Enhancing the Understanding of Manufacturing SME Innovation Ecosystems: A Design Visualisation Approach

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ImaginationLancaster

"When spider webs unite, they can tie up a lion"

African Proverb

Declaration

This thesis has not been submitted to any university for the awards of a higher degree, diploma or other qualifications in substantially the same form. It is the result of my independent work/investigation and includes nothing that is the outcome of work done in collaboration except where specifically indicated. This thesis was produced under the supervision of Professor Leon Cruickshank and Dr Daniel Richards.

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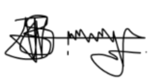

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Abstract

Small and Medium-sized Enterprises (SMEs) associated with manufacturing often form complex ecosystems that are difficult to understand and manage. This is particularly common in developing economies. Whilst the role of manufacturing SMEs has grown in creating jobs and businesses in most industrialised nations, SMEs in developing economies are lagging. To enhance the understanding of local SME ecosystem complexities, this thesis engages 17 manufacturing SMEs and two incubators in Botswana. The research also explores four makerspaces and eight manufacturing SMEs in the United Kingdom (UK). Participants are engaged through semi-structured interviews and exploratory visualisations to construct rich knowledge on their local innovation ecosystem micro-level structures. Further, the qualitative data is analysed through thematic and visual network analysis techniques. Data from Botswana and the UK contexts provide the opportunity to perform a cross-case discussion between an industrialised and a developing economy.

This thesis proposes a framework to enhance the understanding of manufacturing SMEs' innovation ecosystems and contribute to the scarce local SME ecosystem design literature. The 'Jigsaw ecosystem design framework' is built through exploratory case study projects in Botswana and the UK contexts. This framework is tested through a series of co-design workshops with 105 participants in Botswana and at a virtual conference. The thesis findings demonstrate that the framework is useful and applicable in enhancing the understanding of local manufacturing SME ecosystems, suggesting a continual learning process of ecosystem structures by all key stakeholders in local ecosystems.

The thesis concludes by highlighting the potential for future research focused on developing the Jigsaw framework into a digital application that can capture local ecosystem configurations in real-time. This work may further enhance the continual learning of ecosystem configurations and support decision-making at the micro-levels of the local ecosystem. Further testing of the framework with diverse agents and contexts is proposed to increase its scope.

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I also extend my thanks and gratitude to my best supervisors, Prof Leon Cruickshank and Dr Daniel Richards, for their time and patience, I suspect it must have been taxing to read through my rudimentary ideas and figuring out what I wanted to do and how to guide these ideas into something impactful. I also thank my internal reviewer Dr David Hands, for providing a wider lens during the early days of my work, which was key in steering the ship in a whole new and exciting direction. Being part of Imagination Lancaster, and specifically, Beyond Imagination team towards the end of my PhD project exposed me to nice people from across the world, I would like to thank them for providing free academic and emotional counselling during COVID 19, the virtual coffee meetings and chats made it less stressful to write this PhD thesis.

I also thank all the participants who dedicated their time and expertise to construct data with me on their local innovation ecosystem structures. Special thanks go to makerspace owners in the UK and other SMEs who participated in this study. I also extend my thanks to manufacturing SMEs and incubation spaces in Botswana, workshop participants from across African countries who participated in the co-design workshops, and online participants at the Design Research Society (2020) virtual workshop. This work was made possible because of your altruism. Finally, I thank my beloved wife Boi, two children Bame & Bama, and my entire extended family, who are my strength and social support ecosystem. Their undying support made this impossible work possible.

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List of Abbreviations and Acronyms

Abbreviation	**Description**
3D Printing	3 Dimensional Printing
AFDB	African Development Bank
BIH	Botswana Innovation Hub
BITC	Botswana Investment and Trade Centre
BOP	Bottom of the pyramid
BWP	Botswana Pula
CEDA	Citizen Entrepreneurial Development Agency
Covid-19	Corona Virus disease of 2019
CSR	Corporate Social Responsibility
CSV	Creating Shared Value
DRS	Design Research Society
EUR	European Monetary Unit
GBP	Great Britain Pounds
GDP	Gross Domestic Product
LEA	Local Enterprise Authority
MDGs	Millennium Development Goals

NGOs	Non-Governmental Organisations
OECD	Organisation for Economic Co-operation and Development
SADC	Southern African Development Community
SMEs	Small and Medium-sized Enterprises
STEM	Science, Technology, Engineering and Mathematics
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
USA	United States of America

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1 Introduction

This chapter starts by highlighting the researcher's motivation, connecting this to the need to understand SME ecosystems. The chapter also discusses how an ecosystem approach might enhance the understanding of local ecosystems in Botswana. The chapter highlights gaps in innovation and strategy research and outlines the aim and research questions underpinning this thesis. Lastly, the thesis structure is presented.

