim, Parida, and Ortqvist, in 2014. Data were collected through voice recording and other sources of information (e.g. websites, news, and social media pages). Also, some insights were concluded through observation and writing notes during the interviews. The results showed how the five tactics were managed by the managerial team in each PSS category differently and depending on the context, the barriers and opportunities presented by the ecosystem and series of events..

2.4.Participatory Workshops

Participatory workshops are widely used in different contexts for the aim of brainstorming new ideas for a certain purpose. Workshops are described as a group of people who participate in a certain planning where they learn, obtain knowledge, contribute in problem-solving through creative methods, and/or innovate in solving a particular issue (Ørngree and Levinsen, 2017). This research is part of the Lens project (www.lens-international.org) which has the aim of developing a set of methods for the design of S.PSS and testing them (Vezzoli et al., 2015). The network has a set of tools that allows designers to develop economic scenarios for the coupled models that are both environmental and socio-ethical.

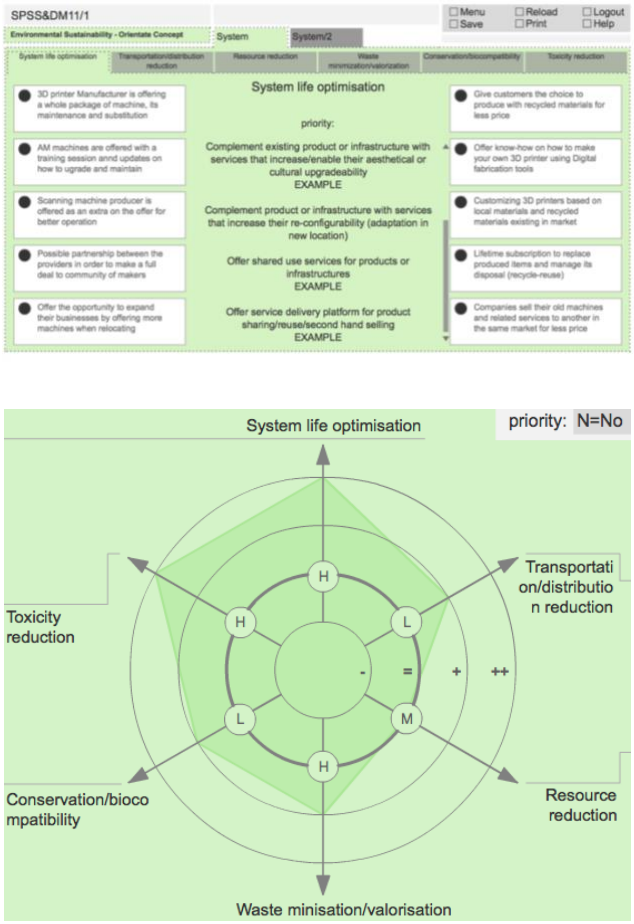

Figure 2-3 Snapshots of the SDO toolkits for ideas generation and evaluation

Using Sustainability Design-orienting toolkit (SDO toolkit, http://www.sdo-lens.polimi.it) sustainable PSSs are explored through the proposal of concepts and scenarios that follow criteria in the online modular toolkit, see Figure 2-3. The process starts by setting the priorities, analyzing the best practices (from international case studies), develop sustainable concepts and assess the improvement in sustainability aspects. Polarity diagram is another tool that helps in exploring promising concepts from which scenarios can be developed. In a way, it organizes the concepts to visualize them for the audience and categorize them according to their function and modality. Workshops were conducted using this toolkit to generate visions in a collaborative barnstorming environment. The workshops took place at

the design department in the university of Politecnico di Milano, in January 2018. The participants with background in product and service design contributed with some ideas and concepts for how to fill the gaps in the AM industry found while reviewing and presenting international case studies and the best practices in the field. Gaps involved negative environmental impact, absence of network-based aftersales services, lack of procedures towards safety of operators, and neglection of socio-economic benefits on the communities where PSSs are taking place.

2.5. In-Depth Interviews with Stakeholders

After generating possible visions for near-future scenarios, localizing these scenarios to the Egyptian context required semi-structured in-depth interviews with individuals who had a background and an overview about the AM field in Egypt. In order to gather primary data, in-depth interviews are the main method in qualitative research to collect it first hand from the interviewee, and to get the information needed for the study (Merriam, 2009). The stakeholders were from private, public and civil society sectors. They were asked in an open manner through a discussion to give them freedom to express their opinion about: how applicable the visions were in Egypt, opportunities and barriers they could face, to what extent the ecosystem could promote and support sustainable initiatives, and what they recommended for the improvement of the ecosystem (Please refer to Appendix 3 to review the questions).

2.6. Sampling

In case of the in-depth interviews in both the case studies and the stakeholders' interviews, sampling was done through Egyptian market research in the field of AM. The sampling technique took the approach of convenience sample. In a study by Martin Marshall about qualitative research, in 1996, it was described as when the researcher chooses the most accessible sample to answer the research questions. Also, there is an advantage in studying wide range of subjects, outliers, those who have certain experience or expertise, or those who are recommended by other subjects (Marshall, 1996). Several companies and fab labs were found but few were relevant to the scope of S.PSS applied to DM. Entities' services were scanned through, and the main criteria of an S.PSS business was the base of making choices: pay per unit of satisfaction, no transfer of ownership, easy access to technology, building a strong network to satisfy more needs and keeping small-scale manufacturing facilities. Two

examples of PSSs were chosen for investigation to formulate the case studies: a use-oriented fab lab, and a result-oriented company. They were both referred to with pseudonyms for the confidentiality of their identities: UO Fab Lab, and RO Company respectively. Two operational managers were interviewed in the first entity and two business partners, Partner (A) and Partner (B), were interviewed in the second entity. The UO Fab Lab delivered services of digital fabrication, mentorship on machines, and workshops of design thinking and problem solving. The RO Company delivered requested prototypes done on 3D printers, postprocessing services and home delivery for their customers. Generally, the two entities offered services for young makers, entrepreneurs and students to make prototypes and semi-finished products tp test their ideas and designs through 3D printing. The investigation focused on how the PSSs handled operational tactics in respect to their offering of services.

All the interviewees were in direct contact with customers and supervised the activities running in their entities closely, therefore they were chosen to speak about the way they ran these businesses. As for the final in-depth interviews, eight main stakeholders were chosen from different backgrounds covering the private, public and civil society sectors in the Egyptian ecosystem:

Stakeholder N°	Background	Experience
Stakeholder 1	Academic – background in Operation	Research area in operation management applications in Egypt, and in SMEs development in specific. His academic background includes supply chain innovations, operation development and selection/evaluation of suppliers. His motivation is responsible business empowerment. He was in charge of supply-chain consultation services at an Egyptian auditing company, which is a partner and a member in the network of an international auditing company.

Stakeholder 2	Governmental officer – Development Unit Director	Developmental career in the role of ICT for community development (ICT4D), with more than 10 years' experience in the initiation and development of best practices and models of ICT for the socio-economic development. Also, responsible for resources mobilization and fund raising in the ICT ministry. One of her main responsibilities is to establish public, private, and civil society partnerships for the execution of ICT developmental projects in Egypt and Arab region.
Stakeholder 3	Entrepreneurship Consultant	He has a background in accounting, he worked as a financial and distribution consultant. While working as a consultant, he had an experience in IT and Address Resolution Protocol (ARP) systems. He shifted his career to corporate finance, strategy and restructuring, and establishing new entrepreneurship centers in universities after finishing his Master of Business Administration (MBA) at one of the finest business schools in Europe. Now he works at an entrepreneurship empowerment project under a United States agency for international development.

Stakeholder 4	Manufacturer – fabrication of FDM 3D printers	Founder of a successful 3D printer manufacturing startup company in Egypt. In the aim of promoting digital fabrication, he also initiated another project for open source design. With a background in electronics and communication engineering, he had the passion for digital fabrication since his studies at the university and after his graduation he managed to fabricate his first 3D printer after several trials and errors. Building on his experience, and the knowledge he received from international 3D printing networks and events, his business is now the leading in the country.
Stakeholder 5	Manufacturer – fabrication of DLP 3D printers	As a graduate of mechatronics in 2008, he was interested in product development and worked as an intern in a multinational company where his interest in 3D printing developed. He collaborated with a friend who had a background in business to fabricate 3D printers. These 3D printers were to be used by the two founders in order to produce and offer prototyping services for students and architecture consultancies. However, they changed focus when they found a gap of dental 3D printing in the Egyptian market. Now his startup is producing 3D

		printers for dentists and dental labs, suing DLP technology.
Stakeholder 6	Corporation CEO – ICT and development projects	CEO of a leading corporation in systems integration in the MENA region and deploying of technologies related to industry where they support in standardizing the operation of their customers through consultations and offering solutions. He started his career, in the late 80's in the oilfield and then became a network manager in a data services company in Canada. In the late 90's, he returned to Cairo and worked for a while in a multinational network company, then moved to the ICT corporation as a managing director in the late 2000, until he became its CEO due to his success in developing its services. The company now offering access to its fab labs and digital fabrication use-oriented services.
Stakeholder 7	NGO Manager – fab labs and development projects	Manager of a non-profit foundation with a focus in civil education projects that fight poverty and ignorance in marginal communities. By using technology and its technical experience, the foundation is seeking solutions through partnerships with private sector and governmental institutions to conquer social and economic issues in the Egyptian

		context. They launched a fab lab to empower creativity and innovation of young entrepreneurs. Her expertise helped in launching initiatives toward sustainability, entrepreneurship and social innovation. She focused on transforming the challenges of sustainability into green projects.

2.1.Data Analysis

The data collection in qualitative research is often done through interactions' recording, therefore the outcome of the research is based on the analysis and understanding of this recorded data (Flick, 2013). Inductive approach was used since the research was based on a qualitative methodology. Consequently, the inductive thinking helped in analyzing the data moving from specific observations and understandings to broader theories while detecting themes and patterns in the data (Creswell, 2005). In-depth interviews were used to collect data, then the data were analyzed and categorized into themes. These themes were formulated based on the resemblance between certain data and after identifying the main topics that needed to be covered by this research. Across the interviews conducted to formulate the case studies, thematic analysis was used to integrate the themes where operational tactics are highlighted. In inductive methodologies thematic analysis comes in handy to link the data to the main research themes efficiently (Patton, 1990). Through such approach in analysis different data collected should be framed under precise words to better present the whole study's proceedings in analyzing data (Alhojailan, 2012). The data from the interviews were divided into the themes of: background and interviewees' opinions of the entrepreneurial scene, and the five tactics of operation that needed to be covered. The tactics were the design of services/products, contracts, network, marketing and sustainability.

Workshops followed the SDO-toolkit to generate ideas and concepts. These concepts were clustered to form potential scenarios for the AM business development in low and middle-income context. A polarity diagram of x and y axis was used to organize and place the

clusters according to the variables of decentralized or distributed, and use-oriented or result-oriented, see Figure 2-4.

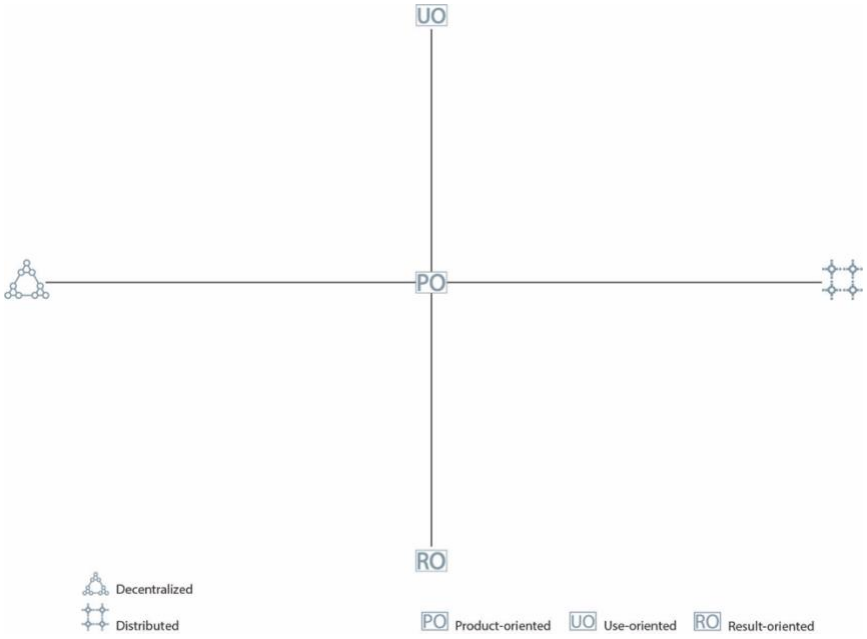

Figure 2-4 Polarity diagram illustrating the categories of S.PSS and models of DM

From this polarity, four visions were developed to represent how 3D printing could offer new services and great value for young makers. In-depth interviews data were analyzed, like the interviews done for the case studies, according to the thematic analysis where the thoughts and the insights collected from the interviewees were organized under the five main themes covered during the discussion with the stakeholders: the applicability of visions in Egypt, the barriers that might face them and possible opportunities, their impacts on economic, social and environmental development, sustainability promoters in the ecosystem, and recommendations of the participants to facilitate their application. From these data collected, future research and initiatives could be drawn easily on the gaps that need to be filled to launch responsible and sustainable businesses.

2.2. Summary

The methods helped in the divergence and the convergence of the entire research process. At the beginning the literature review and the international case studies gave a wide overview about S.PSS and DM, and the areas to be tackled for better sustainable performance. The idea generation workshops came after in the convergence stage of the first diamond to highlight the focus on AM as one form of DM. Furthermore, the local qualitative case studies shed the

light on how PSSs operate in the Egyptian context, advantages they had and the disadvantages they faced while working. All the data collected from previous stages made the focus wide again at the divergence stage in the second diamond. Data and concepts were organized, clustered and polarized so that several scenarios could be developed to fill the gaps and tackle the barriers discovered. To narrow down, at the convergence stage in the second diamond, four visions were concluded from all scenarios and a proof of concept had to be made. Stakeholders in the Egyptian ecosystem were interviewed to discuss these scenarios and their application in the near-future.

3. Findings

This chapter shows the results of the methods used and how the analysis has taken place in order to cover the research gaps. It starts by explaining the data analysis process, then results are included in each section with the name of the method used to collect data. Sequence of methods is: qualitative case studies, workshops and idea generation, and finally in-depth interviews with stakeholders.

3.1. Qualitative Case Studies

This section covers the qualitative case studies formulated to investigate the operational tactics of two PSS businesses running in Egypt. The first case is use-oriented (UO): an enabling platform to empower makers to create and test their designs in return of a payment per unit of satisfaction. Followed by the result-oriented (RO) case that delivers final results of semi-finished to finished products and prototypes to their customers with all-inclusive services starting from ordering till delivery. Operational tactics formed the main structure of the cases with a background information about the business and opinion of people in charge about the entrepreneurial ecosystem in Egypt. Operational tactics are: design of services, contracts, network, marketing and sustainability. These tactics were developed in the study of (Reim, Parida, and Ortqvist, 2014), and qualitative case studies were recommended by the study for future research to investigate the operation of PSSs when applied to DM.

3.1.1. UO Fablab

The concept of a Fab Lab has existed for more than a decade now, and it keeps on evolving while adopting new technologies to facilitate small-scale fabrication. Digital fabrication is now leading in Fab Labs due to the huge potentials it presents from the very basic advantage which is transforming the digital into physical to distributed manufacturing and cloud production. Such a concept allowed many makers to realize their ideas by themselves and launch their own startups. One foundation, working under a company, noticed the difference a fab lab could make and established its own to promote digital fabrication in the local Egyptian market.

Background (Business Model-Products/Services)

UO FabLab started its operation in 2015 B2C and developed gradually into B2B cooperation, targeting students (8-20 years old) and adults from all ages; it was easier then to reach for school and university students, especially of technical and science schools, who wanted to make things in their imagination real. Also, professional designers and makers were welcomed from beginning to come realize their projects. The main aim UO had in mind was to spread awareness about digital fabrication through science communication (fun and entertaining methods of learning). This aim could be realized through prototyping of ideas and hands-on experience of manufacturing, in consequence helping in the capacity building of a person and his/her mindset through: encouraging makers to be socially conscious about everyday life challenges especially in a low and middle-income country like Egypt, making things instead of buying them, and breaking the barriers they had with technology. In order to achieve these potentials in makers, the services were designed to provide a learning process where Do-It-Yourself and open access to machines were endorsed by the lab along with one-to-one mentorship on machine operation, and consultation on projects planning, technicalities and application. Programs and workshops were offered regularly to promote design thinking, get familiar with technology and software and teamwork workshops for companies. These workshops duration varied from 30min to one hour maximum to be influential on their attendees in a concise manner. The lab machines increased and developed step-by-step to include 3D printers, 3D Delta printer, laser cutters, Computer numerical control (CNC) precision milling for Printed Circuit Boards (PCBs), CNC router for furniture, 3D scanner, Vinyl cutter, and electronics and hand tools. The expertise of the team who managed the operation at the lab was diverse, with backgrounds in electronics, mechanical, production and others. At this fab lab alone 9 employees worked to help and support makers, and all other branches that were launched later in governorates involved in total 20 employees.

Design of Services

The services were fixed and clear in general, but at a point they had flexible setting in services, customers asked for certain workshops, so they made it for them. But they became exhausted with time, so they made the services more focused and made sure the capacity for it was available. In every branch, they made a different setting depending on the needs in the area. Teamwork workshops were one of these flexible services designed for companies,

where they developed a product together as a team and produced it on digital fabrication machines. This collaboration happened with the learning center of companies as a special training for employees. For kids, they kept launching competitions for fun and challenging way to learn. Although they are a prototyping facility, in some situations they achieved a final product, and if the required number of produced artefacts was adequate to the lab's capacity, they supported the customer in their fabrication. Otherwise, they did referrals or outsourced the task with third-parties who could deliver the products ready. The lab's team has been aiming to add a 3D printer of ceramics and PCBs to cover more needs and has consistently been upgrading machines based on insights of customers. The technology they have had since beginning was moderate to high. To have a better outreach and a proactive attitude the team launched the FabLab bus tours. The bus while touring was introducing the concept of digital fabrication in a simple way by inviting people in streets on board and supporting them in producing an item of a 50-60LE in a fast workshop (45min to 90min max). In these workshops they showed the limitations and advantaged of 3D printing. As mentioned, the aim was to invite anyone on board but due to bureaucracy and national security restrictions the bus could not just park anywhere, they could only park in institutions they partnered with. The team's aim has been to refine the shape of the bus, the workshops delivered and interaction with participants for a better impact; the design of the bus was not appealing to people walking in the street to jump in and try to fabricate something. It was looking strange and the activity inside was not clear for people passing by due to its invisibility. The team expressed their enthusiasm about making a better design where the activity inside the bus would be transparent for most people, so they would not feel scared to join in.

Contracts

In order to reach the targeted students and make an impact, they needed to cooperate with other entities like educational institutions and NGOs who worked closely with students. Memorandum of Understanding (MOU) contracts had to be signed between the foundation of the Fab Lab and these entities to document responsibilities. Formalized contracts, with articles of the Egyptian law, were only applied in big-scale cooperation and every contract had a different format and details based on the project. Customers who walked into the lab no contracts or agreements were signed with them, and they have not noticed any contract

signed between makers and each other as the cooperation was always done based on gentlemen agreements and estimation of services' price. This kind of cooperation without contracts is in a way reflecting the culture of Egyptians who prefer not to sign official papers, especially in small-scale collaborations. This is only due to the fear of legal procedures and consequences in case of disagreements. The team saw contracts as necessary and should be introduced slowly and grow naturally in the work environment. Also, they should be flexible to have different versions for all purposes with legal articles involved. The presence of contracts would have changed the whole maker spaces scene by avoiding conflicts, encouraging collaborations and spreading awareness about preserving rights (including copyrights).

Network

Partners of the lab were chosen carefully through a transparent procedure handled by managers: they started by highlighting potential partners and running a background check about them, then they chose based on the need they had, what this partner could offer, the reputation of this entity and reviews, history of cooperation if there was any, and the list of past recommended partners. These partners had diverse organizational structures whether non-profit, NGOs or companies for profit, the main target was to facilitate the work of the lab. Some partnerships were in the aim of launching events (e.g. conferences, workshops, etc.) and projects, others were to offer their tangible and intangible resources like funding, technical support, facilities, or just networking. The FabLab bus managed to reach people only through cooperating with institutions allowing it to park in their premises, as an alternative for long governmental procedures to get an authorization to park anywhere. Importing companies were a great support also in providing the technology and machines and the materials that the lab needed. However, when it comes to maintenance of these machines, these companies were not able to provide good technicians for support in 3D printers and CNC machine; only in laser cutters the technician could be relied on due to the technology's long-term presence in the market. Marketing, finances, legalities and public relations (PR) were managed internally by the employees of the foundation. PR representative was responsible for big scale legalities, communication and events organization with partners. As for technical agreements, the project manager was the one responsible for the labs' cooperation with others.

In cases of two-sided partnership, the lab has always provided the space and machines. Also, the partners were allowed to be in direct contact with customers when the partnership was established with the customer in focus. And when a third-party was involved in fabrication the cooperation happened only through the lab, no contact with customers was required. However, in some cases referrals were done by UO FabLab to other labs and their facilities with no interference from its part. All these partnerships were successful only because the lab's consistency in building trust with customers and business partners. With customers, they investigated their ability first to work on machines and encouraged them to learn not just get things done. Once they were able to work alone on a machine, they left them unsupervised without the need for a license. With such attitude, customers became open in their behavior after being conservative due to their limited information about digital fabrication. The advance technologies in fabrication have always stimulated high expectations of users about their capabilities, which in some cases were false expectations due to the limitations of machine. Finding a common language was the key to communicate the real value, especially to those with no technical background and whom the technology was targeting in first place. Due to the difficulties Egyptians have faced in the past years politically, socially and economically, they developed a non-trusting behavior with service providers avoiding frauds until they could establish trust. Only when customers (also researchers) needed support in a project (had a ready file), they behaved openly. Every time the process was clear and agreed upon, less disagreements happened.

In all cases, the team of the lab adopted a friendly and welcoming attitude to break the ice and show their will to share and offer technical support. For business partners, the fab lab has never had permanent partners, and third-parties who delivered services the whole process happened B2B and no customer was involved. So, establishing trust was simply based on transparency and clarity in handling cooperation and they were the main criteria for choosing partners; when companies had hidden agendas the collaborations then did not succeed. Even with companies delivering low cost 3D printers, the team offered them advices on how to improve their 3D printers. They consulted other companies in founding their own fab labs. Co-creation was an advantage they emphasized on through supporting their customers technically with no formal agreements signed. Pictures documented during the process in lab were usually posted after the permission was given by the customer. Students and entrepreneurs were not typically concerned about legal rights except when the product is

about to be launched in the market. In this case, the pictures were not posted by the lab but the customer, and he/she tags the lab for their contribution. What concerned the lab was the recognition of the effort, even without contracts.

Marketing

Building a trusting relationship with customers was only because the team aimed for long-term relationships that could form one day a community and people helping and volunteering in events organized by the lab. Freelancers however were not the type of permanent customers the lab could rely on: they have come for a specific purpose and left when their aim was accomplished. Until recently they have not reached the community atmosphere they were aiming for, but despite of that, they kept a database of their customers' information in all branches. They used social media and direct interaction as a method to collect insights from customers of the lab, programs, workshops and also some tours with. The lab has never launched an official marketing campaign only frequent posts on social media and networking through events. In general, the team described their marketing as weak and did not communicate the message right: it created confusion about the value they were delivering. Only a website was developed poorly and small-scale campaigns on social media. They have been discussing marketing with the foundation to launch a big campaign which involved a clear message and for people not to have wrong expectations for the foundation and the fab lab (e.g. giving funds). The bus also has a separate website but not active or updated, but the project itself of fab lab on wheels worked intuitively as a marketing tool. Recently, they became part of an international network of fab labs, so the need to launch a strong identity and clear communications through a proper website started to urge. The values they have been always communicating were hands-on experience, locating digital fabrication in value chains, fun learning experience, community to help, make and share, friendly and welcoming place, quality of services and fabrication, and finally technical superiority. In return of these values, the prices proposed by the lab were always affordable for all segments. In the bus, people did not need to pay for the experience they had nor they product they made, it was fully funded by the foundation. As for the lab, customers paid per time and per material depending on the machine they used. The pricing was based on the positioning between the different labs, and these labs were basically companies for profit. Therefore, the pricing in UO Fab Lab was a bit different due the financial support the foundation gave to its fab lab's

services. Hence, all offered prices did not include running costs, or employees' salaries because employees were paid by the foundation. This gave the advantage to the customer, by lowering cost on him/her and freeing the employees from the burden of pushing customers to pay more to earn profits. Pricing of PLA material in 3D printing was set by gram because it had been always easy to understand by all. Gram costed 1.5pound, and a minute on the machine was for 1pound, compared to laser cutting minute that was for 1.5pound (market price 2-3pounds). The concept of ownerless consumption by promoting fab labs has not yet been recognized by Egyptian makers, it needed a culture change; if they have had enough fund to buy the technology they would have done it already. Nonetheless there has been a fast growth in the fab lab field in Egypt since 2011, of around 25 labs were inaugurated all over the country. The UO Fab lab still had to develop more to make customers feel at home but being inside a foundation affiliated to a company gave the users a commercial feeling. Egyptians began to recognize the benefits of digital fabrication, like fast solutions and the ability of producing a 3D printer through another 3D printer and a laser cutter. In comparison with importing technology, producing it locally would cost way less fortune, and people have already grasped this opportunity and started to produce their own while adapting it to their needs. Maybe they have not managed to be efficient in using resources, due to the failures of the printers, yet a vision for growth was presented in the yearly makers' fairs.