1.1 Motivation

When this PhD work started, my motivation was to explore additive manufacturing technology and how this might contribute to manufacturing SME competitiveness in Botswana. This was but a glimpse of the source of motivation for this work. I started my design adventures before high school. Growing up in one of the poorest regions in the world in the early 80s, life was not so easy as today. Making things through improvisation was part of my daily design encounters, from farm work to household appliances. When I went to high school in the late 90s, design and technology became my favourite subject because it resonated with my interest to create things and express myself through making.

At the time, the Government of Botswana also recognised design and technology as an important subject that could contribute to the country's socio-economic development. This led to the introduction of technical wing groups in a select few (four) high schools around the country to offer a combination of design and technology, electronics, and computer numerical controlled machines. Introducing technical subjects was meant to promote technical skills development. I was one of the top students in the design and technology subject selected to attend one of the four technical wings. The adventures of exploring design became stronger in high school. This motivated me to study for an undergraduate degree in Design. After my graduation, I worked as a product designer in the military. I contributed design knowledge to improve a range of military equipment.

After three years of my expedition in the military, in 2008, I decided to move on to study for a Master of Science in mechanical design and theory in China. Although this course was a combination of engineering and design theory, it matched my needs as a product designer because I needed a more depth appreciation of products' mechanical and tribology aspects. Spending three years in China expanded my interest in design methods and product design. I admired the simplicity of making things on the streets of Beijing, Shanghai, and Shenyang, the art of selling products on the streets of Guangzhou and Shenzhen, and the effortlessness of infusing indigenous materials and knowledge in product development processes on the streets of Tibet. In 2011, I went back to Botswana, where I worked for a power company for a few years as a training and development officer.

In 2012, I also co-founded a digital marketing SME named Massive Advertiser. My entrepreneurship journey quickly became about growing the local SME ecosystem by providing marketing and advertising spaces in our print advertiser and website. At Massive advertiser, I got to appreciate the challenges SMEs encounter every day in growing their competitiveness. Working with manufacturing and service SMEs through consultancy, business support, and trade, I learned that SME challenges were more of a systemic nature than just about individual business resources. Most of the system-level challenges that I observed were associated with a lack of skills to manage dependencies. For example, managing complementors in the innovation system, whether it was to do with suppliers, other SMEs, or customers connected to the value creation network, was a huge challenge. Most SMEs also preferred working in isolation and did not want to share resources through group marketing or supply chains.

In 2015, I joined a University institute as a teaching instructor in design methods and renewable energy. My interests expanded towards exploiting research and how this might be resourceful in solving SME challenges in Botswana. My position at the University gave me the leverage to travel and intermingle with policymakers in Government, the private sector, research centres, and non-governmental organisations involved with SME development. I also collaborated with other University scholars in engineering design pedagogy, which led to three conference publications.

After two years of teaching design methods, I was motivated to explore research in solving entrepreneurs’ challenges in the country. In 2017, I was awarded a prestigious and highly competitive UK Commonwealth Scholarship to study for a PhD in Design at Lancaster University, a top 10 University in the UK. I initially delved into the topic of additive manufacturing technologies (3D printing) and how this technology might be augmented to improve SME ecosystems in Botswana. This study later metamorphosed into how design and visualisation techniques might enhance the understanding of local manufacturing SME ecosystems. This change was motivated by the realisation that the solution to enhance manufacturing SMEs was not just in importing technologies and in what technologies could produce but in how it could contribute to creating new business model innovations. Consequently leading to a focus on exploring local ecosystems.