Sustainability

The foundation lately started to align its priorities with the sustainable development goals of the UN. In the light of this, the team was oriented towards supporting individuals, so they could leave positive impacts on the community. In their recent workshops, they introduced design thinking as a method to solve challenges (e.g. water issues) faced by the community. They instructed participants to the necessity of creating comprehensive and sustainable solutions. In addition to this, they taught them also how to earn a living using digital fabrication and the potential small-scale units of fabrication has over large-scale ones. In this context, they promoted entrepreneurship by partnering with organizations contributing to the capacity building of entrepreneurs, providing good technical support on the fabrication level, and good optimization of resources. In managing resources, the lab still had not reached a point where they were satisfied with their performance in recycling and reusing. They had never thrown leftovers but after a while the storage area where they kept them was messy, so

it was disposed of. It needed a structure of sorting, categorizing and whether to go for reusing or giving them away to recycling entities. However, they encouraged the use of leftovers, and the efficient usage of materials (start from the edge of the sheet, not the middle). To better control over production and waste, they reorganized work stations, monitored the consumption rate of materials over a period, and assessed the worthiness of each operation. They noticed generally during the assessment and monitoring that customers did not value the materials as the team did, nor they preferred to work with this lab specifically because it cared about its environmental impact. They only cared about the profitability of working with it and the satisfaction of their needs. In some cases, customers bought their own materials and paid only for the machines, so they were efficient. The efficiency in using resources was only introduced by the foundation and the lab through their workshops and consultancies; the government did not launch any inspection or auditing initiative over the lab's operation.

Entrepreneurship Scene in Egypt

During collaboration with customers/makers who were in process of developing a product soon to be launched, the team noticed that entrepreneurs could not sometimes differentiate between a prototype and a final product. This decision was in most cases due to lack of experience and misconception, impatience, or both. The consequence was selling a product that needed constant technical support because of malfunctions in the hardware. In other words, some makers sold their support service to the hardware, not the hardware itself, believing that their services' offer guaranteed to the customer a good operation and earned his trust, which was not the case. Services have always had a cost same as products, and delivering aftersales services constantly meant extra financial burden. With the increasing number of customers and burden of services, the entrepreneurs could not sustain their business and had to quit. To reach a product ready for sale, it should have gone through several stages, moving from the early stage to a mature one where the product development and its industrialization were finished. Of course, selling a product at an early stage would cost less for both maker and customer, but it was neither efficient, nor sustainable.

The pricing of services has been always an area of failure in collaborations, especially in the start-up scene, entrepreneurs have always priced each other's services not fairly. This means that supporting someone in a project is often not recognized or commissioned properly because of no contracting procedure to preserve rights. Entrepreneurship in general is a

recent ambition for Egyptians; turning from communism into capitalism there is still a gap in adopting win-win concepts and letting go of winning alone attitude. The majority is still used to the idea of being employees not entrepreneurs and business owners. So, the true problem was the education and capacity building of an entrepreneur and not money. Capacity building in the sense of establishing collaboration, understanding capabilities and limitations, how to overcome limitations through outsourcing, the need of trial and error, and growing gradually to sustain the business offering. Cultivating an entrepreneur successfully is still a gap in the Egyptian entrepreneurial ecosystem.

3.1.2. RO Company

Additive Manufacturing (3D printing) is a new field in the Egyptian market, and the access to such technology can be in some cases expensive; it needs still time to be adapted locally and have enough recognition to become affordable and accessible.

Background (Business Model-Products/Services)

RO company is based on the idea of making 3D printing a convenient and accessible service for the community of makers (students, researchers and entrepreneurs) in Egypt. Five young individuals came together to discuss the issue and the market gap in AM field and decided to have a service-based business that could allow easy access to on-demand 3D prints for a reasonable price. Starting with five people who eventually became two partners, Partner (A) and (B), who actually were committed to the idea and launched this start-up, in 2016, with the support of a non-profit organization that empowers entrepreneurs and trains them on the right set of tools to sustain their nascent business during the incubation period. The great advantage the two partners had was their study and work background: Partner (A) had the know-how from his studies, knew how to operate on FDM 3D printers and configured them to receive the appropriate results he was aiming for; as for Partner (B) his past experience in business and management reinforced his management skills to sustain such a start-up. They followed a transparent process where they received the file for printing, confirmed the quota and price with the customer, and finally printed the model and delivered it to the customer's address. For any customer this process was clear from the beginning through the information provided on their website and Facebook page, to avoid confusion. The plan was to receive files and requirements for FDM prints directly through the online ordering system on the

website, yet it failed. Their vision was to have a service-based website to manage agreements and contracts. However, the business maintained ordering procedure through emails, face-to-face agreements and phone calls. Such a business model followed a result-oriented approach in PSS applied to DM that has always been based on delivering final results to customers without their involvement in 3D production.

Design of Services

In the same year of 2016, the two partners noticed that they were not getting enough orders although the demand existed. During the investigation they figured out a gap other than the accessibility to the technology; they discovered the incapability of some customers to build 3D models and have STL files ready for printing. The focus of their company was mainly to print the provided models as prototypes, semi-finished and finished products and have them delivered to customers on time, but this gap looked like a big risk for business survival. At the beginning, they offered developing the 3D model and printing it to big customers, however this proposal was not successful due to some factors: there is a big risk of merging two processes in one and setting one price for both, customers who do not have technical background tend to ask for a lot of edits, and finally you might lose the customer for any reason without getting paid for either required tasks. Of course, this was the actual scenario where the two partners lost time and effort developing the model and product and ended up not getting paid for their services. To solve this issue, they could have developed a business solution department to investigate the exact need of the customers and adjust the production to satisfy the demand, but they could not have it at that time as they needed to establish a strong identity first, so they would not confuse their target group. In the light of this, they made a good connection with third-party designers and 3D modelers to execute this task for their customers. Being an intermediate in deals also caused them problems, especially when trying to coordinate with customers' requirements and designers' outcomes. Therefore, at this point they decided to get themselves out of this process and build a community where customers could find designers directly to build their models without the need for the partners' involvement. On their website they included five profiles of modelers with their profiles, portfolios and ratings for customers to choose among and make deals directly. Through building a community they managed to make a good network as well with postprocessing service providers. In case a customer would want to make a good finishing for

3D prints, they could do referrals to others in the market who made this happen. So, the community helped not only in the prefabrication phase, but also post processing one. Staying focused on their main services helped them to maintain quality and monitor customers' satisfaction and feedbacks on the services, while the community filled the gap of modelling and increased the number of orders. The belief these two partners had from start was raising awareness about 3D printing and educating the community how to print while providing the best tools would not only make their business successful, but also having a network of partners and makers would support the industry to excel. Launching their business, they targeted university students who were in constant need for prototypes to test their projects. The advantage in taking students as a target group was their familiarity with 3D modelling and digital production, in addition to their wide imagination and passion to make ideas real. With time, the circle grew, and they started to get recognized in the market as pioneers in on-demand printing, so companies began to consult them about integrating 3D printing in their production and supply chain, and in some cases asking for large amount of production.

Contracts

In general, their customers needed 3D printing in prototyping, casting and making spare parts. Therefore, they expanded their network and made partnerships with others who had more capacity for production, other technologies like SLS and DLP, or could provide local or international printers to those who needed them. To establish a transparent cooperation with those third-parties, they had to sign agreements and contracts. With international providers, like the company that provided the machine, they signed an international detailed contract that was governed by the law of the company's country. As for SLS and DLP service providers, they either signed one-sided or both-sided referral agreements that eventually turned into formal agreements and contracts to insure quality. They were adapted from international contracts and localized according to Egyptian law. "These referral contracts are customizable but still generic," said Partner (B), "they are usually gentlemen agreements". Not all the rights written in contracts were governed by the Egyptian law, even compensations and deadlines were included to clarify common understanding. Only Non-disclosure agreements NDA and confidentiality terms were the ones governed by law. NDA agreements were signed with design companies and customers who wanted to keep their data undisclosed, and with third-parties for the sake also of their customers. The last section of the

contract usually contained by which law the contract is governed (Egyptian or foreign law). Despite of all these contracts and detailed agreements, insuring quality was not dependent on this paperwork as much as testing partners capability to produce good quality models before signing a contract.

Network

With the increase in demand, RO company had to expand their capacity in operation, either vertically or horizontally. On one hand, expanding vertically would require more funds and capacity building from employees and machines; such a procedure required more monitoring and control to maintain the same quality they managed to deliver by that time. On the other hand, expanding horizontally would give them the opportunity to expand operation through the reliance on third-parties in the market who had different technologies than FDM and maybe machines with wider surfaces and other options of processing. The second option seemed more appealing, especially that the two partners always referred to lean production, which is based on efficiency, in managing their business. Therefore, the whole business had been always running by the two partners, and 2-3 other employees who helped them on daily basis. For the other services they wanted to integrate, they established cooperation with governmental institutes who had SLS machines, other private entities who had SLS, DLP and postprocessing (like coating, molding with silicon and others). In running their business and daily activities, they also depended on shipping companies to deliver orders, accountants and legal accountants to handle paperwork, receipts and taxes, HR recruitment company to hire employees, freelancers to make videos, content and ads on websites, foreign provider company for tools and machines, local company to provide materials needed in production ABS and sometimes PLA and importing company for technology assistance and provision. The main reason they relied on a foreign supplier of machines was their negative experience with locally produced 3D printers and their suppliers. Out of 10 trials to print a model 10 were total failure and 2 succeeded, while imported machines it is 2 failures out of 20 successful prints. The amount of waste and inefficiency lead them to discard using these machines despite of their low price.

Though they had built a strong community of service providers through which they managed to satisfy customer demand and offer convenience, the 3D printing service always happened through them. The partners only depended fully on specific partners whom they trusted in

maintaining the quality, using the packaging of the RO Company and sending it directly to customers. This strategy of controlling this service and being an intermediate was due to the fact that it was their main service and they made sure not to lose customers to others due to any reason. Therefore, they built trust and evaluated their partners through testing and grading of the models' quality (out of 10). This procedure took place as follow: complex setup prints were sent to know the failures the operator could fall into, the operator produced the models and sent it to be graded, and afterwards feedback was sent with corrections. After the grading and testing was done, the partners agreed on a price per unit with the operator. This way of testing could only happen due to the standardization of the 3D printers' configuration and software, which in consequence lead to quality dependence on the operator machine, know-how and skills. Guiding the operator is a critical point and the grading system was the right method to build criteria that differentiate between those who they wanted to collaborate with and sign a contract, and whom they wanted to avoid contracting with.

For 3D modelers, the procedure of partnering was a bit different, the modeler usually initiated cooperation through sending an application, and a welcome email was sent with "Learn, make and print". "Learn" was for the modeler to check their blogposts about 3D printing technology, "Make" was to make 5cm^3 functional part, and finally "Print" to take the print for free and make an assessment and recommendations for enhancing skills. The rank (out of 5) was published on website under the modeler's profile along with his/her portfolio, pricing and skills. The company always tried to keep only 5 modelers on the website, so they would not overload the platform, would give the modelers opportunity to profit, and keep their cooperation issues with customers under control.

Since the 3D modelers worked independently with customers without the interference of the company, the partners decided not to have a percentage on prefabrication process. As for postprocessing services, they started a testing phase of whether they should be only referrals or collaboration with customers should happen through them. In case of referral, they would not be able to control quality, and making these services their own should be sustainable through covering costs and bringing good profits. However, the testing phase. It did not seem successful because customers would need time to integrate these services in their manufacturing and understand how to satisfy a need with these technologies. In general,

customer acquisition in 3D printing would happen late due to lack of awareness about the technology and its postprocessing options to achieve a finished product.

The partners were keen from the beginning to build trust with the community even competitors through win-win partnerships. Yet, there was a mistrusting attitude in the Egyptian ecosystem based on the fear of losing opportunity and not believing in win-win models; it was due to the hidden agendas and partners not being fully honest and transparent with each other. Especially when initiating a collaboration with a competitor to bring profit for all, which was the strategy of this company, its competitors usually did not believe in the good intentions behind this initiative. This attitude was highlighted when collaboration was initiated by the RO Company with other players in the same market, which they doubted the intention especially when they were asked about a quotation of services' prices, or when the RO Company had been already in a strategic partnership with a company that presented a competitor for them. The only incentive for cooperation in this case was leadership because the company was already leading in the AM field in the market and they built a strong community. If the opportunity offered was appealing, these players would definitely start to trust and be open to partner. The two partners learnt from experience in the market that they should focus on building trust, transparency and honesty. Services were clear, the offers were transparent, and no conflict of interest had been highlighted. Also, commitment and consistency in their activities as a business helped them to build their community starting with two or three partners and growing gradually through sustaining activity. Trust and open communication were the fundamentals in launching partnerships even with competitors to build a diverse community and deliver more services to end-users.

Marketing

Their core values were clear from beginning: convenience and accessibility for their customers. Until this day, they have tried to position the company as an on-demand service, and a period of 3 days to print and deliver. Also, all customers, whether students or big businesses, were treated the same way and given same attention. Building long-term relationships with the customers had been always the strategy due to the immaturity of the market, and the potentials of such field were unknown from start. Although students paid little to realize their projects, but the great potential was educating them about the technology for a long-term cooperation; these students would become one day employees in companies

and then they would refer to their company for 3D printing, so they are customers in both stages of their lives. To keep these long-term relationships, they had to collect customers' feedback regularly either by email or in person after they received their orders. If these two methods were not successful they called customers to receive the feedback. From these feedbacks they developed a learning curve in understanding people's real needs from FDM technology in 3D printing and the other services they might need. Rating and reasoning were how they collected insights to cover both qualitative and quantitative (1 to 5 stars) methods in data collection, and all data related to customers and their history with the company was documented by account manager. The vision initially was to depend on the online pricing platform on the website to interact with customers; customers would access the website, upload files and receive quota, confirm the order, expect delivery in 3 days, then finally give feedback. Through this system they would choose all specific details they needed in the models without the need to interact with an employee. However, this system presented a complete failure due to the incapability of customers to make a right order: confused between colors, technologies, number of prints, number of files uploaded, or even confirmed orders without knowing. This platform remained online for almost one month and they stopped immediately when they sensed the issues that might result if they kept it running. It was like taking a step back because the market was not ready for such automated systems; customers still preferred to use emails and face-to-face agreements rather than a bot online. Forcing a new culture would not give them what they were targeting which was good positioning in the market, growing, spreading education about the technology, surviving the nascent phase and establishing a strong brand.

The strong positioning in the market among other service providers allowed them to survive and breakeven; the positioning was based on maintaining affordable prices for their customers, offering extra services through community and developing a consistent procedure of on-demand 3D printing: receiving orders, fabricating models on STL files and delivery of the models. Their competitive edge was their know-how of 3D printing and spreading knowledge about it, then it became their marketing tool because educating people about 3D printing made them gain even more customers. Nevertheless, marketing was not a priority for them at that time since they were still establishing value, and a marketing campaign would require more experience in this field because it was still at an immature stage in the Egyptian market. Of course, the community of markers would understand the value they were

delivering but the rest of potential customers would not, and a marketing campaign would bring more customers which was something they avoided for a while because their need to maintain quality of fabrication. Small-scale marketing was their way to communicate with their customers and potential ones, so they managed three types of small-scale marketing: lead generation, story and blog. Lead generation was a sort of data collection of possible customers and they consisted of online forms to leave contact information for someone to call them later and give an overview about their services and how to integrate 3D printing in their work. The conversion was low and the outreach with lead generation was not still high. To publish updates about their operation and what they do, they published a story every now and then showing their customers' satisfaction with the services and they did to make this happen. The third tool was the Blog, and they considered it as an online education about 3D printing where they collected all necessary information for their community. These methods of handling small-scale marketing gave them a good outreach and enough customers to survive in the market. As for interacting with customers on social media, they developed an automation bot to respond and answer questions automatically for a quick response. Awareness about new services took time until the customer started ordering, it required a gap of time so that the customers would detect the need that could be satisfied by the offered service. Generally, customer acquisition in 3D printing was delayed: after being contacted about the new service they made the order 3-4 months later, and to make an order it required meetings, asking for information until he/she made an actual order.

Pricing was a bit complicated for them in the beginning because using FDM technology: in order to receive a good quality a customer would need to pay a lot, and it had no low-cost option. This was due to the fact that it was an emerging technology with a high price and not everyone had access to it, in addition to the challenging process of pricing FDM services all over the world. They had set the price to 12 LE to stay sustainable in operation and affordable, while covering the running cost and all expenses of the business. Cost was not the base of their pricing because it was not enough as they were more expenses related operation, not forgetting that it was still a new market when they launched. This price was a reasonable one between the other pricings they found in the market which varied from 5 to 40 pounds. They remained with this pricing for a while despite the Egyptian pound devaluation and other economic constraints the country faced, but they started also to consider recently raising the price a little to sustain and bring a small profit. Keeping the pricing while giving discounts

helped significantly in acquiring more customers and expand their market share. Also, Decreasing the price would not maintain operation and increasing it would make them lose customers.

Sustainability

Partner (A) was concerned since the business launched about lean production and efficiency in operation. Thus, when running operation, he always kept the excess in plastic and waste in the aim to find a feasible solution in recycling them. Until, one day an enthusiast about recycling came along and made a deal with the company to collect the waste and test the possibility of recycling it into filaments again for printing. After he was done with the recycling process, Partner (A) tested the filaments the other produced and checked the settings for being reused for more improvements. He was also conscious about the amount of energy used in production, which was not high "3D printers use energy equivalent to energy used by a monitor screen", said Partner (A). When it comes to pollution, he was aware about the emissions in 3D printing were due to the oil-based ABS material. The alternative was to use PLA but because of its low functionality and hardness, ABS presented a better option for customers. Nonetheless, some customers still ordered PLA material. To avoid health problems, they forced a rule of wearing masks while being close to the machine and put separators between the area of production and rest of the office. Additionally, to produce less emissions, he adopted better techniques in production that produced less pollution, e.g. Six Sigma. Despite of all these initiatives to lessen the environmental impacts of their operation, customers were only interested in what this offered them as an economic benefit. As for the government, they forced regulations only when it came to allow the machines to pass the customs but there was no auditing process nor inspection after the machines were released from the ports of the country. In some cases, they needed to get four consents from different governmental entities. Some employees in these entities offered to facilitate the process in return of bribes, but they insisted in following the legal procedures. Bureaucracy and corruption would present great barriers to the growth of the 3D printing field in Egypt. But to remain positive, they always empowered entrepreneurs through offering technical support, discounts, operational and managerial advices, and right tools for production. On one hand, young makers managed to win competitions, start-ups were launched, and those who had ideas succeeded in making them true. On the other hand, companies consulted them in

integrating 3D printing in their processes to make the production more efficient and cut several phases in production, and universities asked for recommendations about 3D printing machines to have in their labs. Their contribution did not stop to this extent but also involved the launch a prosthetic project for those who need artificial limbs and educational 3D prints for the visually impaired, and in consequence of their initiative several entities locally and internationally joined the cause to satisfy more needs. In a way, RO Company not only provided access to 3D printing for a reasonable price but also helped spreading awareness and education about the technology, supported businesses in many ways and provided tools for those who needed empowerment.

Entrepreneurship Scene in Egypt

Speaking about a new industry in a market, a network of partners always helps the industry to excel fast. However, in the Egyptian ecosystem the lack of trust hinders a lot of collaborations and win-win business models from happening. When talking about Digital Fabrication and specifically 3D printing, governmental laws related to 3D printers passing the customs were bureaucratic and very complex, and to avoid this complexity illegal procedures were a getaway. 3D printing technology until this day is considered a national security issue, due to the fear of making 3D printed weapons, and security bodies should authorize their operation. Also, the knowledge base and awareness about Digital Fabrication are still missing; in another sense, people do not know how to utilize it in their daily life or benefit from the many opportunities it presents. Nevertheless, there are no spaces designated for small-scale fabrication for entrepreneurs to start their businesses, although the government has been encouraging manufacturing industries in the last few years. Starting a business in 3D printing in most cases does not require a high capital, but still entrepreneurs fail to sustain their start-ups due to lack of knowledge about operation and failure in business management.

3.2. Idea Generation Workshops

The two workshops took place in Milan, in the University of Politecnico di Milano, and the participants were product and service designers and researchers in design studying at the university. They were familiar with the research topic and at the beginning of the first workshop a presentation took place to introduce the focus and the international case studies collected to show the best practices. Then, the brainstorming activity started using the SDO-

toolkit to follow the environmental, social and economic principles in developing new ideas and later on scenarios. They contributed with some ideas and concepts for how to fill the gaps in the AM industry found while reviewing and presenting the case studies. Gaps in the best practices of AM involved negative environmental impact, absence of network-based aftersales services, lack of procedures towards safety of operators, and neglection of socio-economic benefits on the communities where PSSs are taking place. The concepts are divided into environmental concepts and socio-ethical concepts. The economic concepts, related with DE, were excluded during analysis due to their high resemblance with the concepts generated under the environmental and socio-ethical pillars. The SDO-toolkit presented the main criteria to build the concepts upon. Environmental concepts covered: system life optimization, transportation/distribution reduction, resource reduction, waste minimization/valorization, conservation and biocompatibility, and toxicity reduction. The socio-ethical concepts covered: improve employment and working conditions, improve equity and justice in relation to stakeholders, enable a responsible and sustainable consumption, favor/integrate low-income, weaker and marginalized people, improve social cohesion, and empower/enhance local resources. Most of the concepts were developed during the workshops, others were added later after the local investigation happened through qualitative case studies. Each category had a different color to identify those developed earlier and those concluded later through research. The concepts were later clustered and polarized in the second workshop to show possible near-future scenarios and develop them into visions of S.PSS business models.

3.2.1. Environmental Concepts

This section presents the environmental concepts clustered under the principles of a S.PSS business model. The principles are covering resources management, transportation and distribution, biocompatibility and toxicity avoidance. Each principle had some priorities in generating concepts; these priorities were approaches that could trigger ideas during the brainstorming about the life cycle assessment of the business offered value, so it would not leave negative environmental impacts and optimize its operation. The concepts generated were solutions of how to achieve this goal and help in shaping new sustainable business models based on products and services, including life cycle optimization services.

3.2.1.1. System Life optimization

The principle of system life optimization discussed how the system as a whole from products and services could be optimized in order to decrease the environmental impacts and make the system durable. The priorities had concepts like: maintenance, repairing, substitution, upgrading, re-configurability, shared use services for products or infrastructures, product sharing/reuse/second hand selling, cultural and aesthetics upgradability. Therefore, the ideas generated during discussion were following the optimization of the resources used in the system, see Figure 3-1.