This thesis details an account of how manufacturing SMEs understand and shape their ecosystems. A design visualisation approach is developed in collaboration with SMEs in Botswana to understand local ecosystems. The use of visualisations helps stakeholders to gain access to new insights about their ecosystem structures. The UK SME ecosystem actors, i.e., makerspace owners and manufacturing SMEs, are also explored in this present thesis to compare contextual differences and how insights from these much more industrialised contexts might be augmented to develop SME ecosystems in Botswana.

This thesis combines co-design principles, visualisations, and innovation ecosystem constructs to bring together local ecosystem actors and facilitate active involvement in designing the understanding of local SME ecosystems in Botswana.

1.2 Understanding local innovation ecosystems

Recently, the role of SMEs has grown in creating jobs and business innovations, thus accounting for a significant share of the economies (AFDB/OECD/UNDP, 2017). A holistic approach to nurturing entrepreneurship is necessary to grow economies (Buckley and Davis, 2018; Audretsch and Belitski, 2016). This idea is also demonstrated by the Government of Botswana (Schutte and Direng, 2019) and other African governments through massive financial investments in promoting entrepreneurship (Benjamin, 2019; Mujinga, 2019; Hadassah, 2019). However, as noted in OECD (2017), drawing up policies for SMEs is a cumbersome endeavour:

> *"Since SMEs are often embedded in local ecosystems, which represent their primary source of knowledge, skills, finance, business opportunities and networks, it is also important to consider factors affecting framework conditions at the local level, and how policies developed at national level are tailored to local conditions, as well as how they coordinate with policies that are shaped at the regional or territorial level" (OECD, 2017, p.5).*

The above quote indicates that much of the work needs to be focused on exploring the local SME ecosystems, where entrepreneurs are embedded. Nurturing entrepreneurship at the bottom of the pyramid market requires more than just giving out money to SMEs, but understanding, nurturing, and managing local interrelationships and interdependences (Von Stamm and Trifilova, 2009). This is highlighted in (Noh and Lee, 2015), where authors demonstrate how critical external collaborations can be to SME competitiveness. The concept of innovation ecosystems is receiving heightened attention from strategy and innovation management research scholars (Adner and Feiler, 2019; Dedehayir et al., 2017; Iansiti and Levien, 2004; Jacobides et al., 2018), thus indicating its significance.

Although there is no single definition of SME ecosystems (Spigel and Harrison, 2018), this thesis defines ecosystems as networks of actors that are working together and dependent on each other for survival and growth, where these collective networks are capable of fostering innovation (Adner and Feiler, 2019; Dedehayir et al., 2017; Iansiti and Levien, 2004; Jacobides et al., 2018). Over the years, there has been a gradual shift in innovation management research from firm-centric approaches, e.g., resource-based views, to an interest in using ecosystemic approaches (Moore, 1996; Iansiti and Levien, 2004).

The ecosystem metaphor is becoming increasingly crucial to strategy, innovation and entrepreneurship research because firms are now heavily reliant on external resources to make innovation happen (Adner and Feiler, 2019; Jan et al., 2020). Although business managers acknowledge the significance of ecosystems in growing businesses (Lyman et al., 2018), they still lack the knowledge and tools to understand, develop and manage innovation ecosystems in their environments (Rosli et al., 2017; Jacobides et al., 2018).

Many connected stakeholders are unclear on what their interconnectedness means for their companies and the broader SME ecosystem (Sniderman et al., 2016). Consequently, there is a need for a better understanding of innovation ecosystem structures (Radziwon and Bogers, 2019) and how to create new opportunities for interconnected and interdependent actors (Su et al., 2018; Rong et al., 2018).

Some researchers have long predicted that the future of inter-firm shared value might be shaped by how well actors manage and understand distributed innovations in ecosystem environments (Von Stamm and Trifilova, 2009; Baldwin, 2012). In the past, SMEs operating under traditional models struggled with developing innovations due to a lack of resources, e.g., external knowledge (Traitler et al., 2011). Recently, it was reported that developing innovations is about creating an ecosystem where actors such as firms, people, sectors can collaborate and create value (Granstrand and Holgersson, 2020), which is anchored on leveraging system-wide resources and heterogeneity of actors.