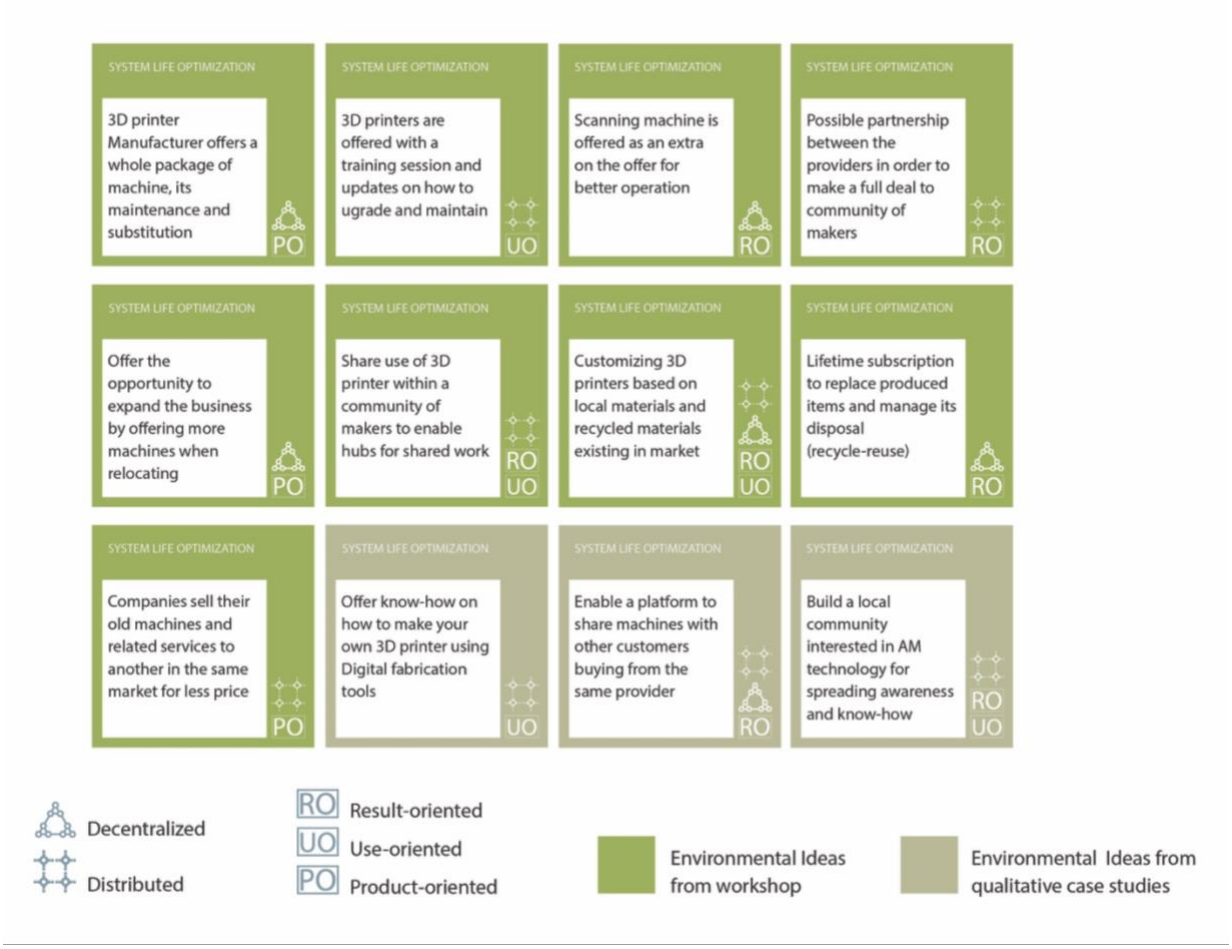

Figure 3-1 Ideas of System life optimization

3.2.1.2. Transportation/Distribution Reduction

One of the major environmental issues is CO_2 emissions and their impact on the atmosphere. Therefore, during the workshop the priorities followed were: use of digital infrastructure, alternative partnerships of short distances, use of local resources, on-site production, on-site assembly, partnerships to reduce transportation and packaging, and reuse of packages. The ideas generated during and after the workshop were going toward proximate partnerships and on-site production, see Figure 3-2.

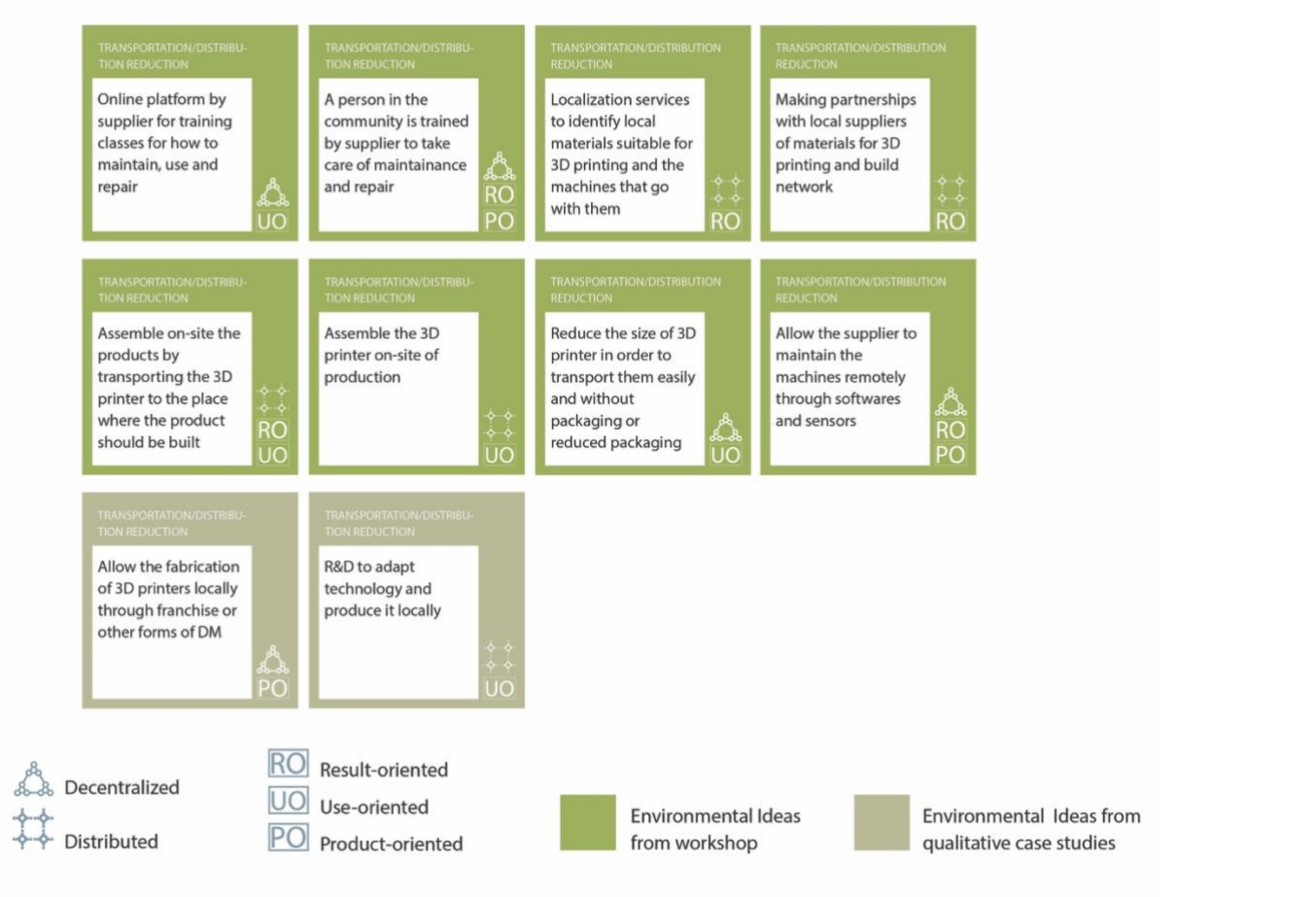

Figure 3-2 Ideas of Transportation/Distribution Reduction

3.2.1.3. Resource Reduction

Each system should be responsible for the amount of resources used and management of these resources efficiently is a standard for a sustainable PSS. In this perspective, the priorities in resource reduction principle were: collective use of products and infrastructures, outsourcing of activities requiring specialization, partnerships to efficient use of existing products and infrastructures, outsourcing activities in high scale economies, adaptation of the system to the context, design services for the adaptation of the system to available resources, offer the available products, and offer products on pre-determined demand. The ideas were generated based on these priorities in the aim of better management of resources, see Figure 3-3.

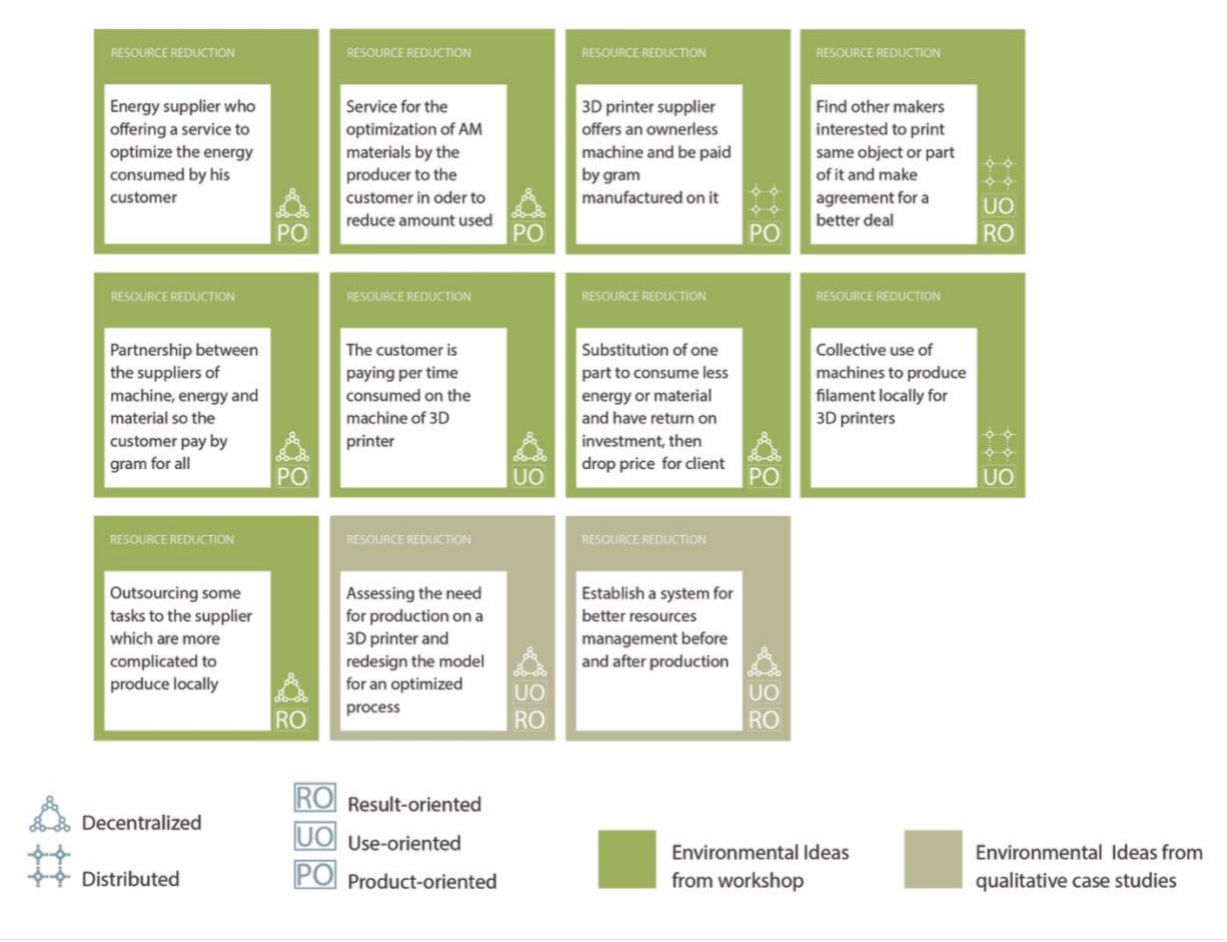

Figure 3-3 Ideas of Resource Reduction

3.2.1.4. Waste Minimization/Valorization

Waste is a big issue when it comes to AM, products and machines. To tackle such issue, a reconsideration of how waste is managed had to be done. Under this principle, the priorities gave a positive path towards what should be done in PSS businesses. The priorities were: take back services for re-using, re-manufacturing, recycling, composting or energy recovery, and local partnerships for secondary use of resources. Ideas were covering the priorities in order to find out solutions for better waste management, see Figure 3-4.

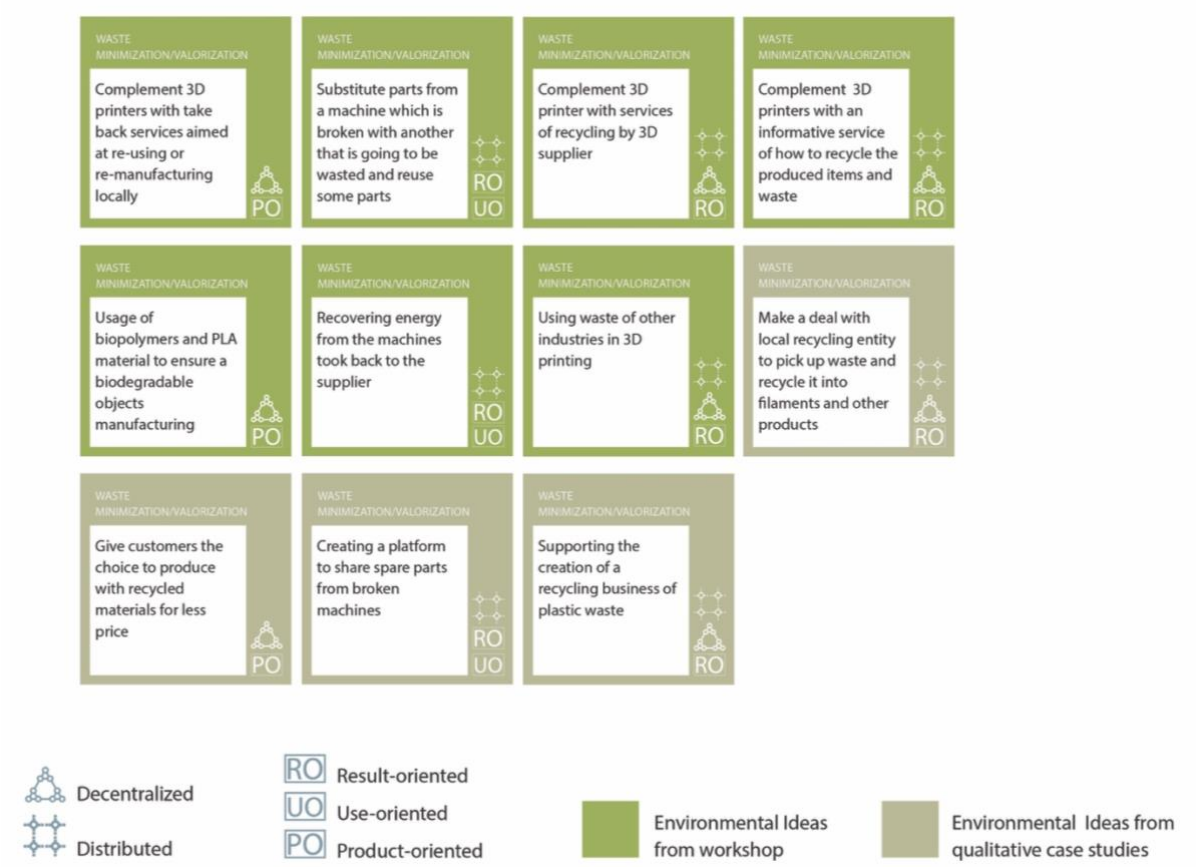

Figure 3-4 Ideas of Waste minimization/valorization

3.2.1.5. Conservation/Biocompatibility

Each business should investigate local resources first in order to utilize them instead of getting resources from out of context. Therefore, biocompatibility principle is concerned about these priorities: partnerships aimed at decentralized and renewable energy resources, utilization of local renewable and bio-degradable materials, utilization of passive energy resources, and utilization of local recycled materials. See Figure 3-5, the ideas were generated based on the mentioned priorities.

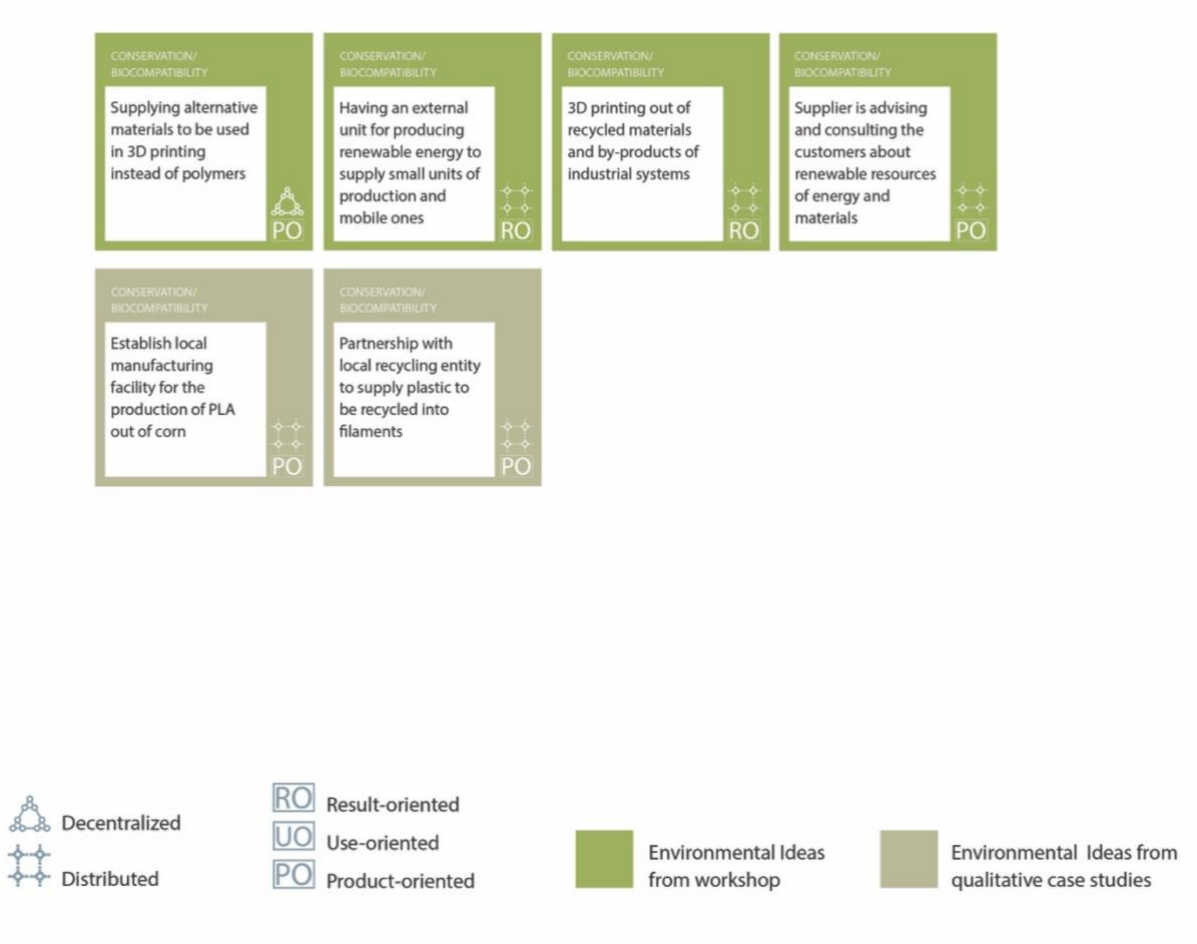

Figure 3-5 Ideas of Conservation/biocompatibility

3.2.1.6. Toxicity Reduction

Toxicity is a concern of manufacturing businesses and the lack of awareness and good management of toxicity can have major environmental impact. Thus, knowing possible ways to handle toxicity is what attributes S.PSS. Priorities in this principle were: partnerships to reuse and recycle toxic substances, services to minimize or treat toxic and harmful emissions, end-of-life treatment of toxic substances, and toxic management services. Ideas targeted the emissions resulted during AM and how it could be treated and treatment of waste, see Figure 3-6.

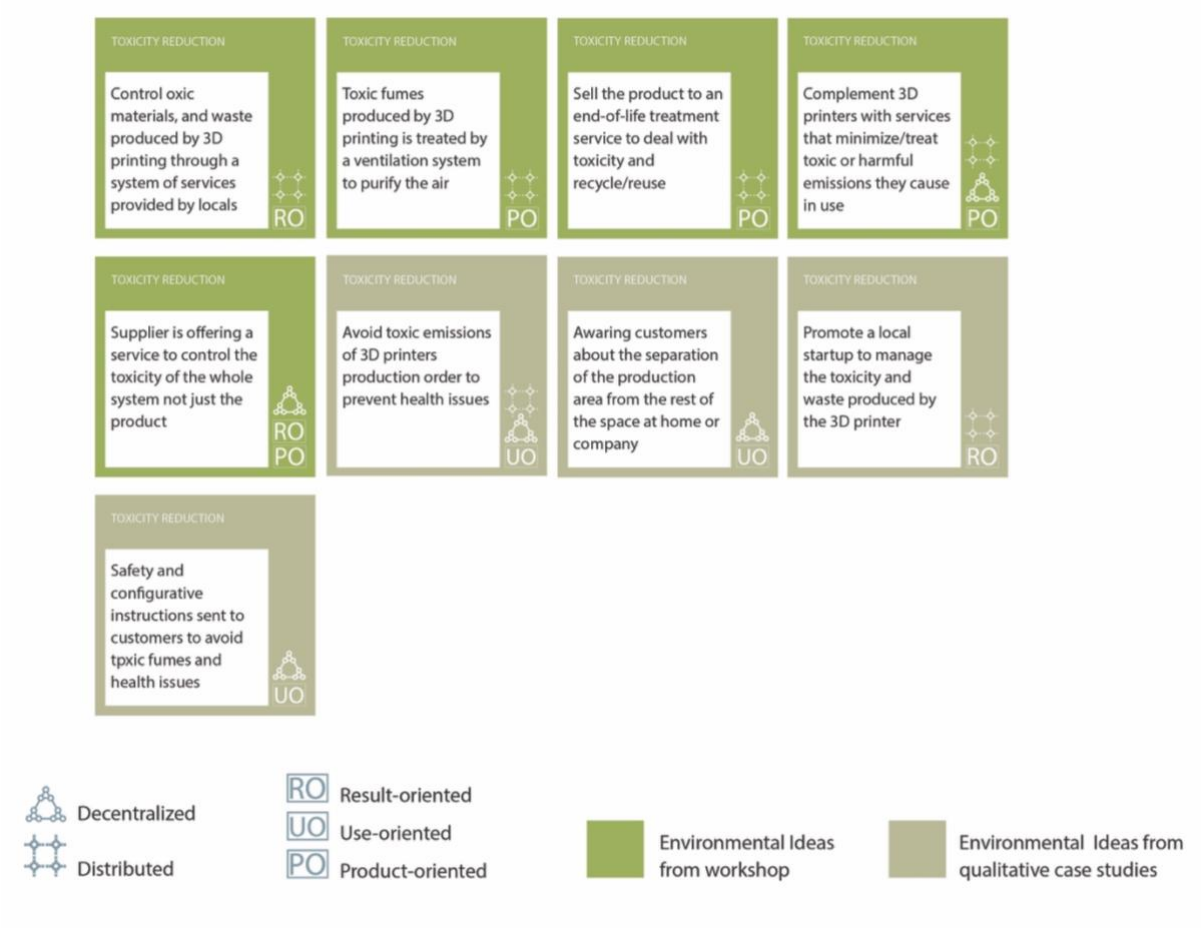

Figure 3-6 Ideas of Toxicity reduction

3.2.2. Socio-Ethical Concepts

This section represents the socio-ethical concepts developed during the participatory workshops. The concepts were covering the principles of improvement of working conditions, employment opportunities, equity among stakeholders, responsible and sustainable behavior in business, integration of marginalized communities, promotion of cohesion in society, and local resources enhancing. Each principle had priorities to follow in order to generate ideas for a sustainable and responsible business towards the society. These priorities were approaches to decrease inequality between social classes and stakeholders, enhance the quality of life for all, and promote a cohesive society where resources are distributed fairly and managed properly.

3.2.2.1. Improve Employment and Working Conditions

Employment opportunities and working conditions are not at their best in low and middle-income contexts, therefore there is a need to focus on improving them to offer a better quality of life for people living in these contexts. This principle had the priorities of: access to product than buying its ownership, enhancing working conditions, promoting health and safety in working conditions, setting appropriate working hours and fair wages, and achieve the satisfaction, motivation and participation of employees in the system's operation. The ideas under this principle targeted employees' satisfaction and fairness in treatment, see Figure 3-7.

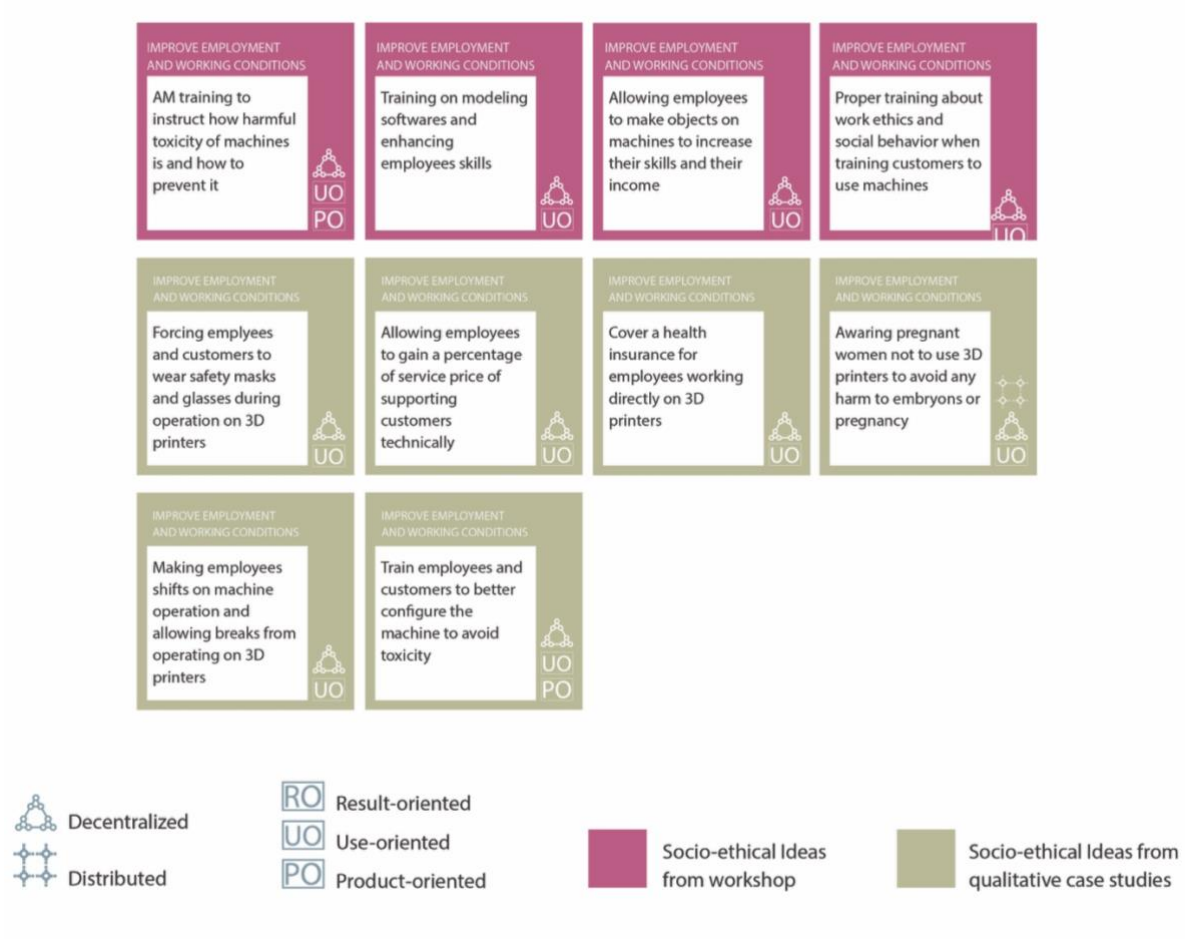

Figure 3-7 Ideas of Improve employment and working conditions

3.2.2.2. Improve equity and justice in relation to stakeholders

Equity and justice among stakeholders are crucial factors in running a socio-ethical business. Without equity, the system can fail due to injustice or unfair transactions between different players in the ecosystem. Ideas under this principle were formulated with this aim as a base, and priorities were: promoting just relations with partners and customers, just relations affecting the community, and just relations with institutions and agencies. In the light of these priorities, ideas were formulated as in Figure 3-8.