The role of entrepreneurs in shaping the local ecosystem through a bottom-up approach is not clearly defined (Motoyama and Knowlton, 2017). Regional theories such as cluster, quandruple and quintuple theories provide limited analysis of the structure and networks of local entrepreneurs (Motoyama and Knowlton, 2017). For example, the Quintuple Helix as an analytical model evaluates interactions amongst actors seeking progress in society by looking at political, educational, economic, environmental, and social systems (Barcellos-Paula et al., 2021). However, these models do not fully explain how actors can actively shape, understand and navigate local ecosystems. The lack of analysis and understanding of the SME ecosystem structure means that SMEs are not fully leveraging their potential to enhance innovation.

1.3 Need for an ecosystem-level approach to SME innovation ecosystem understanding

Research has been done on national innovation systems to explore the competitive advantage of interconnected firms (Nylund et al., 2019). This thesis expands on the national systems view by exploring how SMEs in local ecosystems might contribute to the local economy. There is a need to develop system-level capabilities required by manufacturing SMEs to actively design the understanding of local innovation ecosystems (Radziwon et al., 2014). This need calls for practical tools to support actors, i.e., entrepreneurs, policymakers, researchers, customers connected to the manufacturing SME ecosystem.

Holistic questions about how entrepreneurial ecosystems are structured, what assets they need cannot answer the operational and interactional dynamics between ecosystem actors (Motoyama and Knowlton, 2017). This thesis uses SME networks as structures defining the local ecosystem form. This idea requires an in-depth understanding of interconnections between actors to decipher complexity in local SME ecosystem structures. This is achieved by focusing on exploring actors' mental models of local innovation ecosystems.

1.4 Highlighting the gap in innovation and strategy research

Little has been done to develop local ecosystem-level understanding through practical tools that decipher complexity across interconnected actors in a local context (Audretsch and Belitski, 2016). Roundy et al. (2018) also highlight the limitations in entrepreneurial ecosystems' literature in developing a theoretical framework that acknowledges ecosystem complexity, i.e., interactions between agents, firms, and socio-cultural forces. Ecosystem configurations are mostly viewed from the lens of objective social facts, yet they are subjectively shaped through continual social interactions (Vink et al., 2019). Understanding the contextual socio-cultural, technical boundaries, and behavioural factors that shape the local SME ecosystem is crucial (Roundy et al., 2018).

Developing design capabilities to aid SME ecosystem actors in visualising, analysing and understanding their local ecosystems is essential to ecosystem literature, innovation policy, and practice in which this thesis seeks to contribute new knowledge. The gap highlighted here, and also in sections 1.2 and 1.3, is in line with what other ecosystem researchers have acknowledged as a theoretical and practical limitation of existing ecosystem literature and practice (Pankov et al., 2019; Jacobides et al., 2018; Su et al., 2018; Rong et al., 2018; Rosli et al., 2017). This research gap has been identified after an extensive literature review reported in chapter 3.

In the following section, the thesis outlines the aim and research questions guiding this thesis.

1.5 Aim and research questions

This thesis aims to develop a design visualisation framework to enhance the understanding of SME ecosystems. This approach is necessary to help manufacturing SMEs better understand local ecosystems.

1. What is an innovation ecosystem, and how does this fit within the manufacturing SME environment in Botswana in terms of contributing to socio-economic development?

    - This question highlights the status of SME support in terms of policies targeted at growing the SMEs' innovation ecosystems and how this might lead to socio-economic development in the country.

2. In what ways might local manufacturing ecosystems in SME environments be supported to create shared value?

    - This research question seeks to explore the growing body of literature around innovation ecosystem design by highlighting and discussing key concepts, e.g., innovation ecosystems, creating shared value, disruptive innovations, co-design, and visualisation methods (these concepts are fully explained in chapter 3).

3. How might insights from decision-makers in innovation ecosystems in the UK be augmented to support the understanding of manufacturing SME ecosystems in Botswana?

    - First, this research question explores the 3D printing-based innovation ecosystem cases through engagement with experts to build an understanding of how they shape their innovation ecosystem structures.

    - Second, it explores makerspaces as innovation ecosystems in the UK through interactions with experienced makerspace owners and some affiliated makers/SMEs.