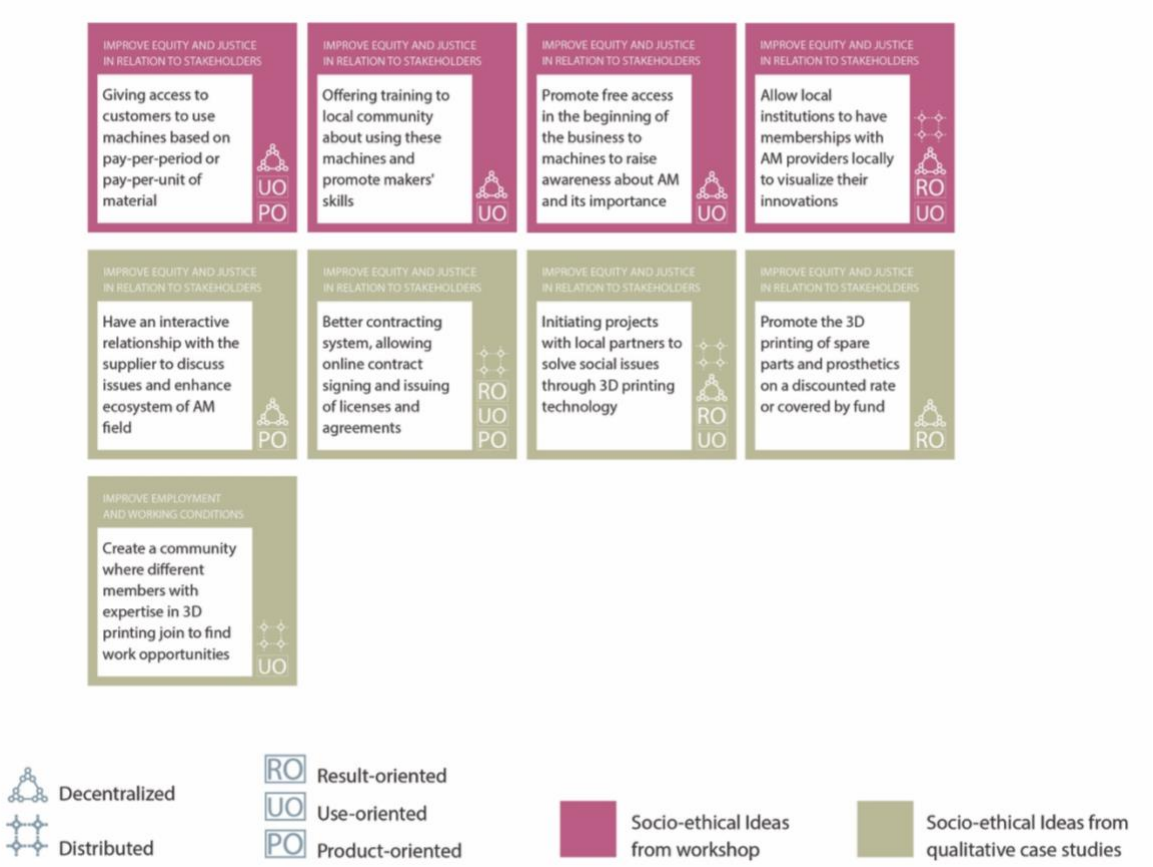

Figure 3-8 Ideas of Improve equity and justice in relation with stakeholders

3.2.2.3. Enable a responsible and sustainable consumption

Sustainable consumption and production are a base for sustainable development where individuals are not exploiting resources in irresponsible way, neglecting the right of future generations in these resources. This principle tends to cover this concern through proposing possible concepts to eliminate such behaviors through the promotion of responsible consumption. Priorities under this principle were: enhancing social sustainability of stakeholders, educating customers and end-users about responsible consumption, promoting responsible participation of customers, involving s in customization of systems toward sustainable behavior, and involving customers in the design of systems. Ideas were developed towards promoting a responsible behavior of all those who were involved in these systems, see Figure 3-9.

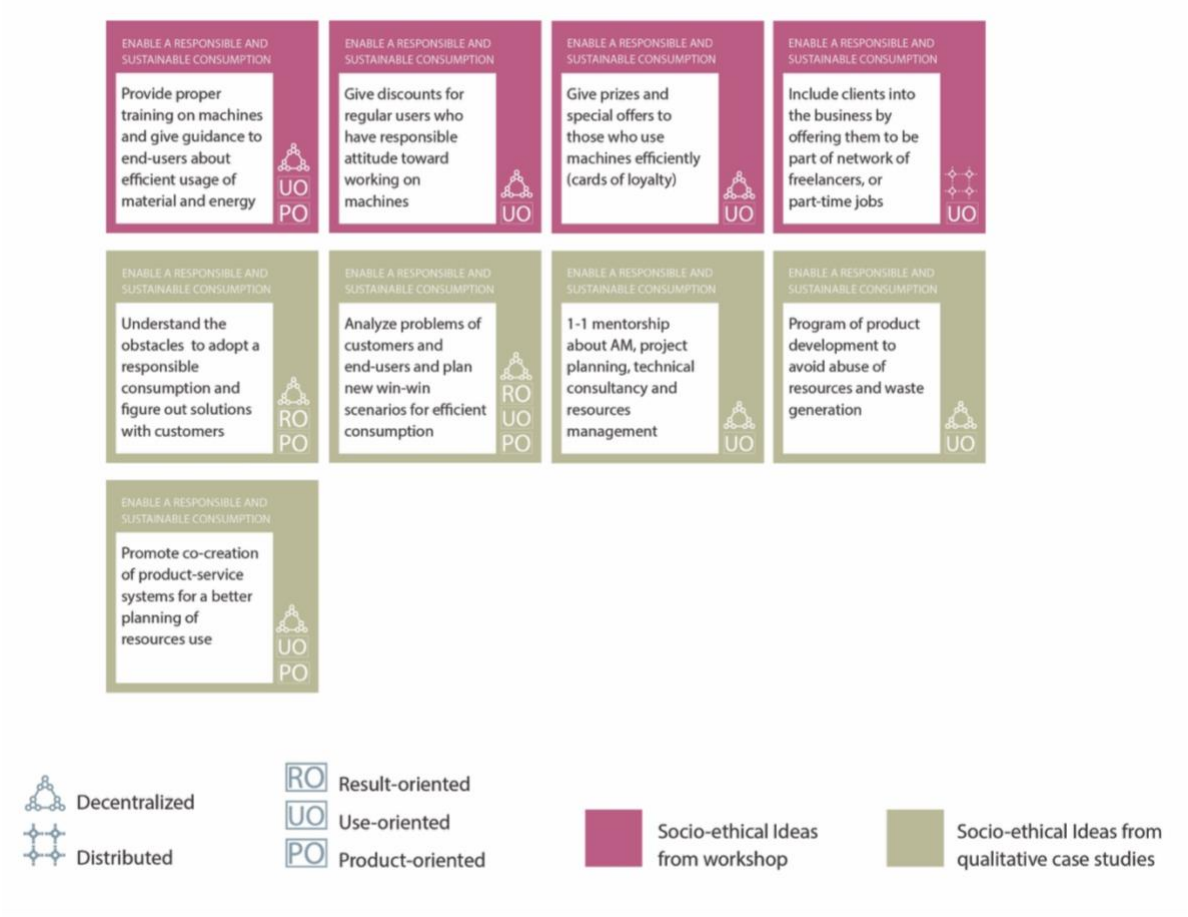

Figure 3-9 Ideas of Enable a responsible and sustainable consumption

3.2.2.4. Favour/integrate low income, weaker and marginalized people

Marginalized communities are suffering due to lack of attention given to them. Individuals living in these communities in most cases suffer from poverty, poor living conditions, and unemployment. This principle covered the following priorities: allowing access to products to low-income people, offering all-inclusive running costs to avoid interruption of use, developing affordable products and services, diversifying the offer with high and low costs, promoting shared economic property, promoting labor services with equitable access, allowing easier access to credit, and improving conditions for weaker people. Ideas were developed in the aim of providing better opportunities for people in low-income contexts, see Figure 3-10.

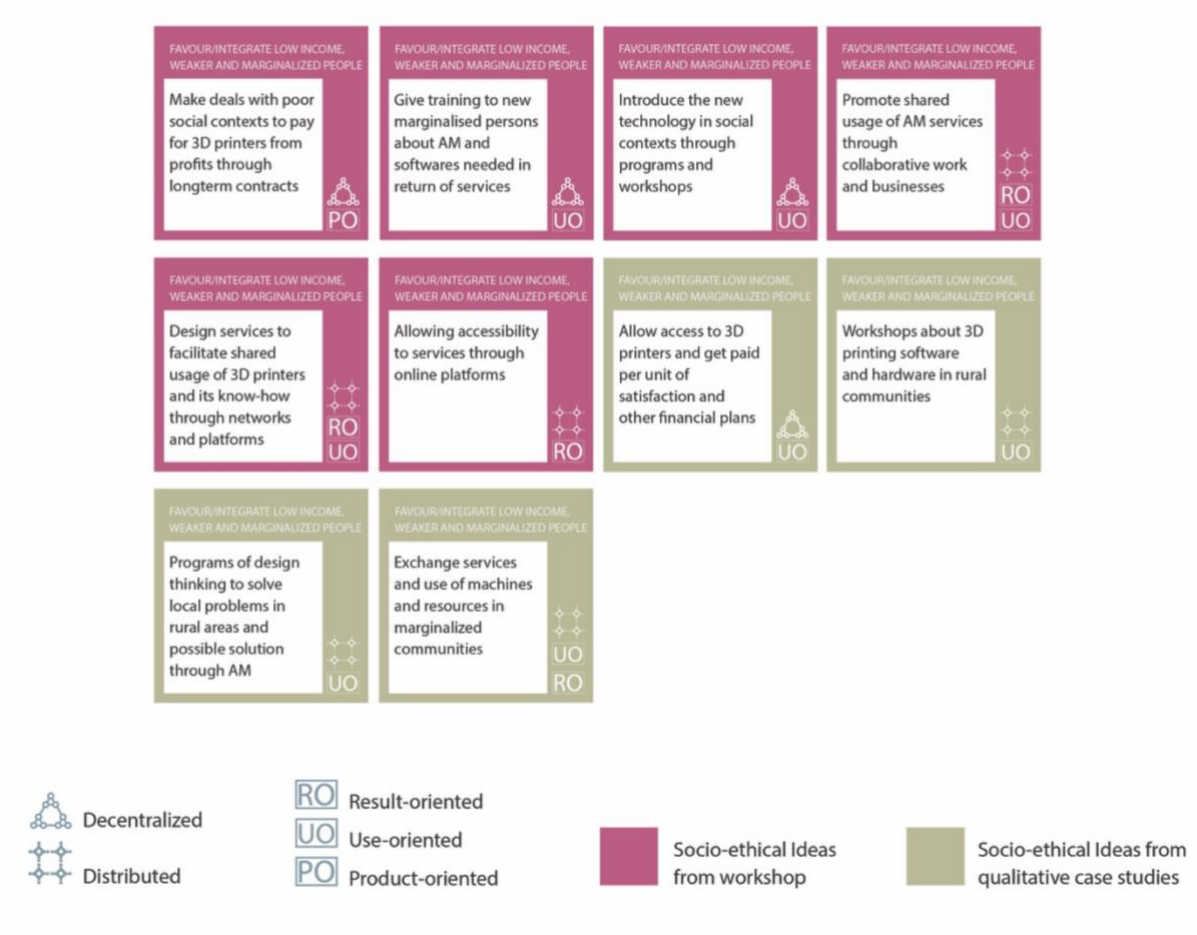

Figure 3-10 Ideas of Favour/integrate low-income, weaker and marginalized people

3.2.2.5. Improve social cohesion

For a society to be equitable, social cohesion must happen at a certain point. Excluding some segments from the social benefits and rewarding opportunities would only create negative consequences. In an unfair society, entrepreneurship is not enabled due to lack of equal opportunities for all. Hence, this principle seeks to follow the priorities of: promoting systems for neighborhood integration, sharing of common goods and services, promoting co-working, encouraging participation of inhabitants in co-design of common goods, and enabling social integration between different generations, gender and cultures. Ideas followed the priorities in concept for better social cohesion, see Figure 3-11.

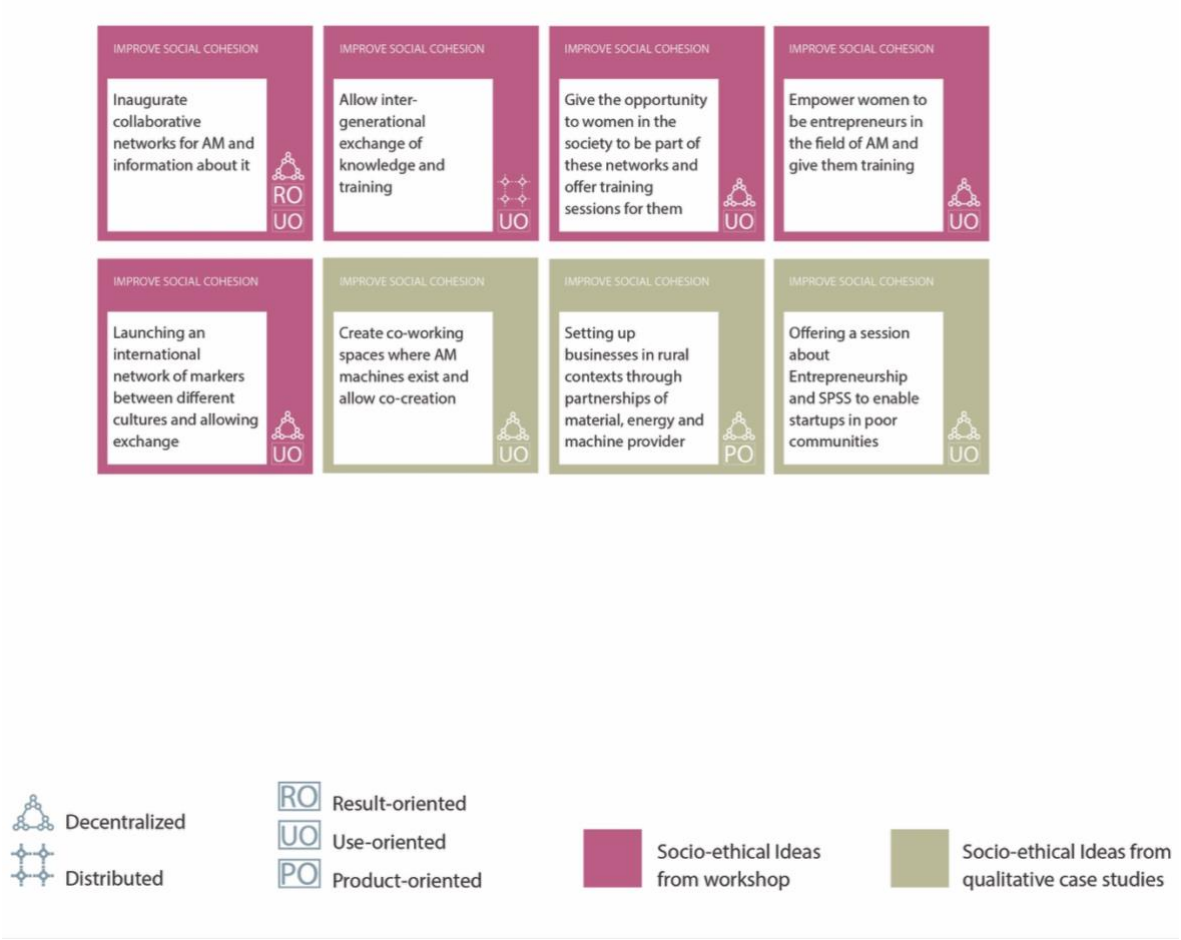

Figure 3-11 Ideas of Improve social cohesion

3.2.2.6. Empower/enhance local resources

Local resources are often neglected, and needs are covered by resources out of context. The distributed and decentralized systems allow the access to local resources to decrease dependence on central units and allow off-grid independence. The principle of empowering local resources focused on specific priorities to enhance its exploitation; priorities were: extending the access to local resources to low and middle-income entrepreneurs, including in the offer all-inclusive running costs, offer the access to distributed/decentralized economies of energy, food, water, manufacturing, software, information and design to low and middle-income individuals/organizations, creating services in local contexts where they are needed, empowering local capacity in goods' production, and encouraging systems using local natural resources, local cultural characteristics, cultural identities, and different tastes and aesthetics. Ideas were generated in respect of these priorities, see Figure 3-12.

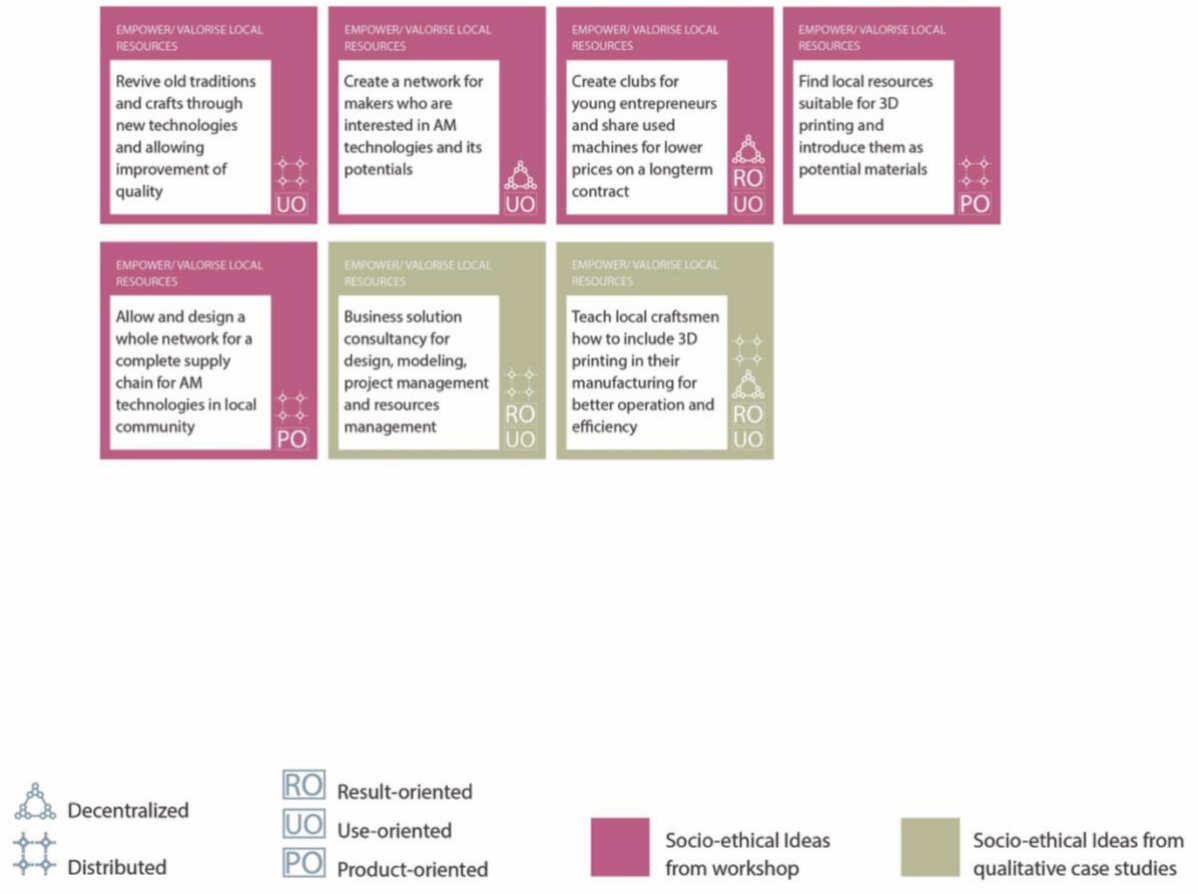

Figure 3-12 Ideas of Empower/enhance local resources

3.2.3. Clustering and Polarization

After the ideas' generation process, the second workshop of the two involved clustering those concepts on a polarity, to exhibit possible scenarios that could turn into visions. Scenarios developed were tackling environmental and socio-economic issues in AM field, and showing possible opportunities from 3D printing adoption in PSSs in low and middle-income contexts, see Figure 3-13. Scenarios developed were: networking for better opportunities, better operation to strengthen the employee for customer's sake, allowing access to technology and training, offering all-inclusive services from supplier, empowering locals socio-economically through AM, promoting responsible behavior of stakeholders, efficient use of resources, supporting growth of business through services provided by suppliers, offering end-of-life treatment of machines and waste, establishing strong local infrastructure for 3D printing, sharing the use of machines and services, localizing services to be based on local resources, promoting on-site production, adapting technology to be suitable for local use, and integrating 3D printing in daily life activities for better quality of life and business opportunities. These scenarios were further developed into four visions, which could transform in their turn into business model.

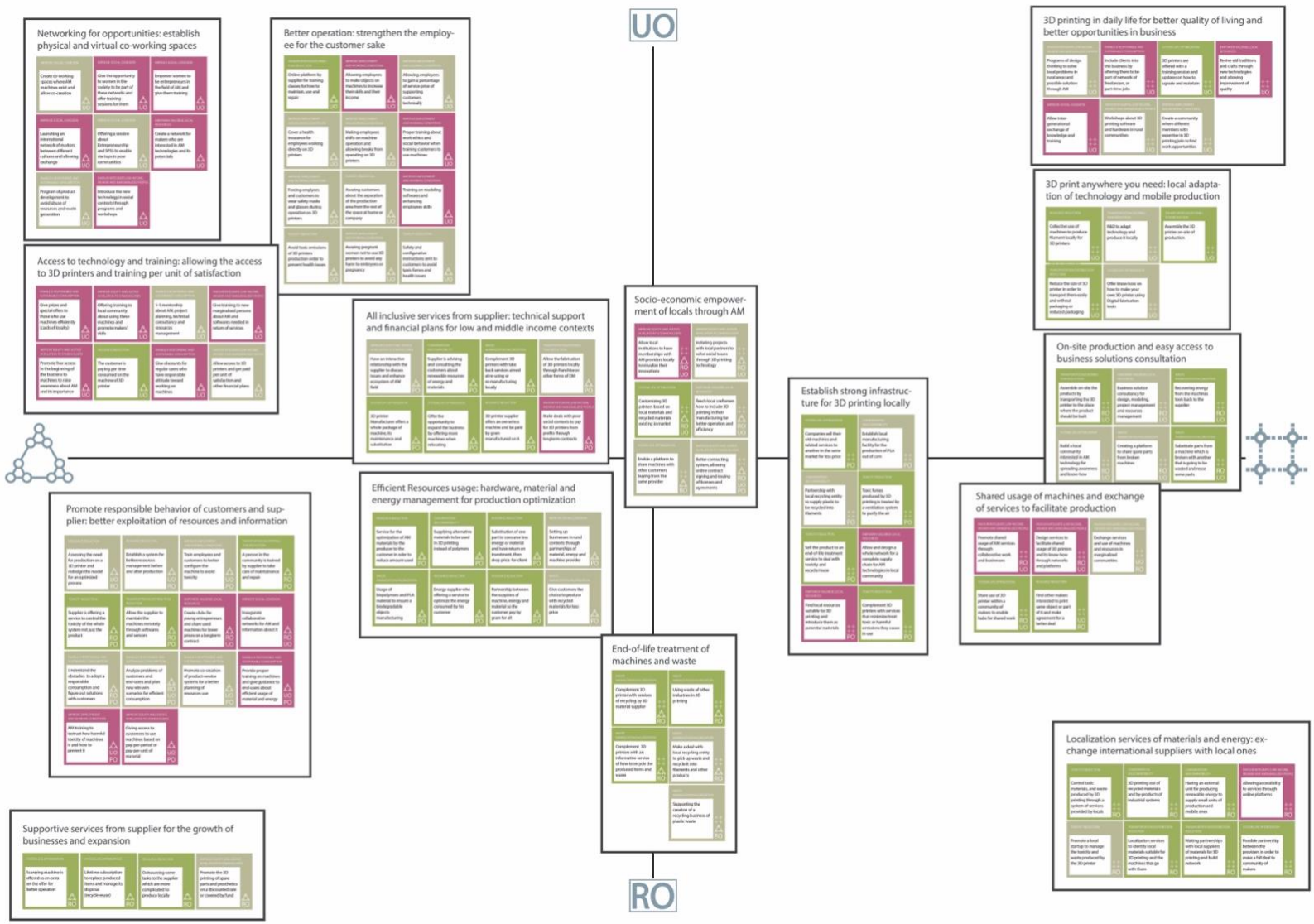

Figure 3-13 Clustering and polarization of ideas into scenario

3.2.1. Proposed Visions

The scenarios developed throughout the workshops and analysis process were the base of the visions in Figure 3-14. The visions involved use-oriented decentralized, use-oriented distributed, result-oriented decentralized and result-oriented distributed. They were referred to in numeric sequence (1st, 2nd, 3rd and 4th) for easily discussing them with stakeholders in the in-depth interviews. Use-oriented visions were more towards enabling users and makers to create products through access to digital fabrication tools and information about it or receive on-site units of manufacturing to produce locally. Result-oriented visions were targeting aftersales services of lifetime support for 3D printed products and initiating joint ventures with local service providers to deliver services and goods. The level of servitization in these visions were aimed to be high in order to insure the dematerialization process of offerings. The scenarios leaning more towards product-oriented approaches were included in the two distributed visions, where customers could have access to 3D printers in return of satisfaction unit.