- Third, the question explores manufacturing SME incubations as innovation ecosystems in Botswana through interactions with manufacturing SMEs and incubation managers.

4. How might ecosystem design and visualisation approaches support and enhance the understanding of local SME ecosystem structures in Botswana?

    - First, this question tests the proposed ecosystem design framework from question 3 via co-design workshops with manufacturing SMEs, researchers, policymakers, customers, and others.

    - Secondly, this question also tests the ecosystem design visualisation framework at a Design Research Society (DRS2020) virtual workshop with design researchers to improve the approach for use with different ecosystems.

5. Where could the design visualisation approach be improved to enhance the understanding of local manufacturing SME ecosystems?

    - This question discusses the framework based on both the UK and Botswana insights and suggests an expanded ecosystem design framework for enhancing the understanding of manufacturing SME ecosystems in Botswana.

1.6 Research outline

This thesis is arranged into eleven chapters, of which the introduction is the first.

Chapter 2- Botswana context: This chapter highlights critical milestones in policies targeted at growing the SMEs industry in Botswana. The chapter also underlines the challenges, and an ecosystem-level need to grow the manufacturing SME contribution to socio-economic development.

Chapter 3- Literature review: This chapter presents the literature review related to design research, creating shared value, disruptive innovation, innovation ecosystem, co-design, and visualisations. The chapter discusses gaps and current debates around these concepts and outlines the need for further empirical research underpinning this thesis.

Chapter 4- Methodology: This chapter presents the research approach and a rationale behind the research methods adopted. This includes discussing data collection techniques used, i.e., explaining semi-structured interviews, visualisations, and workshops. The thesis also discusses the sampling, data analysis techniques, validity, and ethical considerations.

Chapter 5- Pilot project and tools development: This chapter discusses the main findings from an exploratory project with three ecosystem case studies in the UK. As the first phase of an exploratory study, the chapter provides insights and modifications to the research design and early suggestions on the direction of the thesis.

Chapter 6- Exploring makerspaces as local SME ecosystems: This chapter builds on the findings from chapter 5 by presenting the main findings from an exploratory case study with three makerspace ecosystem cases in the Northwest of England. This is the second phase of the explorative study in the UK.

Chapter 7- Exploring incubators as local SME ecosystems: This chapter presents the main findings from an exploratory case study with four incubators and independent SMEs in Botswana. This is the main chapter of the thesis, illustrating how local manufacturing ecosystems are structured in Botswana.

Chapter 8- Co-designing the understanding of localised SME ecosystems: This chapter discusses findings from co-design workshops, i.e., three in-person workshops conducted in Botswana. These workshops tested the proposed framework with manufacturing SMEs, researchers, Universities, policymakers, and administrators.

Chapter 9- Co-designing the understanding of research ecosystems: This chapter presents findings from a virtual co-design workshop conducted at the DRS2020 virtual conference. The workshop also tested the proposed ecosystem design framework with design researchers to explore how the framework might be improved from diverse ecosystem settings.

Chapter 10- Discussions: This chapter builds on findings from both the UK and Botswana, presents a comparative discussion between the UK and Botswana context, and collates discussions against existing literature. Major findings from both the UK and Botswana are discussed to expand the ecosystem design framework for practical application in manufacturing ecosystem milieus.

Chapter 11- Conclusions: This chapter concludes the thesis, outlining how the study has contributed new knowledge by demonstrating how the aim and objectives have been addressed. Limitations of the study and future extensions of the research are also outlined in this concluding chapter.

2 Context

This chapter presents a brief overview of Botswana's diversification drive and how Small and Medium-sized Enterprises (SMEs) fit within the broader socioeconomic interplay of Botswana's economy. The chapter also briefly sheds light on opportunities and challenges to SME policy interventions to date, targeted at growing the local entrepreneurship development. Finally, the chapter underlines the need for design to grow the manufacturing SME ecosystem.

2.1 Botswana Context

Botswana successfully transformed its economy from one of the poorest countries in the world from 1966 when it gained independence until it attained a middle-income status in 1986, and in 2005 it was classified by the World Bank as an upper-middle-income country (United Nations, 2016; African Development Bank, 2014). The country is deeply reliant on diamond mining as the primary commodity contributing around 35% towards the country's GDP (African Development Bank, 2014). As a result, Botswana invests a significant amount of diamond proceeds towards the socio-economic development of the people (Government of Botswana, 2016), i.e., through social services such as free education, healthcare, and social welfare for those who need it. Although the country exhibits excellent macroeconomic structures, challenges of high unemployment (at more than 20%), poverty, and high-income inequality still exist (The Vision 2036 Presidential Task Team, 2016). Concerning how the Government might diversify the economy away from the mining sector, SMEs are identified as potential drivers of the country's diversification drive (Government of Botswana, 2011).

Throughout this thesis, the use of the acronym ‘SMEs’ is used in place of Small, Medium, and Micro Enterprises (SMMEs) to explore manufacturing SME ecosystems. SMEs represent an important sector for industrialised economies (European Commission, 2015) and developing economies (Zulu-Chisanga et al., 2020). There are varied definitions and classifications of Small and Medium-sized Enterprises (SMEs) globally for various reasons. For example, in Europe, SMEs are categorised into micro, small and medium-sized enterprises consisting of fewer than 250 persons, annual turnover not exceeding EUR 50 million, or an annual balance sheet total not exceeding EUR 43 million (European Commission, 2015). This definition is meant to guide officials in European countries to draw up schemes and grants to support deserving SMEs.

Specifically, the UK defines SMEs as registered businesses of up to 249 employees (Ward and Rhodes, 2014). Within the SME category, small enterprises are those employing fewer than 50 persons and having annual turnover or a balance sheet total not exceeding EUR 10 million, and micro-enterprises employing fewer than ten persons and making an annual turnover or balance sheet total not exceeding EUR 2 million (European Commission, 2015). The Organisation for Economic Cooperation and Development (OECD) notes that there is no standard international definition for SMEs, but for its statistical purposes, defines SMEs much like the European Commission, where SMEs are classified as micro, employing up to nine people, small, employing up to 49 people and medium, employing up to 249 people (OECD, 2017).

While acknowledging the varied definitions of SMEs, which depend on each region or country, the study adopts the definition of SMEs as outlined in Botswana context (Rapitsenyane et al., 2014). In Botswana, SMEs are classified as micro employing less than six people and having an annual turnover of BWP60,000 (Approx. GBP 4,000), small enterprises employing less than 25 people, and an annual turnover between BWP60,000 and BWP150,000 (Approx. between GBP 4,000 and 10,100), and medium enterprises employing less than 100 people with annual turnover between BWP1,500,000 and BWP5,000,000 (Approx. between GBP 101,600 and 338,700).

Several reports and research articles identified SMEs as key in the country’s economic development agenda (Mutoko and Kapunda, 2017; International Trade Centre, 2019a; Rapitsenyane et al., 2014; Hague et al., 2016). The SME sector employs about 70% of the workforce in many countries (International Trade Centre, 2019b), making the sector critical in the country's socio-economic strategy. Botswana is no exception (Mascolo and Fischer, 2005), and the country acknowledges the significant role SMEs could play through the national development plan 11 (Government of Botswana, 2016) and the new vision 2036 agenda. Vision 2036 is aligned to the sustainable development goals (SDGs) 2030 agenda on socio-economic development (The Vision 2036 Presidential Task Team, 2016) to reaffirm the country's commitment to SME development.

2.2 Key milestones in SME policies

As shown in Figure 2.1, by plotting the SME policies in a timeline, the thesis synthesises the key policy status and progress across the years since the 1960s. This is important to show an overview of how SME policies evolved with time. Although the Government of Botswana introduced the Financial Assistance Policy (FAP) in 1982 to assist SMEs with small loans and grants, only 4% were successful at the time, most of the funds reserved for SME development were allegedly mismanaged (Tesfayohannes, 2010). Later, as illustrated in Figure 2.1, the Government stopped the Financial Assistance Policy and introduced the Citizen Entrepreneurship Development Agency (CEDA) in 2002 to Assist SMEs with loans, training, and mentorship.