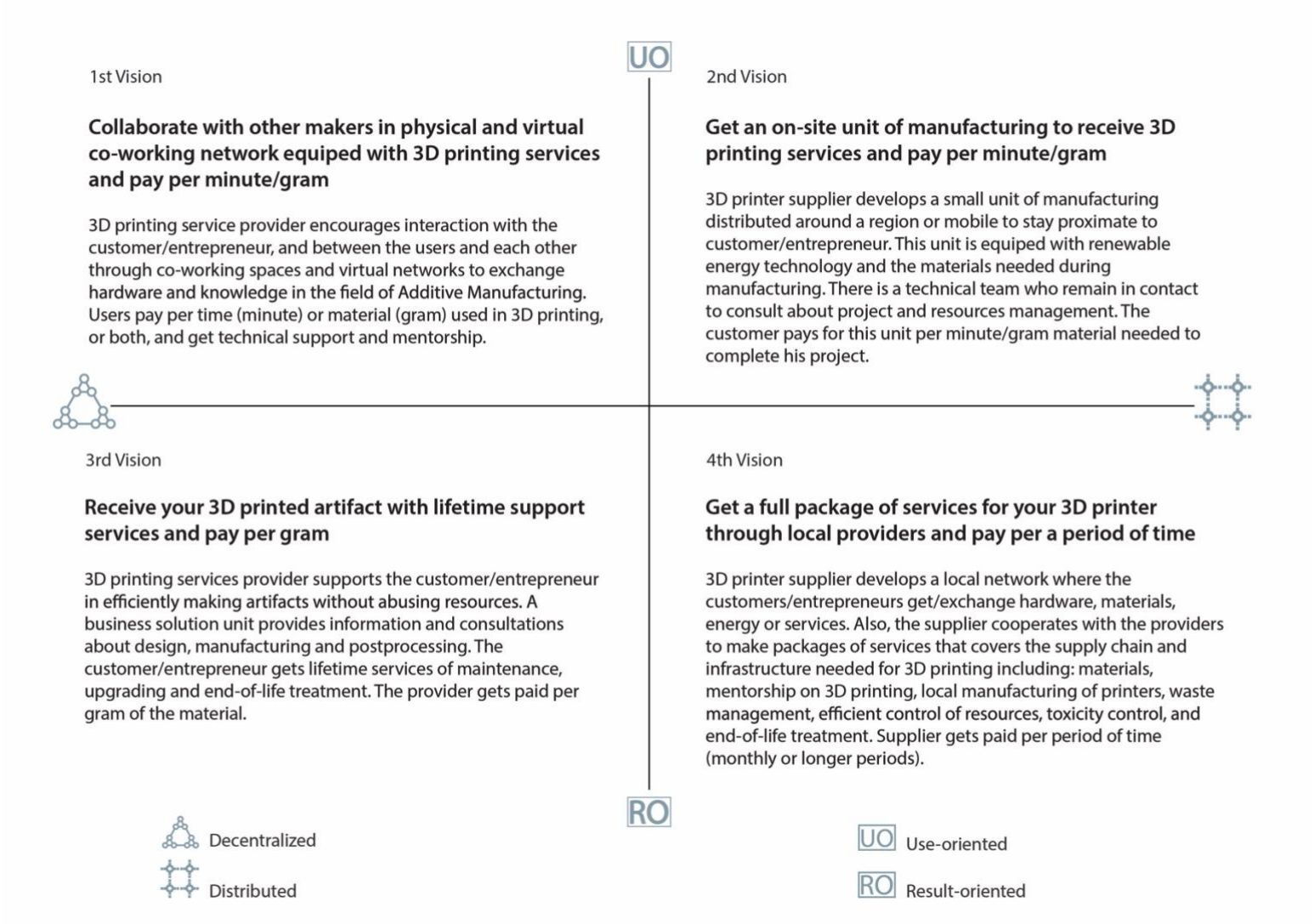

Figure 3-14 Four visions for S.PSS business models

3.3. In-depth Interviews

The participants started the discussion with identifying their background and how they have come across AM in their career. Some were in direct interaction with the technology due to their roles in their entities, and others' roles were to empower entrepreneurs and young makers to launch their own business to face the socio-economic challenges.

3.3.1. Applicability of Visions

When presenting the four visions concluded from the workshops' data analysis of the outcomes to the interviewees, they showed their understanding of these models and their familiarity with similar concepts that are more service-based for low and middle-income contexts like Egypt. The first participant who had an academic background about operation was interested to discuss the operation details of each model and what process the value chain should follow in order to deliver the final value. He confirmed the fact that these visions would need a big network structure in order to deliver the promised products and services, and one entity would not satisfy the need on its own. Each of these visions were claimed useful in certain sectors and industries and not all of them will be comprehensive for all.

> *"The visions are applicable in different industries, for example on one hand, the 3rd vision of lifetime support would be beneficial in prosthetics' making where a kid has access to an artificial arm and grows with it. When he reaches a certain age, it must be replaced with another more convenient with his physique. Prosthetics will not generate an income to pay for services, therefore smart solutions should be developed to sustain such model. On the other hand, the second vision of distributed and use-oriented scenario, it is applicable for example in agriculture for when a farmer is facing certain issues that can be solved through a technology… a product-based offer will be of a high cost and he will not afford it, then we have to offer a service-based model, which is use-oriented, to have a win-win cooperation for both the customer and service provider, especially when there is a profit resulting from this cooperation." (Stakeholder 6, CEO of ICT corporation)*

There was a general opinion among all interviewees that the 1st vision was very similar to fab labs and incubators settings in Egypt, and that the main customers in this context would be students and researchers. Therefore, most of these settings were initiated by universities, NGOs and few by individuals for the sake of profit. The governmental participant confirmed

that most of the labs were inaugurated in educational institutions due to lack of expertise, immaturity of technology and availability of limited resources. Hence, the decentralized networks were the preferable strategy in launching such settings across Egypt, rather than the distributed approach.

> *"The cost is the main criteria here… it will determine whether the machine will be decentralized or distributed, in case of expensive machines the decentralized approach is much feasible than to have a machine at each distributed unit. The expertise is also an important variable because it will define whether there is a need for more control over the operation, so the machine will remain at a decentralized level, or everyone has enough experience running a 3D printer, so it can exist on a distributed level." (Stakeholder 1, academic background in operation)*

Thus, cost and expertise were the two main factors stated by the academic interviewee to choose between a decentralized or distributed setting. In differentiating between the need for expertise among use-oriented and result-oriented, Stakeholder 1 has confirmed that the use-oriented visions would provide low cost services through training expertise to customers and allowing them to make their products on their own. However, with result-oriented the cost would remain higher due to the delivery of a ready product, the cost in this context covered the expertise and running costs. Relating to cost and expertise, all participants confirmed the fact of technology dropping in price eventually, stating that with the high demand, fast development of any technology and the increasing usability of devices, everyone could have access to it for a lower cost and manage it perfectly.

> *"We are a price-driven economy, when expertise accumulates people will move to use-oriented models to lower the cost on themselves" (Stakeholder 1, academic background in operation)*

In other words, those who are training users to earn expertise will be use-oriented, and those who want a ready product will depend on the expertise on result-oriented companies. Universities are of the first kind who want to raise the experience in dealing with new technologies, and commercial companies will target 3D printing service providers who can get the job done. Stakeholder 1 confirmed during the interview that fab labs were not as commercial as result-oriented companies.

The 1st vision had similar attributes with fab labs and maker spaces, so most of the interviewees could relate to it immediately. The consultant for entrepreneurial ventures could identify it as coworking spaces, incubators and fab labs due to his work background.

> *"Use-oriented decentralized vision is the most common and existent in the ecosystem, they are seen in fab labs and incubators. This model allows the discussion and coworking atmosphere among the users themselves… the services they are getting from the place is not as valuable as the interaction happening between any customer and others in the place whether teammates, colleagues, other users, etc. Also, the technical advice a customer could get from the people working in these places or from the other users is a very important feature… even if all tools are available, the customer still needs technical mentorship." (Stakeholder 3, entrepreneurship consultant)*

Despite of the advantage a customer could get in coworking spaces and fab labs, which all participants confirmed during interviews, they also specified a major gap found in this atmosphere: these settings have always offered access to machines, but technical support and advice were lacking in some contexts. Educational and introductory programs were stated as necessary before having full access to machines. Customers in a lot of cases were unfamiliar with machines and needed mentorship due to machines' low usability. Some labs provided this mentorship as part of their programs, others were not aware about this gap until recently. In addition to this gap, the localization of the labs was mentioned during two interviews where the participants clarified the need to adapt to local needs and provide machines needed by local customers.

> *"Fab labs are not useful for common people, the technology there is not for everyone. Maybe these places should equip their spaces with other machines needed by locals, like sewing machines, carpentry, etc. depending on the local common industry and interest in the governorates and cities." (Stakeholder 5, manufacturer-DLP printers)*

Another gap detected through discussions was the lack of awareness about services provided by fab labs and coworking spaces. It was mostly due to poor marketing adopted by entities and absence of introduction about the benefits of new technologies such as 3D printing, its capabilities and limitations. This gap contributed to the constraint in segments interested in

acquiring these services to be restricted to researchers, students and entrepreneurs from tech background. These customers represented the market segments that had already enough awareness about such technologies and what they could do. DIY concept is until this day relatively new and spreading awareness about it is necessary for other segments to detect the need that can be fulfilled by technologies like 3D printing.

> *"We don't have the culture of DIY, so digital fabrication is already something new to the society. Expecting a jump from the point of not having such culture to having a whole ecosystem for digital fabrication… there is a gap we need to fill, and we have to shift from the habit of consumption to production. Spreading awareness is what need and empowering people to be makers is necessary because they are not used to make things by themselves." (Stakeholder 7, NGO manager)*

The culture of consumption has been dominating over the culture of production as confirmed by the NGO manager who has been in contact with several users coming to their fab lab. For years, there were initiatives toward promoting manufacturing to produce local goods instead of importing from abroad. Thus, to overcome such gap, the interviewee suggested spreading awareness about DIY and digital fabrication since they were simple manufacturing methods, and their users could fabricate goods for themselves to satisfy their needs.

The 2nd vision sounded promising to the entrepreneurship consultant in the perspective of what it could offer from temporary access to machines and paying per period of usage.

> *"The use oriented distributed vision that offers mobility of machines is very promising… I would suggest combining it with the virtual services in the first vision from mentorship and access to information, along with the ability to order online the units needed for production then receive on-site. If a technical background team is also available for inquiries, this will add also a value to the offer. Involving online ordering in this model will give it much more value." (Stakeholder 3, entrepreneurship consultant)*

He reflected on the high expenses for purchasing 3D printers and other complementing devices, especially when the need for them is temporary and the machine will run only for a short period of time. The 2nd vision presents a great value in this context for those who need

temporary production as mentioned in the next quote by the local manufacturer of FDM printers.

> *"In mega projects, this vision will be the most applicable. 3D printers of metal present a great example for this vision… One service supplier can have its ownership and shares it with other companies while running big projects in need for such printers. It will be very appealing for some customers who don't want to have it on-site for long." (Stakeholder 4, manufacturer-FDM printers)*

For temporary production, this vision was recommended by most participants due its reliance on time as main factor in operation. Especially when talking about machines that were very specialized in certain productions (e.g. metals, ceramics, dental, etc.) this scenario would be useful for makers. However, because the usability of these machines has been poor, the DLP printers' local manufacturer predicted, based on his experience, that the users would face many troubleshoots while using these machines.

> *"For dentists, some devices to be delivered on-site, in the clinic, will be beneficial for them. But the usability of the machines is still poor, so the users will definitely face some issue until they get used to its configuration. I can see that the vision is strong and will be even stronger when the offer includes not only the 3D printer but also a complementing machine for example an intraoral scanner… to be like a whole unit delivered to the dentist to reach a final result." (Stakeholder 5, manufacturer-DLP printers)*

The 3rd vision was identified by two participants as aftersales services, but with a lifetime period the discussion went on about how to maintain the support services financially. Both participants saw great potentials in this vision for prosthetics and products described as essentials.

> *"Example where this vision is needed most is prosthetics… lifetime support services of prosthetics are necessary as it is an indispensable object for them." (Stakeholder 6, CEO of ICT corporation)*

When discussing how to make it sustainable, marketing and selling high-end products to those who could afford them presented a good opportunity to create a margin, as further

explained by the CEO who managed similar services for a low-income target group. This margin could in turn cover low-end products' cost to be given away.

> *"This model would work by providing a way to sustain this lifetime support for a small amount of money, as people perceive what is free as it has no value. Making a prosthetic on 3D printer would cost around 2000 LE while its price in the market can reach up to 15k to 20k, so they can pay to feel like they earn it fairly. The alternative is a donner to support its provision to those who need them. It is doable but there is a need to understand how to make it sustainable… maybe the proper branding for the product, being environmentally friendly and having a social impact, when combined, are good tools to market it with." (Stakeholder 6, CEO of ICT corporation)*

The 4th vision was tackling mainly the presence of localized services for 3D printers' owners in order to fulfil their needs at a distributed level without the urge to go back to the main supplier, who in most cases abroad. Since the level of technology maturity has not reached high standards in the market, most of the machines existent in the market were claimed as imported and the local machines were not qualified for good quality production. The opportunity in this vision was that the support should not necessarily be provided through the main supplier. While discussing the vision with FDM printer's manufacturer, he reflected on his experience in the delivery of services and confirmed "trust" as a crucial issue.

> *"The customer will always trust the entity that gave him/her the machine in first place, when the services are offered through another provider, the level of trust decreases. We have to acknowledge that the machines are not user-friendly, and when the usability increases the price increases. Till this day, the operation of 3D printer is depending on user's skills and know-how to be efficient… it needs expertise about how to configure the machine right to produce a good quality product." (Stakeholder 7, manufacturer-FDM printers)*

When going further in the discussion the interviewee also mentioned the know-how of building 3D printers as machines, and how the information was hard to find. The persistence of digging deeper to find the information in 3D printing communities was necessary and asking members who had previous experience building one. He said during the interview:

"In producing 3D printers, the information is either for free, or for money. No supplier will give the maker the know-how except if he is winning in a way." (Stakeholder 4, manufacturer-FDM printers)

The consultant confirmed this statement by explaining the need for strengthening the network of 3D printing in Egypt and increasing the number of its service providers. Nonetheless, he pointed out the gap in experience and know-how in providing these services, and the lack of case studies in this field for investors to detect the problems and try to satisfy local needs.

"A feeding industry is necessary: technical expertise, spare parts making or exchange, aftersales services, etc. there is a whole industry backing up these machines. Investors should look into providing these services based on case studies of startups proving that they are lucrative and their return on investment is rewarding, otherwise they will keep working in a small-scale." (Stakeholder 3, entrepreneurship consultant)

The infrastructure was the main issue discussed with all participants that hindered the dissemination of technology, suppliers of materials and services were usually absent in the ecosystem. To overcome this barrier, it was concluded that suppliers must evolve along with know-how and acceptance of technology.

3.3.2. Barriers and Opportunities

During the discussions with participants about the visions, on one hand some issues were exhibited as possible threats in the way of 3D printing dissemination in the Egyptian market. On the other hand, some opportunities were concluded like possible ways to handle such barriers and the fundamental steps towards an enabling ecosystem.

Barriers

One of the main barriers was the legislation against 3D printers and the fear of using it in illegal processes like making weapons. The same legislation was put against 2D color printers before due to the fear of money forgery. Most of the electronic devices have always presented a great threat for the authorities due to the lack of information and the consistent fear of what it could do, to what extent it could be exploited illegally and how to avoid these negative consequences. This unawareness pushed the designated governmental bodies to

issue laws against new technologies until proven safe. In the light of this, the customs' regulations for printers in general, and 3D printers in specific, are complicated and four clearances and permits need to be taken from four different bodies for the printers to pass customs. This barrier pushed several entrepreneurs to resort to their acquaintances in power, bribes to facilitate the process, or following the procedures, waiting for long and paying extra fees to receive the devices ordered from abroad.

> *"The fear of making weapons with 3D printers is the result of government's and society's introversion and shutting off the development happening in the world. Imagine a person staying at home for a longtime, he becomes afraid of the outside world and how he will interact with people and they will perceive him if he goes out. When the society is closed, it makes it less adaptive to anything new. When color printers were imported, the authorities panicked from forgeries… however now it is permitted. So, we have to adapt to what we cannot change and avoid what is going to cause us harm." (Stakeholder 6, CEO of ICT corporation)*

Not only allowing these devices and technologies to enter the country was a barrier, but also digital fabrication companies and labs faced a huge struggle in registering as legal businesses. Bureaucratic procedures and absence of awareness at the governmental level about the nature of the industry were standing as obstacles in the way of its diffusion.

> *"Registration of maker spaces and fab labs is not something recognized by the government. There is a paradox of how to do it as they see it as a fabrication facility, so it needs to be located in an industrial zone, not a residential place. Still, fab labs are supposed to be close to customers." (Stakeholder 7, NGO manager)*

The registration of the fab lab as a small-scale fabrication facility close to residential buildings was a great struggle for the NGO manager. Registering a fabrication facility would mean its presence in an industrial zone. But in the case of fab labs, they should exist close to residential areas for easy access, especially that their production capacity has been always limited and their impacts were not huge like heavy industries to be located outside cities. Also, due to lack of awareness about 3D printing, government officials registered business with 3D printing focus under other categories irrelevant to the nature of the technology.

> *"Issuing governmental licenses for 3D printing companies doesn't exist, until this day the government doesn't recognize what 3D printing is, neither taxes… until now we are registered as manufacturer and seller of home appliances. They don't get what we are doing." (Stakeholder 4, manufacturer-FDM printers)*

When the question was posed about what should happen in order to overcome these barriers, the consultant with his background in strengthening entrepreneurship stated that the government should review the legislation against such new technologies and make it less intensive. He suggested that research about their capabilities and limitations and finding ways to allow their presence in the country while avoiding their downside were necessary. Otherwise, the country would hinder the opportunities coming with these technologies and one of them is entrepreneurship.

> *"Lack of awareness about the technology in the government is a barrier, and getting permits for fabrication units, especially those who travel across the country, is still a problem. Government can decrease the security clearances, be more familiar and understand the advantages of this technology in our market." (Stakeholder 3, entrepreneurship consultant)*

After discussing governmental and legislative barriers, cultural barriers were alerting and stressed on by the participants. Since they were all stakeholders in the ecosystem where AM technology existed, each had a different experience to share about obstacles faced. All these obstacles were revolving around one main issue, which was awareness about 3D printing.

> *"There is no awareness about the services and no expertise in using the machines. Education is necessary for people to understand that they can do something rewarding with digital fabrication. Common people are still not interested in this culture like students and engineers." (Stakeholder 5, manufacturer-DLP printers)*

The manufacturer came across a lot of customers, in his case dentists, who were ignorant about 3D printing for dentistry. Due to the absence of awareness about digital fabrication, the local market could not recognize the opportunities it offered. Only students, researchers and engineers could see and pursue such opportunities.

"The technology started to be accepted more and more, especially among students. But there is still a need for training and capacity building, most people don't have enough experience to produce in good quality." (Stakeholder 2, governmental officer)

Despite of the technology's simplicity, the machines were not user friendly for anyone to use without training. Proper training and mentorship were required to avoid repetitive failures and to fabricate a proper quality of 3D models.

"3D printing service providers in most cases seek opportunities of this technology without having the basic knowledge about how to operate the printers, the choice of materials for the models and whether the printer is adequate for the model being produced." (Stakeholder 4, manufacturer-FDM printers)

The ma encountered some investors who sought the opportunity of launching 3D printing service providers before even having a basic know-how. Adding on his words, the investment in hardware manufacturing in Egypt he claimed it was an obstacle due to limited knowledge about its advantages and the investors' impatience in seeing results.

"No investor is interested in hardware manufacturing industry, they have always advised me to stop trying and buy ready-made 3D printers to offer printing services. They don't see the opportunity behind it, and they don't get that it is a new technology… totally different than subtractive manufacturing machines. Some incubators are interested but they are still few." (Stakeholder 4, manufacturer-FDM printers)

Aftersales services were also discussed, and a gap was highlighted by the entrepreneurship consultant. These services were claimed to be inconsistent and inefficient, which would cause the absence of lifetime support for products and controlling their life cycle assessment.

"*Aftersales' support is always a big issue, so lifetime services are tricky. There is no systematic approach to support customers after a product is being sold. That's because of: lack of resources, awareness and capacity to support, no understanding about the need to do such services." (Stakeholder 3, entrepreneurship consultant)*

After talking about the cultural barriers, solutions were argued about the potentials there to overcome these obstacles. Marketing and awareness campaigns about 3D printing were the

main keys to escape from this issue as suggested by the NGO manager referring to her experience.

> *"Using marketing with its strong tools in raising awareness, and not through charity but through teaching and spreading knowledge. This can happen through network and how to collaborate together to make an impact." (Stakeholder 7, NGO manager)*

Marketing was not the only prospect to spread awareness and make an impact, also collaboration among stakeholders in the ecosystem was a strong factor, concluded by the consultant in the following statement, to focus on in order to make things happen.

> *"Awareness campaigns and match making events are necessary to introduce all stakeholders to each other and investigate how we can help each other." (Stakeholder 3, entrepreneurship consultant)*

It was not just about involving stakeholders who were in direct contact with the technology, but also the CEO suggested the involvement of those who could help in finding solutions for spreading the technology and disseminating awareness about barriers standing in the way.

> *"There is work that needs to be done on the social side: partners and different entities need to be pulled along to find solutions not only on technology level but also other elements that need to be addressed." (Stakeholder 6, CEO of ICT corporation)*

Also, there was another opinion about creating new communities expressed by the DLP printer's manufacturer as an incentive to adopt the technology in daily life and make it a common interest.

> *"Maybe if we create new communities from different segments and teach them digital fabrication so they will become interested and encourage each other to visit fab labs and use new technologies." (Stakeholder 5, manufacturer-DLP printers)*

When small and diverse communities become interested in the technology and use it in satisfying their own needs, know-how will be everywhere, and the technology's price will decrease with time. Several participants confirmed this fact, especially the academic.

> *"When small-scale communities use the technology, it starts to be less expensive. It spreads and becomes affordable due to the existence of experience on a large scale.*

Even the price of services will drop eventually." (Stakeholder 1, academic background in operation)

As a conclusion, the price of technology has been always a matter of supply and demand. When the demand is higher with limited supply and know-how of technology, the price will stay high. When technologies disseminate, and know-how is everywhere, their prices drop and become affordable to everyone.

Opportunities

Barriers in the way of the technology dissemination helped not just in highlighting the issues but also the opportunities to pursue. Entrepreneurship in 3D printing machines manufacturing or service providing presented several benefits for different stakeholders.

"Companies now in the ecosystem are spreading awareness and education about 3D printing in order to acquire new customers. When you stimulate needs for 3D printing through spreading information, customers start to recognize these needs and how 3D printers could fulfil them." (Stakeholder 1, academic background in operation)

In order to acquire new customers, the academic participant stated that a proper marketing should be done about the capability of 3D printing to satisfy certain needs. In some cases, people are not even aware of those needs or they do not know that there is an easier way to optimize processes in the aim of fulfilling. AM since its naissance has managed to fulfill the needs of prototyping, customization and spare parts replication; it made the work of many easier through affordable methods.