Nevertheless, many SMEs faced challenges related to bank requirements and the production of viable business plans (Temtime, 2008). The Government then introduced the Local Enterprise Authority (LEA) in 2004 to assist SMEs with business development skills and mentorship programs (International Trade Centre, 2019a), and later build five incubation spaces around the country to support start-up businesses. To build and strengthen the entrepreneurial ecosystem in Botswana, the Government further embarked on an ambitious project to provide entrepreneurs with innovation spaces under Botswana Innovation Hub (BIH), established in 2008 (BIH, 2020).

The Government also introduced several grants and loans, e.g., i) the Youth Development Fund (50% loans and 50% grants) in 2009 valued up to approx. GBP 30,500, ii) Gender Affairs fund (100% grants) valued up to approx. GBP 30,500, iii) Young Farmers fund (100% loan) valued up to approx. GBP 33,900, iv) Arts and Culture fund (100% grants) valued up to approx. GBP 16, 960 (Khanie, 2018). Despite all the above support grants, previous research in Botswana shows that 70% of SMEs fail within the first 18 months of operation, and the overall failure rate is 80%

(Gaetsewe, 2018). These programs seem to have failed to create economic value to support start-ups to grow and create employment. Recently, the Government introduced the innovation fund through Botswana Innovation Hub in 2017 and revised the Citizen Entrepreneurial Development Agency (CEDA) policies to increase the loan threshold for SMEs to GBP 37,700 without the need for security or collateral in 2020. Amongst the new Citizen Entrepreneurial Development Agency guidelines, several sectors of manufacturing businesses are reserved for Botswana citizen-owned businesses, e.g., furniture manufacturing, printing, signage, traditional crafts, and leather products (CEDA, 2020), all aimed at growing manufacturing SME businesses and start-ups.

Previous studies on Botswana manufacturing SMEs found many constraints ranging from lack of access to finance, lack of entrepreneurial and innovation skills, lack of marketing skills, lack of policies, and others that hinder the development of manufacturing SMEs (Temtime, 2008; International Trade Centre, 2019a; Nkwe, 2012; Rapitsenyane et al., 2014). Because of these constraints, the manufacturing industry is contributing less than 6% towards GDP, and this value is reported to be declining yearly (Statistics Botswana, 2017).

Most manufacturing SMEs associated with the leather, textile and crafts industry can employ many people (Motswapong and Grynberg, 2013). However, it seems current policies have not adequately addressed the vexing issue of resource constraints. Scholars have since advocated for inter-firm relationships as ways of overcoming resources and capability challenges (Zulu-Chisanga et al., 2020). A possible contribution to socio-economic development could be through local manufacturing SME ecosystems since SMEs are embedded in local ecosystems.