"Universities now have 3D printers and even mobile labs for digital fabrication, so the technology started to spread slowly. Students use it in graduation projects and at an affordable price. Despite of government's legislation against 3D printing, the technological and industrial revolutions in the world when they spread they impose themselves on everyone. 3D printing should even integrate with handicrafts and their development… the technology is not hard to learn but it needs their acceptance to include it in their work." (Stakeholder 2, governmental officer)

When everyone recognizes the benefits a technology can offer, the technology imposes its existence on societies, regardless of the barriers. Hence, cultural and legislative barriers even

though they can be strong obstacles in the path of technology spread they will not last forever.

> *"Education is critical, and it is not about putting you in a class but through teaching how to do things, and it should address all ages and groups. There is a huge potential in Egypt for the technology, because we are makers by nature… it is only the social barrier of being embarrassed and asking someone else to do it is what needs to be tackled." (Stakeholder 7, NGO manager)*

The participant emphasized the history of art and craft in Egypt shows the great capability of locals in making artefacts since the dawn of time. Adopting digital fabrication will not a great struggle for Egyptians, it just requires the right methods in educating through hands-on experience.

> *"Now the government is looking for local solutions because an assembled 3D printer is not permitted to enter the country. The devaluation of Egyptian pound pushed people to seek local machines especially after it proves its quality. Local businesses are capable of handling customer support much better than foreign manufacturers, because of proximity so whatever the customer is suffering from can be tackled faster and efficiently." (Stakeholder 4, manufacturer-FDM printers)*

Summarizing their opinions about the opportunities presented by 3D printing, participants talked about marketing role in engaging more customers in the field and spreading awareness about the technology and its use in satisfying some needs. Also, the capability of technologies to disseminate was identified very powerful against whatever barriers put from any entity or laws. They predicted that at a certain point everyone would have access to the technology and include it in their daily life and crafts once cultural and social barriers were tackled. Finally, local manufacturers and service providers were claimed more capable to satisfy customer demands and handle issues faced by their customers; also, due to the economic situation in Egypt local businesses were highly encouraged by the government. As a whole, the opportunities mentioned drew an optimistic vision for what AM technology could achieve in the Egyptian market when barriers are addressed by different sectors private, public, civil society and individuals.

3.3.3. Impact on Sustainability

Sustainability pillars were investigated during the interviews and some questions were asked to have an overview about what the 3D printing technology could offer, and the visions could enhance for sustainable development. When tackling the environmental sustainability, most participants were denying the existence of awareness about environmental issues, even business owners and startups had limited knowledge about what they could do to be environmentally friendly.

> *"Egyptians are not conscious about environmental issues like emissions, climate change, water scarcity, electricity overuse, etc. Limited awareness campaigns are highlighting these issues. It is the least focused on when it comes to sustainability of businesses. Financial sustainability if the most focused on, even in strengthening entrepreneurship initiatives. However, initiatives in spreading knowledge about 3D printing technology had a strong potential in making a paradigm shift in people's awareness of what they can do and makes them feel responsible for their society and environment through offering efficient solutions for existing challenges." (Stakeholder 3, entrepreneurship consultant)*

The interviewee discussed paradigm shift as a major factor in changing the way Egyptians managed resources around them. When introducing new practices aiming for optimized consumption and production, a responsible behavior starts to develop. It is due to either economic incentives in reducing the amount of resources used during operation, or due to awareness about sustainable behavior for better society and environment.

> *"People don't know that we have water shortage, however they understand we have food shortage because they feel it. We don't have awareness about this kind of issues, also waste problems you can see it everywhere in the streets, but no actual initiatives are happening." (Stakeholder 6, CEO of ICT corporation)*

Unfortunately, individuals in the society are not aware about a problem unless they start to feel its impact on their lives. Therefore, they were so attentive about food shortage and the increasing prices of commodities, but not about water scarcity due to awareness and legislations against water resources abuse. Also, there was no focus on waste problems and how to manage it properly.

> *"The number of companies that have 3D printing machines are limited. So, there is no inspection for environmental impacts done by the government… the inspection only involves financial obligations on the company or any related issue where there is a violation." (Stakeholder 2, governmental officer)*

The officer negated the need for legislation as one of the fundamental steps toward having sustainable and responsible businesses due to limited practices in the field. However, if the country's laws and policies are not forcing businesses to adopt a responsible consumption and production behavior, the companies will not pay any respect to the environment and society they are operating in, which was emphasized in the next quote.

> *"3D printing is a great way to decentralize the design and print process to happen anywhere. Decentralization is the main advantage, it helps in reducing transportation and environmental impact. But there is no recycling infrastructure of materials, especially the liquid raisin of DLP printers, it is hard to recycle unlike ABS plastic of FDM printers. Even safety regulations we deliver them to customers with the machines, but they don't pay attention to them." (Stakeholder 5, manufacturer-DLP printers)*

AM presents many advantages for the promotion of manufacturing decentralization and entrepreneurship; however, it also presents disadvantages of waste, toxic fumes and safety issues for those who use it regularly. Thus, the downsides of such technology should be highlighted to avoid negative environmental and societal impacts. Confirming the previous statement, the FDM printers' manufacturer stated the same issues.

> *"Electricity use is not a major problem in 3D printing, the technology does not require a lot of electricity to operate. The problem is waste, until now we don't have a solution for waste. ABS fumes are toxic, and customers are sometimes concerned about whether they should do a ventilation system in the production area. However, the concern is not about the environmental impact, but it is an economic concern about whether they should provide extra equipment in their production facilities." (Stakeholder 4, manufacturer-FDM printers)*

From the responses of the participants, it was clear that the awareness related to environmental issues was limited to absent. The government legislations concerned with

companies even did not tackle the impacts of businesses, which in consequence did not oblige business owners to control their operation's impacts. Even waste was not a focus for the public or private sectors. Some participants pointed to the initiatives done by civil society entities, however they were minor and did not leave a powerful impact on neither individuals, nor businesses.

Socio-ethical initiatives on the other hand were more evident and impactful. Due to the socio-economic situation in Egypt and the existing challenges as unemployment and poverty, companies, foundations and incubators focused on promoting projects with a positive social impact. Human development was also part of the goals for some entrepreneurial strengthening projects in order to provide opportunities for youth through capacity building and adopting new skills. Not forgetting that some foundations contributed in this development through the provision of 3D printed prosthetics, which were affordable to those who were in need.

> *"Human development is a paradigm shift in our mindset and culture needs awareness. Instead of giving charity, you shift to offering opportunities through education, mentorship and capacity building. Some incubators focus on the social impact of their startups and they try to encourage them to adopt it in their business strategy. In some governorates we are lacking the entrepreneurship ecosystem that encourages the initiatives and ideas generating there, they are also worth the investment." (Stakeholder 3, entrepreneurship consultant)*

As a stakeholder in the ecosystem, the consultant emphasized that the initiatives for the social-economic development are centralized in the capital, Cairo, and other governorates that have strong industries. Other governorates and cities do not receive enough attention. In the light of this, the entrepreneurship ecosystem often detected as missing in some regions across the country, despite the presence of ideas that are good enough to be invested in.

> *"Involving the beneficiaries at an early stage and bringing them on-board from day one is crucial. The co-creation process is necessary. It is not just going away to build something for a customer and come back with a result. Incorporating their feedback into the design process from day one facilitates the process of building trust." (Stakeholder 6, CEO of ICT corporation)*

Often, the beneficiaries of an initiative or a project are not involved from the beginning causing the development of unreliable solutions that have no benefits for them. Co-creation process is regarded as a necessity when tackling a challenge that has direct impact on people. This necessity was stressed on by the CEO and NGO manager.

> *"Instead of assuming what people accept and don't accept, we should reach out to a number of people as a sample and pose the related questions to collect proper data and statistics to make right decisions." (Stakeholder 7, NGO manager)*

The insights given by the participants showed their intention to make an impact on social level. However, due to lack of information and data about the real needs, and the mindset of charity instead of human development through profitable businesses was hindering a real impact on the socio-economic aspect.

3.3.4. Sustainability Promoters

The promoters of sustainability in the ecosystem were an interesting subject to discuss as each participant contributed with what they came across during their daily work. In a way, their contribution with information gave a holistic view about who the main players were, the potentials and limitations in promoting sustainable businesses based on new technologies.

> *"The new government's plan of "Egypt Begins", one of its pillars is empowering the SMEs and startups, which means new products that need verification and prototyping through new technologies like 3D printing. The new law of scientific research encourages entrepreneurship and manufacturing… also law of sciences and technology was issued by the government for the same goals." (Stakeholder 2, governmental officer)*

The government of Egypt, as stated by the officer, has been working to empower youth and young entrepreneurs through scientific research and promotion of entrepreneurship as the way out of the economic challenges. New governmental plans and projects were launched for this purpose.

> *"The government has developed investment maps for each governorate with its different industries and all components needed by industry focused entrepreneur. This*

tool will help in locating the industries across Egypt and will leave a huge impact in decision making for all stakeholders." (Stakeholder 3, entrepreneurship consultant)

From the positive steps being taken by the government and some helping organizations, to negative or passive attitudes described by the participants that blocked the path towards a sustainable development. One of the participants referred to environmental sustainability of startups as a luxury that could not afford in their early stages and it was not a necessity. Others pointed to the gaps that need to be filled in order to reach sustainability on all levels.

"Still startups are suffering in their early stages and they cannot sustain their businesses. Funding, customs and expertise are the main challenges faced by entrepreneurs." (Stakeholder 5, manufacturer-DLP printers)

Putting aside environmental and social issues, economic issues had a strong impact on sustaining startups in their early stages. Both manufacturers discussed the lack of funds, the complicated regulations of customs against 3D printing, and the lack of its know-how. These three factors were presented as the major drawbacks in technology dissemination and the economic sustainability of startups. The manufacturer of FDM printers highlighted the trivial concerns of companies, compared to essential safety precautions in 3D printers.

"There are some safety precautions required by factories to meet the standards in operation, they always ask to cover the printing area in the machine with a door, in case it opens the machine stops. Also, serial number and warranty certificate for the machine are required. That's all what the companies are concerned about." (Stakeholder 4, manufacturer-FDM printers)

Possible steps to overcome the stagnant state of sustainability promotion in businesses were illustrated by the CEO dividing them into sectors: public, private, civil society and individuals.

"Some ministries are promoters for example the ministries of social solidarity, ICT and education are taking forward steps. Yet, the cooperation between them is a huge challenge, if it is enhanced things will move… they need some protocols between them for cooperation. Civil society organization are sustainability promoters by nature and they have visions they want to achieve. The funding agencies and donners are

working with specific associations and because they want to continue their work, they initiate cooperation between different stakeholders and invite them to work together. The private sector is disharmonious because each company has its own strategy and CSR vision, so they are reluctant to cooperate especially that their CSR is used for marketing. Initiatives in private sector should happen through aligning with the chosen companies' strategies and propose opportunities in making the impact. Finally, individuals who are in the public eye can be promoters as well, if their attention is attracted towards a certain cause they will make an influence depending on the sector they are in." (Stakeholder 6, CEO of ICT corporation)

These proposals were all based on the right means of communication between different entities and individuals to fill the gaps and face challenges related to sustainability environmental, social and economic. It is concluded that the community as a whole need to take steps forward and different stakeholders should cooperate in order to reach real results.

3.3.5. Final Recommendations

The interviewees were asked at the end to share their opinions about what should be done to pave the way for sustainable businesses to develop in the Egyptian ecosystem.

"Putting all stakeholders in one place and bringing on the table the barriers and opportunities. From these big groups, small groups are born to address and face the challenges of forming sustainable businesses." (Stakeholder 6, CEO of ICT corporation)

Again, inviting all stakeholders to collaborate was mentioned to overcome the obstacles and barriers highlighted. Smaller groups of stakeholders born from big initiatives are necessary to pave the way for sustainable and aware businesses to develop.

"Customs' regulations can be eased for 3D printers so that technology spreads faster. Government, education and research institutions should empower young makers through delivering know-how to enhance production quality. Also, there is still a need for databases to map the ecosystem of manufacturing facilities, especially in AM field, so that anyone is able to fabricate a product. It is a way of resources management and integration." (Stakeholder 2, governmental officer)

In order that the benefits of 3D printing are harvested by entrepreneurs, customs regulations should be eased, research and educational institutes should contribute with their knowledge and support, and databases should be developed to have a strong overview about the local manufacturing facilities in each region across the country.

> *"Data is missing for entrepreneurs to accelerate in their startups. There is plenty of unutilized data at the government. Access to information and finance needs to be improved. Entrepreneurship is the only way out from the economic challenges we are facing." (Stakeholder 3, entrepreneurship consultant)*

Data was claimed missing several times during interviews, and unutilized data is the most inefficient management of resources. Data is an important resource for entrepreneurs to accelerate their startups, along with financial support. Without the access to information, the entrepreneur is unable to discover opportunities in the ecosystem.

> *"There is a lack in the win-win approach in doing business where players in the market are seeking to get information but not give back value. Also, the allocation of resources in wrong contexts make them useless." (Stakeholder 4, manufacturer-FDM printers)*

The lack of transparency in collaborations drives mistrust among stakeholders. Before stating a cooperation, stakeholders should state their goals and be willing to share and exchange resources like information, know-how, materials and hardware with other stakeholders. Otherwise, the cooperation will end-up being useless or unfair to one of them. In addition, the allocation of resources should be investigated properly before the execution is taking place.

> *"Incubators can enhance their programs, most of them hire mentors who are not really experts or have the right knowledge to help entrepreneurs. Investors also are afraid to support hardware production startups." (Stakeholder 5, manufacturer-DLP printers)*

Research, awareness, stakeholders' collaboration and good allocation of resources (data, funds, machines, etc.) were the main factors stressed on by the participants. The fabrication ecosystem in Egypt was described as suffering from the lack of these factors that represented a base for any technology to spread and bring opportunities for the locals.

3.4. Summary

This chapter covered the findings of the methods used in research. The data collected were resourceful enough to formulate: two cases studies about use-oriented and result-oriented businesses in the local Egyptian market, near-future scenarios from which four visions of business models were generated, and qualitative data collected from stakeholders presenting their thoughts and insights about the visions, their feasibility, the impact they could leave on sustainability, existent promoters of sustainability in the ecosystem and finally their recommendations for what could pave the way for these business models to transform from visions to reality. In the following chapter, data will be analyzed further to conclude the outcomes of this research and discuss how they could fill the gaps found in literature.

4. Discussion and Conclusion

This study focused on investigating the hypothesis of whether S.PSS applied to DM is able to tackle barriers in the Egyptian ecosystem from limited resources and networking issues. Scholars have identified S.PSS as an offer model where the provider retains the ownership of the products and allow access to them through paid services based on unit of satisfaction (Vezzoli et al., 2014). The unit of satisfaction represents the value delivered to customer and base on it the payment takes place covering the running costs of the system. Retaining ownership promotes resources reduction by increasing the lifetime of the product to avoid extra costs of maintenance, replacement and disposal (Vezzoli et al., 2015). The combination between S.PSS and DM allows more access to resources distributed on network level. Additionally, scholars confirmed that they give a chance for customization, localization of manufacturing units and involvement of customers in product co-creation (Petrulaityte et al., 2017). Legislative barriers like bureaucracy and regulative policies have been also studied for the aim of finding possible ways to overcome them. Scholars argued that the government should promote such sustainable business models through providing supportive policies, proper infrastructure and technologies, and reinforce their existence in the market against business-as-usual practices (Vezzoli et al., 2015; Petrulaityte et al., 2017). To investigate the current status of the Egyptian entrepreneurial scnene, this study has investigated the arguments of the scholars through field research performed in the assistance of three tools: qualitative case studies, participatory workshops and in-depth interviews with stakeholders.

In this chapter the discussion and conclusion of the results are demonstrated. It is covering the study of operational tactics addressed by the qualitative case studies, the discussion of the in-depth interviews' findings with stakeholders, proposed guidelines of the combined S.PSS and DM model's application in low and middle-income contexts, and finally a sustainability assessment of the four visions.

4.1. Operational Tactics

Operational tactics were the main variables to investigate in the two qualitative case studies. Developed in the 2014 study of Reim, Parida and Ortqvist, the study recommended the development of questions based on these tactics (design of services, contracts, network, marketing and sustainability) to investigate how S.PSS business models actually operated in low and middle-income contexts. The case studies developed in this thesis covered two examples of S.PSS, under the categories of UO and RO. The UO case was a fab lab that adopted digital fabrication, including 3D printing, as a main activity along with workshops and programs to spread awareness about it, and the prices were per unit of satisfaction of time and material. The RO case was a company that delivered ready 3D printed products and got paid per gram, which is a unit of satisfaction. Both entities worked B2B and B2C, and offered different values to each from consultancy, postprocessing and knowledge spreading about AM. When tackling operational tactics, the two PSSs handled some tactics similarly, and others differently depending on operation and management needs.

4.1.1. Design of Services

In respect to flexibility and customization aspects in the design of services, the two business models handled these aspects differently. The UO business did not find it successful to be highly flexible as the scholars in (Reim, Parida, and Ortqvist, 2014) stated to differentiate itself from a business-as-usual. They had to stick to certain services that would remain constant and the rest were eliminated to avoid confusion about their offerings. Still, the customers' insights were collected and considered through direct interaction with makers in several contexts. Unlike the UO case, the RO business depended on third-party service providers to fill the gap they found in the market and offer flexible services to their customers. Instead of shifting the focus of the company, they relied on building a community

to connect with third-party designers and companies. The company managed to stay flexible in its services without overloading its capacity through the co-dependence on a third-party.

The concentration on certain services is fundamental to prevent misconception; conversely, maintaining a level of flexibility is also necessary for a PSS to fulfil needs within its capacity, or through partnering with others in the ecosystem. The approach of building a network/community is a strong advantage a PSS can benefit from in satisfying customer demands through flexible and customized offerings.

4.1.2. Contracts

Contracts needed to be evaluated based on its complexity and formalization as the study (Reim, Parida, and Ortqvist, 2014) recommended. In both cases, contracts were identified as gentlemen informal agreements to document responsibilities. Formalized and complex contracts were only signed in international or big-scale cooperation. This is in the consequence of the Egyptian law which only governs contracts of non-disclosure and intellectual property; other contract types are not as official. The contracts signed between the UO entity and other organizations were informal, and only to document the responsibilities of each. Only in big-scale cooperation, formalized and complex contracts with articles of the law were signed with partners; each contract had a different structure and details depending on the type of cooperation taking place. Agreements or contracts were exclusive for partnerships, with users no agreement was signed. The RO company signed contracts with their partners in order to establish transparent collaboration, and they had a variety in format from formalized and complex, to flexible gentlemen agreements. With international partners formal and complex contracts were signed. Others were mostly flexible agreements, one-sided or both-sided, and referrals to other partners who could fulfill a customer's demand. To protect the confidentiality of customers' information and projects, NDA were signed with customers and partners in case of private data transaction.

4.1.3. Network

Continuing on the discussion of tactics, the scholars (Reim, Parida, and Ortqvist, 2014) required the study of three aspects in network, which represent the procedure of choice, decision and execution of partnership. Plus, the level of coordination and sharing of the activities is necessary for the evaluation of value delivery. On one hand, partners of the UO

lab were chosen carefully through proper screening tools: highlighting potential partners, running background check, assessing the need to partner, choosing the partner who can satisfy this need, investigating about the reputation of the entity, and checking history of cooperation if it existed. On the other hand, to insure the quality of cooperation between the RO company and their several partners, testing and grading was the strategy followed. This approach led eventually to building trust with their partners and community.

In both cases, partners were either temporary or constant depending on the need. Also, some were fulfilling fundamental tasks necessary for operation, others were delivering services that were part of the offering of the lab. Some partners had direct contact with customers, others had not; the level of contact was dependent on the necessity to establish this contact. Referrals were done by the two entities, UO and RO, to other partners with no interference from its part. Trust was built with both partners and customers through the consistent interaction and setting rules from the beginning. Clarity and transparency were the rules for cooperation with no hidden agendas from both sides. Win-win collaboration was evident in how the lab and the company handled its relationship with all stakeholders involved.

Overall, each category of PSS handled the procedure of partnerships differently depending on their needs. In the first case because they were concentrated on enabling customers; most partnerships were based on capacity building of the users. Yet, in the second one, the company focused on satisfying demands and delivering results, so coordinating the value delivery to end-users was necessary without their interference in the process. As for the rest of aspects, both entities had the same understanding in relation to: the duration of partnerships, the level of dependence, the level of contact with customers, referrals, and building trust.

4.1.4. Marketing

Marketing of PSS was divided by the scholars (Reim, Parida, and Ortqvist, 2014) into three aspects: how the value is communicated, the level of interaction with customers depending on value's nature, and data collection of customer's insights. A customer relationship management CRM system was claimed necessary by both entities to maintain long-term relationship with customers. The UO lab aimed for long-term relationships to form a community of makers but it did not succeed because they did not collect enough information

about their customers from the beginning. In consequence, they did not manage to win their loyalty and users were not consistent in visiting the lab. The RO company handled relationships differently: they have always targeted long-term relationships with their customers. Hence, feedbacks (rating and reasoning) were always collected face-to-face or through emails from the first day of operation. They kept data and record of ordering for each customer.

In addition, the absence of clear marketing strategy and statement for the UO lab made the information about the value delivered fuzzy and misleading for the target group. They managed through social media and direct interaction to collect insights, which was a positive factor. However, the absence of CRM, a website and a strategy for marketing raised the confusion about their services. Unlike the UO case, the core values of the RO company were clear from beginning: convenience and accessibility. Being clear about their on-demand service and delivery time made customers comfortable in acquiring their services. Spreading awareness about 3D printing was their main strategy in marketing through blog on their website and social media. Besides spreading awareness, they posted sometimes customers' feedbacks and their progress on social media pages.

The prices, in both cases, were based on positioning among other players in the market, which was a positive move towards good positioning. In the UO case, the pricing was clear and affordable for their users; due to the fact it was use-oriented, so customers paid per time and material, unless they brought their own materials then they only paid for the time on machine. Positioning and pricing were also strong features in the case of RO company, they allowed them to survive and break even.

Sustainability was a priority for both of them and they would definitely use it in marketing, but the level of user's awareness about environmental sustainability, resources management and ownerless consumption was low. The social impact done by the RO company through prosthetics was not used in marketing.

Overall, the companies' marketing strategies were weak due to reliance on diverse methods to spread awareness about their offering and attract more customers. Despite of their strong stand in positioning and pricing, which helped in sustaining the operation, building a strong strategy for their marketing would have help them in spreading awareness faster about the

technology and their services. Potential customers were mostly confused about the kind of services they delivered. Pricing was a strong attribute in both companies, and positioning was strong in the second case and weak in the first due to lack of published information about their services. Sustainability as a marketing tool was not used vigorously by both entities although it has always ensured a great impact by drawing a responsible business image in the minds of customers.

4.1.5. Sustainability

The last but not least tactic discussed in the study of (Reim, Parida, and Ortqvist, 2014) was sustainability of the S.PSSs and how they handled waste and overconsumption, in addition to their strategy in reducing negative impacts on the environment. Regarding social sustainability, the team of the UO lab supported the empowerment of users' skills and capacity building so they could leave positive impacts on the community. Activities in the lab included design thinking to solve community's issues, and ways to earn a living using digital fabrication as a tool. As for the RO company, its social and economic role was significant due to their contribution in prosthetics manufacturing through 3D printing, and the consultations given to universities and companies on how to include 3D printing in their systems. The RO company had a significant role in spreading awareness about the technology and leaded the way towards the development of the AM field in the market.

When addressing resources management, the UO lab faced several failures in recycling and reusing waste. The team tried to raise awareness, and used PLA instead of ABS, but storage and segregation of waste was not handled efficiently. Despite their trial of controlling the operation and the materials used in manufacturing, the whole system was not efficient in managing the amount of materials used or thrown away. The partners in RO company were concerned about the waste, so they kept it for another startup to collect and turn it into filaments again. They were also conscious about the energy used and the emissions of the machine. However, they kept using ABS instead of PLA due to its strong properties as an oil-based material. They encouraged employees to wear masks, but this rule was not forced.

Both cases, when tackling sustainability, did not prove an efficiency in resources management and reducing production's impacts; sustainability was on their top priorities. Also, due to absence of governmental inspection on environmental impacts of such

businesses, they did not consider their impact. However, they had enough awareness about responsible consumption and production, so they initiated some trials to avoid the wrong of waste disposal. In the first case it was not successful, and in the second there was a promising approach to recycle it, but the results were not clear. Promoting a responsible consumption and production behavior was still missing regardless of all initiatives.

As a general overview, some aspects in the tactics were applied as the scholars recommended, others were not applicable due to some influences: lack of awareness, trust issues, limited capacity, and regulative and cultural obstacles derived by the ecosystem (Mont, 2004; Catulli, 2012; Vezzoli et al., 2015). Scholars argued that these barriers were the most common and they were divided into three categories of barriers presented by companies, customers, or government (Petrulaityte et al., 2017).

4.2. Actual PSSs' Impacts

The PSSs investigated through the case studies showed the convenience offered to young makers by allowing access to emerging technologies. Digital fabrication is still considered new in the Egyptian industry and the level of accessibility is low due to the high price of the technology. Young makers, through PSSs, were able to prototype and created products through 3D printing where they could test their designs and got a feedback from their customers. This positive impact would not have happened without the co-creation process with their customers and collecting their insights. Also, the initiative of establishing win-win cooperation with other stakeholders was a necessary element for these PSS to succeed in maintain operation and satisfy customer's demands that are out of their focus. However, the fear of contracts needs to be addressed to establish formalized contracts preserving the different partners' rights.

Despite of these positive impacts, the two PSSs neglected marketing strategy to communicate better the value they were delivering and acquire more customers who have not realize yet the opportunities that 3D printing could present to them. In addition, not having environmental sustainability as a priority for them affected their efficiency in managing waste and emissions related to 3D printing. However, they were socio-ethical in their initiatives of introducing design thinking to solve social challenges (UO Fab Lab) and producing prosthetics to empower those who lost their limbs (RO Company). Also,

empowering entrepreneurs was one of the main goals they adopted and tried to achieve through training them to acquire new skills and build the capacity to survive in the market.

The two case studies presented the great contributions of PSS on the social and economic aspects, but they did not invest on the environmental aspect due to lack of awareness.

4.3. Discussing the Barriers and Opportunities in the Ecosystem

The findings of this study endorse that S.PSS applied to DM can actually tackle the barriers in the Egyptian entrepreneurial ecosystem presented by the GEM report in 2017. Stakeholders identified the visions as useful and probably successful in a low and middle-income context like Egypt. The success of such visions is due to the absence of the need for initial capital and covering running costs by providing access to resources instead of individual ownership. Additionally, opportunities like offering a customization option, better products/services for customers, increasing local employment, and creating long-term relationship with the end users (Vezzoli et al., 2015) were discussed in the in-depth interviews as advantages for the local ecosystem to grow and prosper. Likewise, for the network and trust barrier, win-win cooperation is one of the main criteria to have a successful operation for S.PSS. Without a network, a PSS will not be able to satisfy all customers' demands; any business should stay focused on the value it delivers not to be distracted by trying to satisfy all demands and offer other services that are over its capacity. Also, trust can be built through network and transparent cooperation. The consistency in offering a good quality of products and services among different partners and stakeholders allow the trust to grow between them.

Other barriers against the visions were unveiled. There were legislative and cultural barriers that involved: legislation against 3D printers, lack of awareness about the technology and it could do at the governmental and societal levels, difficulties in the registration of fab labs and 3D printing companies, lack of expertise of working on 3D printers, limited investment in hardware fabrication, and the poor quality in the aftersales' services provision. Despite of these barriers, opportunities were evident for most participants. The fast development of technology and its great benefits would force its existence in any context. Companies with 3D printing focus started to spread awareness in order to acquire more customers and stimulate needs. Likewise, universities inaugurated labs in their premises and on the long run

it was predicted that digital fabrication would be used by craftsmen to enhance their products' sales against mass produced artefacts. Scholars discussed the ability of DM in tackling environmental and social issues caused by mass production: developing sustainable patterns in production and consumption, avoiding the exhaustion of resources, and providing a good standard of life for people, especially in emerging markets (Kohtala, 2015; Petrulaityte et al., 2017; Bouton, Lindsay, and Woetzel, 2012). The only gap was education and training on how to use 3D printers efficiently.

4.4. Discussing the S.PSS and DM Near-future Scenarios

During the interviews, the stakeholders declared that the visions for the near-future scenarios were feasible in a low and middle-income context like Egypt under the condition of keeping the price affordable for a better access to 3D printing. In the next subsections, a discussion is conducted about their applicability drivers in the ecosystem, their impacts on sustainability and their application guidelines.

4.4.1. Their Applicability in the Ecosystem

Comparing UO with RO and decentralized with distributed, the UO decentralized model is the lowest in its expenses. UO would provide services of mentorship, along with the temporary access to machines, so that users could manufacture for themselves. Unlike RO the price covered the wages of experienced operators handling the task of fabrication. Also, due to lack of expertise in the ecosystem about AM, the decentralized setting was more feasible than distributed because not everyone would be able to run the machines efficiently. Despite of all these constraints, it was confirmed by all that once the technology spreads, its price will drop in consequence and everyone will have access to it.

Due to the fact that UO models provided access to machines and RO models provided access to ready products (Tukker and Tischner, 2006; Reim, Parida, and Ortqvist, 2014), those who looked for training would refer to the first and those who wanted the job done would refer to the second. UO decentralized model was claimed as the common and the most beneficial for young makers, where they could meet, discuss and share their experience together. Therefore, mentorship was stated as a gap in such setting for users to learn how to run the machines. Another gap was the poor marketing of fab labs and co-working spaces that adopted this

model and could not raise awareness about their services. Therefore, there was a delay in getting acquainted to such model and acquiring its services.

The 1st vision was seen as a good opportunity for students, researchers and tech entrepreneurs where they could get mentorship and proper assistance from a team of experts in digital fabrication. The 2nd vision was identified as promising due to the mobility factor, which gave flexibility in the place of manufacturing, and more power to cloud production allowing decentralized/distributed manufacturing process happening through data transfer (Rauch, Dallasega, and Matt, 2016). It would ease the temporary access to expensive machines during a set period of time. The 3rd vision was described by participants as aftersales services that needed sustainable financial plans in order to cover their costs; they were either to be covered by high-end products' profits to cover low-end products' services, or through donations. Such model would be highly applicable for prosthetics, or basic products needed in daily life. The 4th vision was discussed in the perspective of providing services through other service providers, and trust was the main variable in this situation. Customers would be concerned to get services from a provider other than the one they bought machine from, and companies would be also afraid to lose customers to their partners; researchers identified these two behaviors as: lack of knowledge and uncertainty about the system (Catulli, 2012; Rexfelt and Ornäs, 2009), and fear of consequences of partnership like co-dependence, core competencies decrease, confidential information spreading, complications in the purchase of the customers, and customer's complicated behavior when it comes to purchasing and accepting the service (Vezzoli et al., 2015; UNEP, 2002; Mont, 2004). Also, to have enough providers in the ecosystem, it would refer that the technology has become mature.

4.4.2. Their Impacts on Startups' Sustainable Development

Environmental sustainability has been identified as a challenge due to lack of awareness about environmental challenges facing the country. Therefore most of the enterprises rarely cared about developing a sustainable strategy for production and consumption. Management of resources and waste were identified as points of weakness in the Egyptian businesses' operation. During the in-depth interviews, most participants were denying the existence of awareness about environmental issues among common people or business owners. The findings highlighted the absence of any environmental inspection handled by government to record violations related to safety or negative impacts like emissions and waste. However,

they confirmed that with a technology like AM fabrication and decentralized design could eliminate transportation issues. Localization of manufacturing and design along with mass customization were the main advantages found in both findings and literature to satisfy customer needs without increasing the burden on the environment, limiting waste and CO_2 emissions (Rauch, Dallasega, and Matt, 2016).

Socio-economic initiatives were totally impactful unlike the environmental ones. Part of sustainability promoters in the ecosystem are initiatives done by the government to empower the entrepreneurial ecosystem. However, some startups are still struggling to sustain their businesses economically. Unfortunately, startups still see environmental and social impact as a luxury they could not afford. And in few cases safety precautions from emissions of 3D printers have been taken into consideration, but the majority of users who work closely with 3D printers neglect these precautions. In addition, the participants stressed on the promotion of human development instead of charity through mentorship and capacity building to enhance people's entrepreneurial skills and instruct them about win-win cooperation. This step could be easily done through localized manufacturing models, offered by DMS, in the aim of encouraging the entrepreneurial and manufacturing activity in emerging markets (Rauch, Dallasega, and Matt, 2016). It was also argued that businesses should involve beneficiaries in the process of products/services' design from the start, side-by-side with collecting data first hand to determine people's real needs. These methods are highlighted by researchers in differentiating between business-as-usual and S.PSS offering, as S.PSS is more focused toward the co-creation activity with customers and direct interaction to develop insights about the customer's needs (Tan, McAloone, and Gall, 2007).

Adding on these gaps, the absence of DIY culture that made digital fabrication an alien for common individuals in society, while DIY was identified as one of the AM opportunities that allowed direct interaction of customers with machines to have customized products to their tastes and meet the expectations of the customers from quality, cost, and time of delivery (Zanetti, Seregni, Bianchini, and Taisch, 2015).

4.4.3. Their Application Guidelines

Part of the research's implications is a set of guidelines for the application S.PSS applied to DM scenarios, in the field of AM. It was one of the gaps found in the study of (Petrulaityte et

al., 2017), along with the near-future scenarios development for S.PSS and DM combined. These guidelines were concluded during the research investigation and the collected insights are listed for investors interested in S.PSS. The guidelines are more toward the dissemination of new technologies, especially 3D printing, and the necessary steps that should be taken in consideration to achieve a sustainable business on the environmental, social and economic levels. The guidelines concluded were:

1. It is necessary to focus on one category of S.PSS (PO, UO or RO) to communicate clear values and be transparent with customers. Too many offerings of products and/or services with different orientations will exhaust the provider's capacity to deliver and become unreliable and confusing to customers.
2. Products and services should be mature enough to be launched in the market. Prototypes and semi-finished products are never the final version ready for purchase. The products should go through all phases of product development before they are marketed. Otherwise, the support services will present a huge burden on the provider.
3. Developing an aftersales services system is indispensable. Customers need to feel that they can go back to the product/service provider when they need assistance.
4. Having an experience and know-how about the offered value is essential to avoid interruption of operation. When in doubt, reliance on experts in the local market is an alternative.
5. Starting a business does not mean buying all machines needed for operation; an entrepreneur/maker can always have access to machines through other service providers like UO and RO companies. So, cooperating with third-parties is a great opportunity for S.PSS owners.
6. Market research and ecosystem mapping is necessary to go through before launching a business to have a proper overview about the ecosystem and plan possible partnerships. S.PSSs are network-based, so knowing how to develop win-win partnerships and exchange services are essentials.
7. Establishing partnerships need a good contracting system to avoid conflicts on the long-term. Failure to sign contracts with other partners might cause interruption of operation and inability to deliver value to customers.

8. Partnerships should be initiated after testing the partner's capacity to deliver what is required. Even if it is highly recommendable in the local market, the service provider should test and grade the quality of the product/service he/she is partnering for.
9. The business' marketing strategy should be developed from the start. A startup of S.PSS can always rely on free/cheap marketing tools until they afford paying for them. Unclear statements might lead customers to confusion about the offering.
10. Raising awareness about new technologies and their positive impacts is necessary to receive enough orders. Likewise, sustainable initiatives done by the startup should be used in marketing to raise society's awareness.
11. Consistent positioning and pricing are strong tools to sustain the business and break even in the first three years. Maintaining the same statement with customers makes them more trusting and loyal to the business.
12. Before launching a new product/service system, market research is necessary and should include cultural barriers. A lot of losses can be avoided through co-creation sessions with the target group (young makers). Relying on first hand data or reliable secondary data is crucial to avoid huge failures.
13. Reaching out to the bottom of the pyramid in the society should happen through a well-studied socio-economic plan. Covering the costs of the provided products/services is necessary to deliver a sustainable value for them, otherwise an interruption in delivery will happen eventually.
14. Resources management should be a priority for an S.PSS to prevent the disposal of valuable materials. Also, partnering with life cycle service provider can ease the process for S.PSSs.
15. Safety regulations should be strict for both employees and customers; enough training and mentorship should happen before allowing anyone to use the machines to avoid negative consequences related to health issues.

From the discussion it is concluded that the thoughts collected from stakeholders during in-depth interviews about barriers and opportunities of sustainable business models were very similar to what has been discussed in literature. This similarity only proves what S.PSS applied to DM offers as a new innovative and sustainable model in an emerging market like Egypt. It is similar to the opinion in (Berger, 2013) that the innovation of new business

models is promoted in order to restructure the value chain, the value proposition and redesign goods for efficient and smart usage of resources and industrial processes.

4.5.Practical Implications

This study highlights the possible opportunities of applying S.PSS and DM combined in developing innovative and sustainable business models in low and middle-income contexts. In order to benefit from such opportunities, some barriers need to be tackled in the entrepreneurial ecosystem of Egypt. It is also worth to mention that the usability of machines is poor and needs to be enhanced so the makers do not face a lot of troubleshoots. Educational and research institutions should cooperate with 3D printers' local manufacturers to develop the design of the hardware, so it becomes user-friendly. Once the hardware is enhanced, all those who have good background about 3D modeling will be able to 3D print easily, and the technology will turn feasible just like 2D printing. As an ecosystem overview, the stakeholders in the field are not yet collaborating to strengthen the dissemination of this technology. Referring to frugal innovations, such technology is an innovation that includes new patterns combining already existing knowledge and technology (Govindarajan and Ramamurti, 2011). It is an innovation that provides easily low-cost solutions for people existing in low-income contexts and can face their socio-economic challenges (Hossain et al., 2016).

Despite of the mentioned constraints, strengthening a network of service providers in AM field, depending on each other, was claimed as a necessity for the technology to spread and offer new opportunities for young makers who want to be entrepreneurs. This strong network would represent the advantage of S.PSS implementation from the socio-economic perspective: incorporating new markets, an increase of competitiveness, adaption of efficient operations, and introduction of new technologies into the processes (Omann, 2007).

4.5.1. Solutions Proposed for S.PSS applied to DM Barriers

Solutions discussed for the cultural and legislative barriers were the ability of marketing campaigns to spread awareness about the great potentials of this new technology, the collaboration among stakeholders to find solutions and encouraging small-scale communities

to adopt the technology in their daily activity. Marketing was identified as one of the five main tactics required in the operation of a PSS; a PSS should be able to communicate a statement about the proposed value, set a level of interaction with customers depending on the value, and collect insights of their customers and market (Reim, Parida, and Ortqvist, 2014). So far PSS companies in the ecosystem have not established the proper marketing to spread awareness about the value delivered, and this was evident in the discussion of the two case studies. With the increasing level of servitization and dematerialization in the systems, along with proper marketing about responsible businesses, individuals in the community will be more conscious about their production and consumption patterns.

It is necessary to control the processes of manufacturing within PSS to avoid further negative environmental impacts or health issues caused by AM. Since it is a fact that technologies reach a point where they become available and affordable to everyone, it is necessary to be proactive in spreading knowledge through mentorship and training on these technologies to gain their benefits and avoid their downsides. Resources management and production control should be established by the service providers, to manufacture only based on demand, and to be regulated by the legislation that forces penalties on excess in waste and emissions. Nevertheless, the responsibility does not fall only on the shoulders of the service providers and the government, but also on the shoulders of makers/entrepreneurs who need to be more conscious about their needs and satisfying them without adding on the environmental issues or risking their health by not following safety precautions. Awareness and mentorship should be shared and exchanged among the whole community to adopt a responsible production and consumption.

Also, to overcome the issues related to sustainability, responsibilities should be divided among the different sectors in the ecosystem. Each sector has different duties toward other sectors and individuals in the community.

Public sector

Ministries have to launch awareness campaigns for both individuals and businesses about environmental issues and organize initiatives with other sectors to overcome issues in the way of the three pillars of sustainability. Protocols between ministries should be formulated to strengthen the communication between them and empower the steps taken by them

towards a better quality of life for all. The government should also engage people in solving society' issues and establish systems to handle them, then make laws and policies to ease their work and force penalties on violations done by businesses and individuals.

Civil society sector

They have always adopted sustainability causes in their activities, however the impact is low due to the limited reach to people. Funding agencies and donners should collaborate with different associations, from private and public sectors, to strengthen the initiatives tackling environmental, social and economic challenges in the community. Spreading awareness should be part of their activities too in order to aware the citizens about their duties and rights, and to encourage them to adopt responsible behavior in production and consumption.

Private sector

Due to its disharmonious structure and the reluctance of companies to cooperate together, aligning with each other's CSR strategies is a necessity to collaborate for the greater good of the community. Moreover, civil society and public sector's goals should be transparent and aligned with companies' strategies in case of cooperation. It is the right path for private sector to be positively impactful. CSR strategies should not only involve charity cases as a way of marketing, but also make an influence on society's awareness and development in addressing its issues.

Individuals in society

Public and influential figures should include in their activities causes related to their communities for the aim of encouraging people to adopt sustainable and responsible behavior in their daily life, especially when it is associated with production and consumption.

4.6. Sustainability Assessment of Visions

Finally, a conclusive assessment is done to insure the positive impacts of the visions and avoid negative consequences. Continuing on the scenarios developed in the study of (Petrulaityte et al., 2017) that covered the barriers of lack of fund, identification of customers preferences, know-how of designing, hygiene, privacy of usage and personal information, and end-of-life treatment, the developed visions addressed such barriers with their offerings. Using the SDO-toolkit, visions are assessed with the radar tool according to the principles employed in the participatory workshops. The toolkit includes environmental, social and economic assessment tools. Each vision is assessed by the three tools, their issues are studied, and solutions are proposed to mitigate them.

1st vision:

Environmental, Figure 4-1: this vision solved the issue of design know-how provision, studied in (Petrulaityte et al., 2017), through offering physical and virtual co-working spaces for makers and designers to share/exchange knowledge. Still, two issues were found in the conservation/biocompatibility and waste minimization/valorization principles. The issues were using fossil fuels and unrenewable sources of energy, and proper waste management. Solutions proposed were:

- Conservation/biocompatibility: Service provider should try to integrate off-grid renewable energy systems to generate electricity for 3D printers. This energy could be done by the business owner, or through a partner who has such system.
- Waste minimization/valorization: Along with parts exchange among users, service provider should create a waste management structure or rely on a service provider to handle this responsibility. Also, leftovers should be re-used, or re-manufactured.

Social, Figure 4-2: one issue found related to improve employment and working conditions, safety precautions from gases emitted by 3D printers during operation. Such issue can be addressed through:

- Forcing safety precautions on employees and customers working closely with 3D printers to avoid health issues. Violation in respecting these should have as consequence penalties.

Economic, Figure 4-3: two issues found related to complement DE hardware with life cycle services and optimize stakeholders' configuration principles. They could be solved through:

- Complement DE hardware with life cycle services: the system should rely on other service providers who offer life cycle services to maintain a good resources management.
- Optimize stakeholders' configuration: On the long run, the customers will start to buy their own machines. The provider should from beginning win their loyalty through discounted offers and memberships.

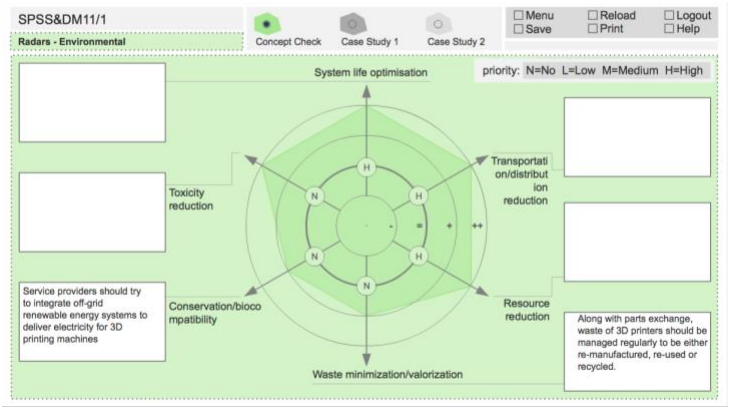

Figure 4-1 Environmental Assessment of 1st vision

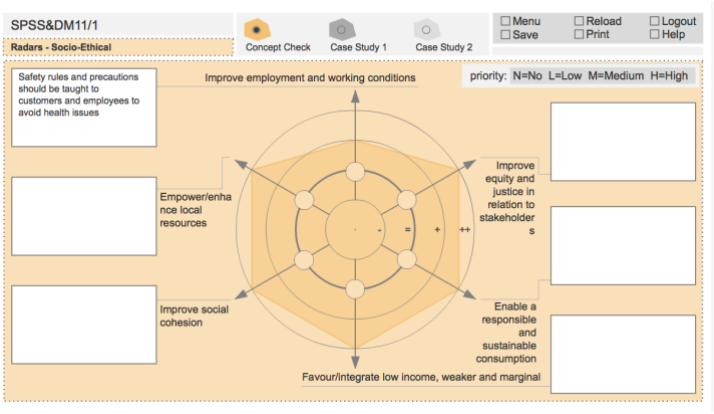

Figure 4-2 Socio-ethical Assessment of 1st vision

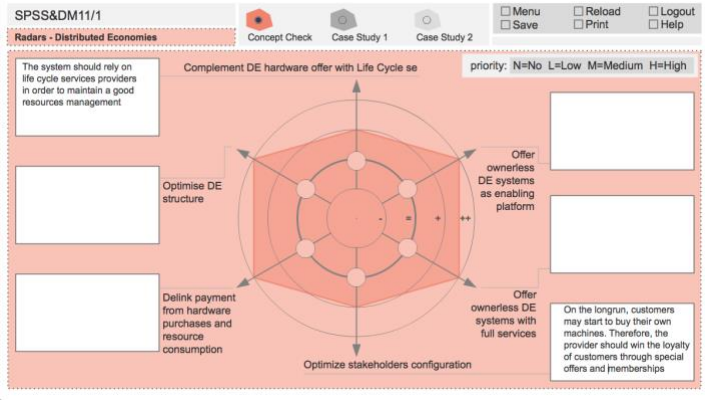

Figure 4-3 Economic Assessment of 1st vision

2nd vision:

Environmental, Figure 4-4**:** This vision tackled the issues of privacy of usage/personal information and hygiene discussed in (Petrulaityte et al., 2017) through offering on-site manufacturing for a specific user, or a group of users, upon ordering the unit. However, one

issue was detected in transportation and distribution reduction due the mobility of the unit to move to on-site manufacturing. The issue was solved through:

- Transportation and distribution reduction: The service provider should be at a proximate distance from the customer to reduce environmental impact caused by the unit transportation to the site. Also, the usage of renewable source of energy in transportation can be another solution to reduce the use of fossil fuels.

Social, Figure 4-5**:** one issue found in favour/integrate low income, weaker and marginal communities, when it comes to the price and cost of mobile units. The solution proposed was:

- Favour/integrate low income, weaker and marginal communities: a group of users could order the mobile unit together to fulfill their needs, or the supplier can have return on investment to reduce the price of service.

Economic, Figure 4-6**:** one issue needed to be tackled in relation with the principle of delink payment from hardware purchases and resource consumption. Solution proposed was:

- Delink payment from hardware purchases and resource consumption: maintaining the system's positioning through proper pricing and marketing. They should stay consistent in order to earn customers' loyalty, and not lose them to competitors.

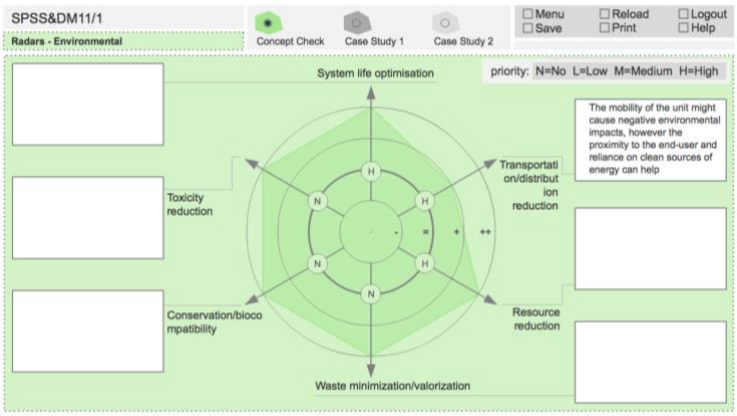

Figure 4-4 Environmental Assessment of 2nd vision

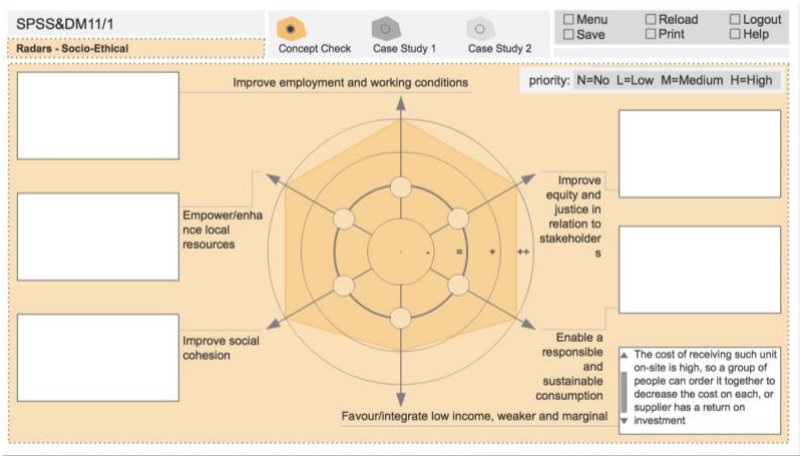

Figure 4-5 Socio-ethical Assessment of 2nd vision

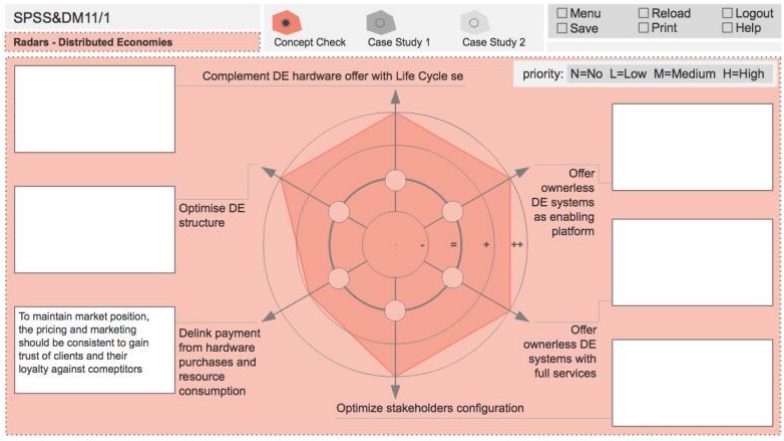

Figure 4-6 Economic Assessment of 2nd vision

3rd vision:

Environmental, Figure 4-7**:** the vision was comprehensive in relation to challenges of lack of fund, identifying customers' preferences, hygiene, and end-of-life treatment (Petrulaityte et al., 2017) through offering a full support in manufacturing and lifetime support for the product. One issue found with the principle of conservation/biocompatibility. Same as the first vision, the issue was due to possible use of grid electricity generated from fossil fuels. The proposed solution was:

- Conservation/biocompatibility: Service provider should try to integrate off-grid renewable energy systems to generate electricity for 3D printers. This energy could be done by the business owner, or through a partner who has such system.

Social, Figure 4-8**:** one issue found with principle of favour/integrate low income, weaker and marginal communities due to the high cost of services offered in this system. The solution proposed was:

- Favour/integrate low income, weaker and marginal communities: To cover the high costs of such services, financial plans should be developed to pay over a period of time, high-end products should be sold to cover the cost of low-end products given to low income individuals, or donations cover the price of indispensable products as prosthetics and their support services.

Economic, Figure 4-9**:** two issues were found offer in two principles: ownerless DE systems as enabling platform and optimize stakeholders' configuration. Solutions developed were:

- Offer ownerless DE systems as enabling platform: the service provider should sustain lifetime services' costs through financial plans, selling high-end products, or donations.
- Optimize stakeholders' configuration: Service provider should find smart economic ways to sustain the cost of services through the cooperation with funding agencies.

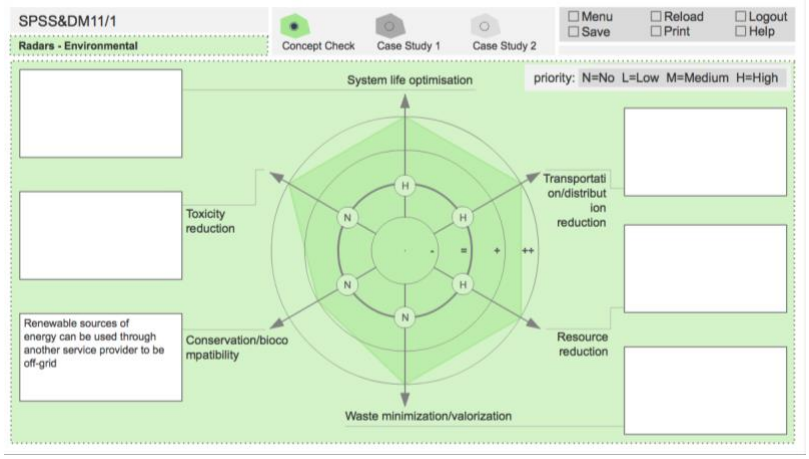

Figure 4-7 Environmental Assessment of 3rd vision

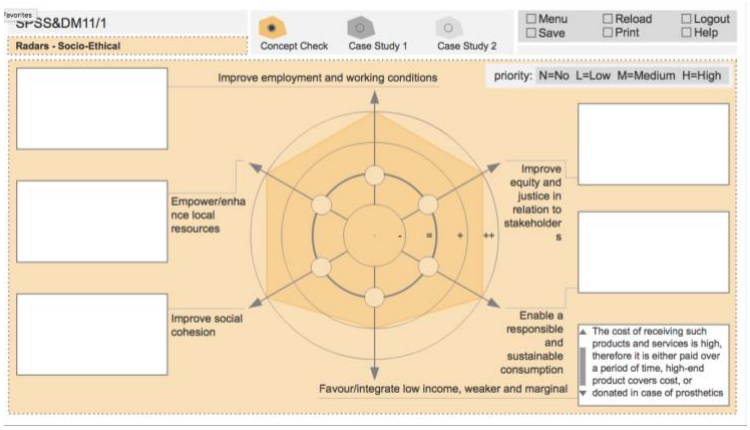

Figure 4-8 Socio-ethical Assessment of 3rd vision

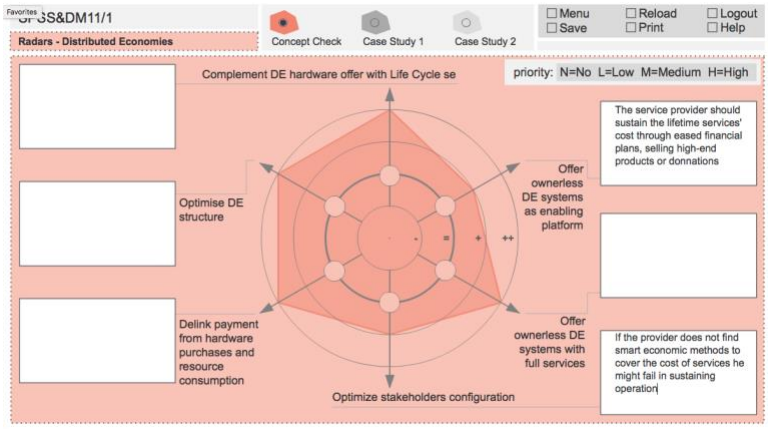

Figure 4-9 Economic Assessment of 3rd vision

4th vision:

Environmental, Figure 4-10**:** the vision covered the challenges of hygiene, privacy and end-of-life treatment (Petrulaityte et al., 2017) through offering the 3D printer with all-inclusive services done by local providers. no issue found in the environmental radar.

Social, Figure 4-11**:** one issue related to the principle of enable a responsible and sustainable consumption due to lack of awareness. The solution suggested:

- Enable a responsible and sustainable consumption: The customers get awareness about possible ways to have a sustainable manufacturing process, decrease environmental impacts and make positive social impact

Economic, Figure 4-12**:** one issue identified related to the principle of offer ownerless DE systems with full services due to services' price. The solution suggested was:

- Offer ownerless DE systems with full services: the price of services will drop automatically due to technology dissemination in the market. However, joint ventures can reflect financial benefits for both service providers and customers.

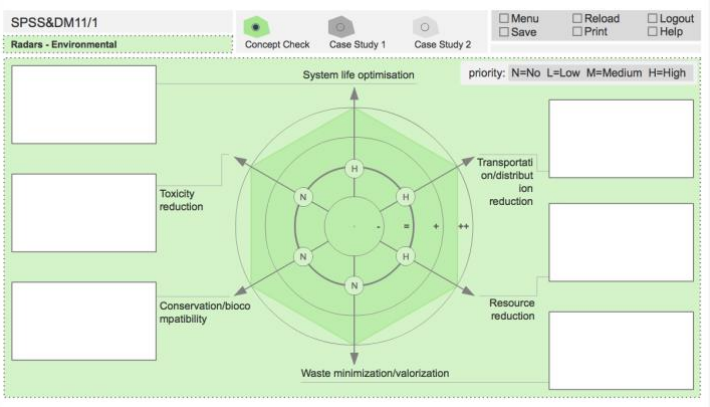

Figure 4-10 Environmental Assessment of 4th vision

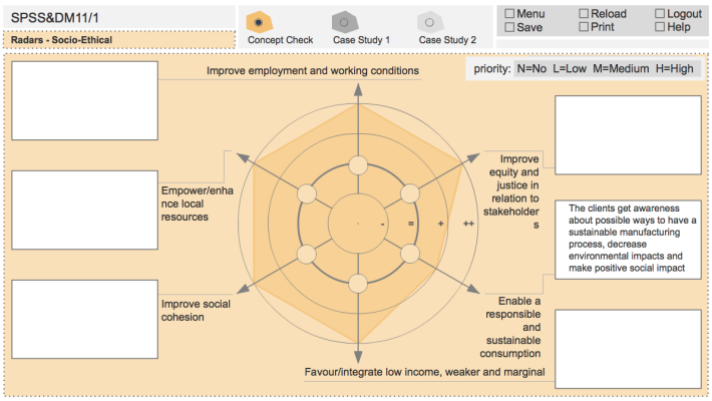

Figure 4-11 Socio-ethical Assessment of 4th vision

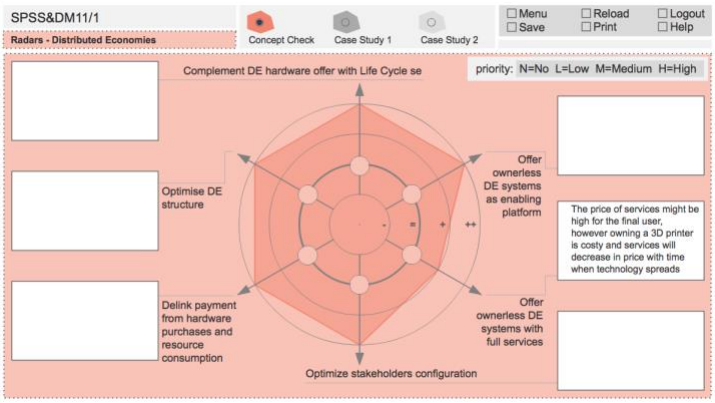

Figure 4-12 Economic Assessment of 4th vision

4.7. Conclusion and Recommendations for Future Research

The aim of the research was to investigate the ability of the two models S.PSS and DM to tackle the problems of limited access to resources and the lack of networking and trust in the Egyptian entrepreneurial ecosystem. Such barriers were claimed in GEM report to hinder makers who want to be entrepreneurs from having their own startups. Also, the research aimed to find out the other barriers in Egypt against the formulation of sustainable practices and the easy access to emerging technologies. The gaps found in literature were put as targets for this research to fulfill. Gaps were: qualitative case studies about operational tactics for PSS in a low and middle-income context, near-future scenarios and their application guidelines. Filling such gaps answered to the questions of how PSSs operate, their impacts on the local market, the possible scenarios of the combined models and their impacts from the perspective of the three pillars of sustainability.

The findings of this study proved the opportunities S.PSSs can offer in order to address the barriers in the Egyptian entrepreneurial ecosystem. In fact, S.PSSs in Egypt have already managed to offer access to new technologies of digital fabrication, especially 3D printing, through networks of service providers in return of payment per unit of satisfaction. Whether the unit of satisfaction was based on time or material, the cost of using the machine was still affordable compared to the cost of acquiring the machine's ownership. Also, the unit of satisfaction controls the production and consumption rate because the customers became aware about the amount of time and material consumed to make a product. Therefore, the barriers of access to resources and network/trust were positively addressed by S.PSS applied to DM. The other barriers of: bureaucracy, regulative policies barriers, lack of DIY culture and absence of formalized contracts, win-win cooperation and environmental awareness, were identified as the legislative and cultural barriers that need to be addressed by the different sectors and stakeholders. Overcoming such barriers would support the dissemination of sustainable practices in businesses and emerging technologies aiming for sustainability.

Furthermore, the findings exhibited how PSS business models working in the Egyptian ecosystem handled the operational tactics, possible visions for near-future scenarios of S.PSS applied to DM, their impacts on the sustainable development of startups, and guidelines of application for young makers. The research case studies and insights from stakeholders were discussed to get an overview about the doable and undoable in the Egyptian entrepreneurial

ecosystem, especially in the trial of empowering responsible businesses toward the environment, society and economy of a country. The stakeholders from public, private and civil society sectors along with famous individual in society were declared as responsible to spread awareness about sustainability issues and adopting a responsible behavior toward the environment and the community.

The study also illustrated that there were opportunities in mixing the products and services in the value proposition of models based on DM for dematerializing the offering and increasing the servitization level. Such models exclude the need of high initial capitals and promote the network structure complemented with trust as the main drivers for value chain. The operational tactics were found present in Egyptian PSSs' management. Yet, their efficiency should be addressed better in the aim of leaving a positive impact on the business itself and the surrounding community.

Limitations of this research involved collecting quantitative data to highlight successes and failures in sustaining PSS businesses in the local economy; future research should fill this gap while relating to the operational tactics. In addition, the economic principles in the DE section in the SDO-toolkit were overlooked due to their high resemblance with the social and environmental principles; using the economic principles would only generate similar ideas to those already generated by the environmental and social. The economic DE section of the SDO-toolkit should be further investigated and developed.

Finally, the legislation and policies hindering the dissemination of S.PSS models and new technologies in the local ecosystem should be further studied, while formulating other laws against negative environmental impacts caused by wrong practices of these technologies. Future studies should also propose other ways to overcome the barriers presented in this research depending on the context and the country.

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6. Appendices

6.1. Appendix 1: International Case Studies

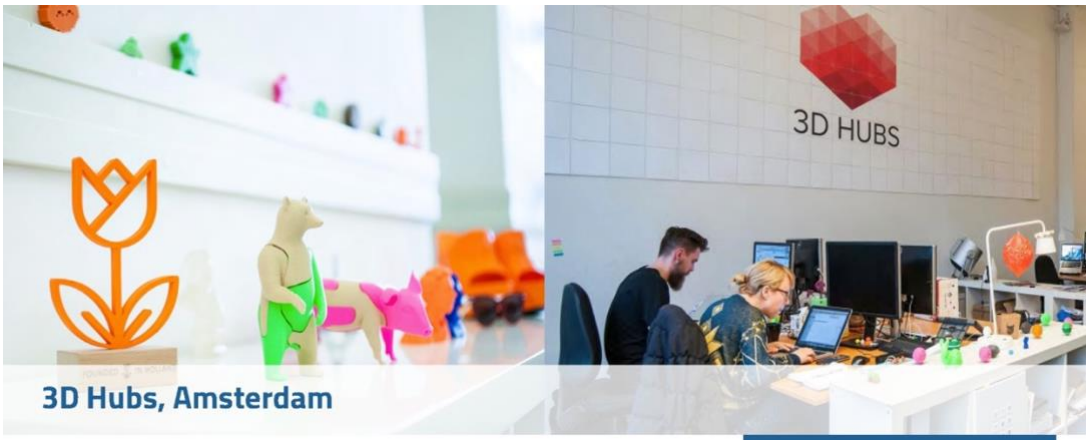
Blue Sky Center, Jabil, USA

Jabil Blue Sky Innovation Centers help our customers engineer growth and establish market leadership in an environment of rapid change. At the forefront of Jabil's technological effort, the centers display some of the world's cutting-edge capabilities like automation, product design, wearable health and medical devices, factory-of-the-future, and more. The centers leverage collaborative spaces for creating, cultivating, and incubating new ideas from vision and prototyping to global manufacturing.

From igniting ideas, curiosity, and collaboration to tackling tough innovation challenges in a thought-provoking environment, Jabil's Blue Sky Innovation Centers are more than facilities — they are an experience. They elevate engagement with our customers, partners, prospects, employees, and the industry overall. Some of the world's leading minds in engineering, science, and manufacturing leverage the powerful, global resources of our centers to elevate ideas beyond expectations.

https://www.jabil.com/contact/locations/blue-sky-innovation-centers.html

PROVIDER: Jabil, provides AM, along with consultation
CUSTOMER: Makers, Entrepreneurs
S.PSS TYPE: Use-Oriented, Result-oriented
SERVICES: Additive manufacturing, smart solutions of supply chains, localized productions, incubation & consultations on LCA.
MANUFACTURER: Jabil, and partners (HP - Ultimaker)
OWNERSHIP: Jabil & partners
PAYMENT: pay-per-use, material
UNIT OF SATISFACTION: Access to digital manufacturing, other technologies and incubation
DE TYPE/CONF.: DM (Decentralized)



3D Hubs, Amsterdam

"3D Hubs is an online 3D printing service platform. It operates a network of 3D printers with over 20,000 locations in over 150 countries, providing over 1 billion people access to a 3D printer within 10 miles of their home. The company facilitates transactions between 3D printer owners (Hubs) and people that want to make 3D prints. Printer owners can join the platform to offer 3D printing services while customers can locate printer owners to get their 3D models printed nearby." (Wikipedia)

Any user who has an appropriate 3D printer can become a hub and offer their 3D printer to others. This encourages more users to purchase 3D printers because in this way, they can subsidize the cost of the printer. So the service promotes designers, makers, house users, small businesses ... to own a 3D printer to manufacture for their own use as well as provide 3D printing to other making use of the unused time of their 3D printers.
There are no membership fees for neither parties. 3D printer owners can set their own start-up price for a print, and charge an additional fee for each cubic centimeter of material used.

https://www.3dhubs.com, Cenk's Thesis

PROVIDER: 3D Hubs provides service to connect 3D printer owners to users who wants to use 3D printers
CUSTOMER: Users who want to use 3D printers (designers, makers, ... etc.)
S.PSS TYPE: Use & Result-oriented
SERVICES: Provides users access to nearby 3D printer owners and use their printers
OWNERSHIP: 3D printers owners
PAYMENT: pay-per-use, material
UNIT OF SATISFACTION: Access to local printing service
DE TYPE/CONF.: DM (Decentralized)

Becoming 3D, USA

GreatAmerica FINANCIAL SERVICES
HARD WORK • INTEGRITY • EXCELLENCE

ascentium CAPITAL

Becoming 3D is a leading provider of 3D printing design-to-manufacturing solutions including 3D printers, print materials and supplies for both professionals and consumers. Our products and services replace and complement traditional operational methods and reduce the time and cost of designing new products by printing real pieces directly from digital input.

Established companies may lease equipment to keep bank credit lines open for other purposes. Young, start-up companies lease primarily to conserve cash, while businesses requiring state of the art technology lease equipment to avoid technological obsolescence and to preserve the ability to upgrade. Again, the needs of each company are different and leasing can meet those needs.

By leasing, the small companies can have these advantages: getting the best machine that suits the need of the business, no down payment is required, services are included in price, low monthly payment, and option to buy after leasing period for an amount of 1 dollar or upgrade to a new release. The company is in cooperation with Great America for financial services to find best plan for their customers.

https://www.becoming3d.com/3d-printer-leasing/

PROVIDER: Becoming 3D provides good deals for leasing 3D printers, along with its services
CUSTOMER: Start-ups
S.PSS TYPE: Use & Result-oriented
SERVICES: Provides users access to 3D printer and services related to it
OWNERSHIP: 3D printers owners
PAYMENT: pay-per-time, monthly
UNIT OF SATISFACTION: Access to 3D printers and related services
DE TYPE/CONF.: DM (Distributed & Decentralized)

Facit Homes, Team of Designers, UK

Facit Homes is a company that creates customized houses using digital design. Every home is designed according to customer's needs and lifestyle. Materials are chosen based on durability and ease of maintenance beside the texture and aesthetics. External cladding is applied to architecture form to protect the structure. Facit Homes company uses hyper-real 3D visualization software to give the customer an opportunity to experience his/her home as it will be. The founding team has developed a technique called the D-process which enables them to both design and digitally manufacture homes. They take the responsibility of creating sustainable homes: the place is designed to emit less GHG and use less energy to make less burden on their client when it comes to energy cost.

Also, they are bringing the technology of digital fabrication into the building technique where all machines and materials are brought to site and fabricated directly there using CNC router machines. This allows the team to fast change any detail that is not working and fabricate it again avoiding time waste. Also they are providing other companies in Europe with the D-process so they manufacture their own designs but using the technique and tools provided by Facit Homes.

http://facit-homes.com

PROVIDER: Facit Homes
CUSTOMER: Community
S.PSS TYPE: Hybrid between Product-oriented & Result-oriented
SERVICES: Design, fabrication, delivery, coding and system configuration in other companies
OWNERSHIP: Facit Homes (D-process)
PAYMENT: pay-per-unit (£2,100 per m^2)
UNIT OF SATISFACTION: Designed homes according to customer's taste and lifestyle
DE TYPE/CONF.: DM (Distributed)

Protoprint, India

Wastepickers belong to a socio-economic community in India that make their living sorting through waste and separating recyclables, which they then sell to local scrap dealers. Despite the fact that these individuals form the base of the recycling pyramid, they are often inadequetely compensated and socially marginalized.

The Protoprint initiative is structured as a social enterprise aimed at empowering these wastepicker communities by providing them with low-cost technology to produce 3D printer filament from the waste plastic they collect. The goal is to market the filament globally as a fair trade, ethically produced alternative to virgin plastic filament with a vertically integrated model to ensure that the vast majority of the profits flow back into the community. We are currently working on a pilot in partnership with SWaCH and the National Chemicals Labs to improve filament quality.

PROVIDER: Protoprint provides plastic filament for 3D printers at low-cost
CUSTOMER: Community of makers
S.PSS TYPE: Result-oriented
SERVICES: Material of plastic filament provided at low-cost because of recycling
MANUFACTURER: Protoprint
OWNERSHIP: Machines are provided in cooperation with SWaCH and National Chemicals
PAYMENT: pay-per-material
UNIT OF SATISFACTION: Access to alternative, recycled materials
DE TYPE/CONF.: DM (Distributed)

http://www.socialseva.org/protoprint/

MakerBot, Stratasys, USA

MakerBot is a world leader in desktop 3D printing, providing effective solutions for every stage of the 3D printing process. Founded in 2009, MakerBot was one of the first companies to make 3D printing accessible and affordable with the first 3D printer, the Cupcake CNC. The company became the first company to present a 3D printer, in 2010, at the Consumer Electronics Show (CES). After being acquired by Stratasys in 2013, makerbot introduced the first Wi-Fi connected desktop 3D printer in 2014.

Today, makerbot is both serving the largest install base of 3D printers worldwide and running the largest 3D design community in the world. In this sense, the company is not just offering products and network of makers community, but also leasing, education, support, store and information about 3D printing. Education is offered through Thingiverse along with 3D files available on the network to share and print.

PROVIDER: MakerBot provides 3D machines, leasing through Stratasys, knowledge/education and network.
CUSTOMER: Community of makers
S.PSS TYPE: Product & Use-oriented
SERVICES: Access to information about upgrading machines, software, materials, education, leasing, etc.
MANUFACTURER: Makerbot
OWNERSHIP: Makerbot
PAYMENT: pay-per-period
UNIT OF SATISFACTION: Access to 3D printers and education about it
DE TYPE/CONF.: DI, DM (Decentralized & Distributed)

https://www.makerbot.com

6.2. Appendix 2: Case Studies Interview Questions

General

1. Please explain the products and services you are offering
2. After explaining the systems: Product-Oriented, Use-Oriented, Result-Oriented, which category do you feel your business model is close to?
3. B2C or B2B?
4. Which materials do you use in production?
5. To what extent the business gives attention to Life Cycle Assessment of products and materials?
6. Which market segment are you targeting? To what extent is it attracted to the value you are proposing?
7. To what extent your customers are trusting and open in their behavior with the company?

Contracts

8. Are your contracts formalized? Why and how?
9. How flexible/complex the regulations in the contracts? Adjustable between customers? (listing services, compensation, rules and requirements)

Marketing

10. How intense is your Customer Relationship? Do you insure long-term relationships?

11. How do you collect insights/feedback from your customers?
12. How do you communicate the value you offer to your customers? (value-driven communication of products and services)
13. How do you adjust the pricing of your products and services?
14. To what level your product and services are adaptable to customers' needs?
15. Have you managed to influence positively the ownerless consumption into your customers?
16. Do you incorporate sustainability (social, environmental and economic) in your marketing?

Network

17. Who are your partners? What type of services they provide? (financial, legal, marketing, LCA, materials, energy, design)
18. To what extent they are in contact with the customer?
19. Do you allow some services to be done by third-party provider?
20. How do you choose your partners? (trust)
21. Do you emphasize on the co-creation process with the entrepreneur/customer?
22. How do you manage the legal rights like privacy and access customer information?
23. How do you handle communication and coordination with partners?

Design

24. How customizable/flexible your operations, products and services to satisfy customer demand?

Sustainability

25. How well do you optimize the use of resources?
26. Are there market and legal regulations that you need to meet?
27. Do you think that customers favor the business if it has a sustainability focus?
28. How high is the level of innovation/technology used in the business?
29. From socio-ethical perspective, do you feel that your business model is lowering the financial burden on the entrepreneur/customer?
30. How is your business helping in the creation of other businesses?

6.3. Appendix 3: Expert In-depth Interview questions

After explaining scenarios and visions, these questions were asked:

1. Brief background: tell me a little about yourself
2. How applicable are the visions in an Egyptian context?
3. What are the barriers/the opportunities?
4. To what extent can they help on economic, social and environmental aspects?
5. Are there promoters of Sustainability in the ecosystems? Why?
6. What are your recommendations/opinion in paving the way for such models to be applied?