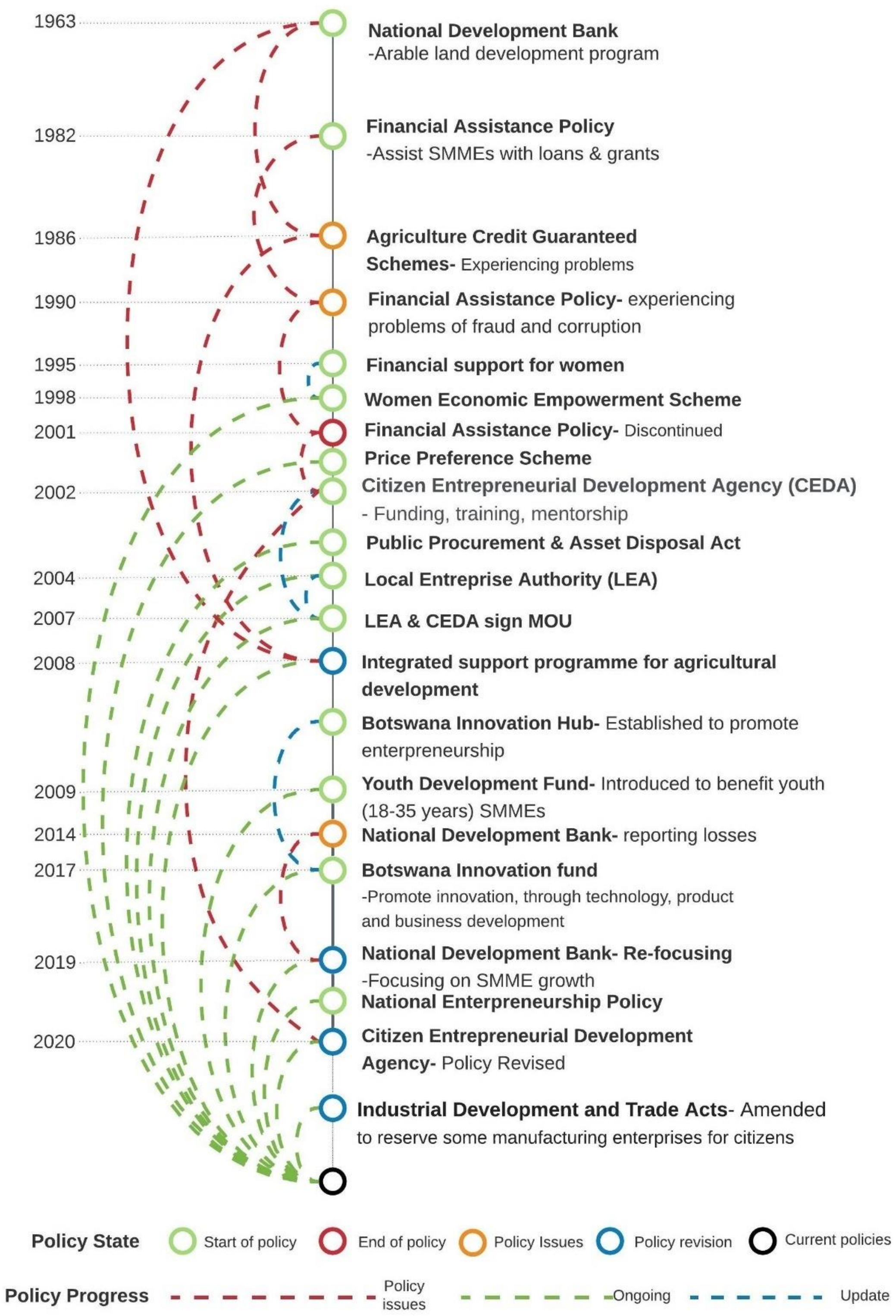


Figure 2.1: Major milestones in policies for enhancing SMEs

2.3 The need for policies aimed at interconnecting manufacturing SMEs

Recently, the COVID-19 pandemic stalled most of the Government's policy initiatives to promote entrepreneurship development in Botswana. Government priorities were swiftly channelled towards the fight against COVID-19, resulting in some SMEs closing. Also, most manufacturing SMEs were affected by a series of lockdowns, and without proper internet connectivity and reliable electricity, working from home was impossible. However, there have been significant opportunities for some SMEs in the digital space, i.e., in the software application development domain, who benefited in the fight against COVID-19. This accounted for a small number of SMEs. Consequently, as shown in Figure 2.1 above, the Citizen Entrepreneurship Development Agency recently launched the revised policy to stimulate the manufacturing industry from the COVID-19 lockdown effects (CEDA, 2020).

The main constraints raised during the launch of the revised policies were manufacturing SMEs' competitiveness, specifically against imports and large foreign-owned firms (AllAfrica, 2020). The question was on how manufacturing SMEs can be assisted to grow their competitiveness. Through the industrial development and trade act amendment of 2020, policymakers identified key manufacturing sectors, e.g., leather, arts and crafts and glass or ceramic products, to preserve indigenous knowledge and practices and promote locally inspired SME innovations (CEDA, 2020). This policy only allows citizen-owned firms to partake in the selected manufacturing sectors because the importation of cheap products has long been identified as one of the major threats to competitiveness and growth (Temtime, 2008). Other threats include decreased diamond prices and changes in climatic conditions, affecting beef production, access to water, and electricity (International Trade Centre, 2019a). Increasing manufacturing SMEs' contribution to GDP holds the key to economic diversification, job creation, and growth (International Trade Centre, 2019a).

Having tried several policy instruments to grow the manufacturing SMEs, little has been achieved to date. Further, the COVID-19 pandemic seems to have uncovered new vulnerabilities in the manufacturing SME environment. Therefore, there is a need for manufacturing SMEs to explore ecosystem-level factors, e.g., access to skilled workers located outside SMEs, new policies to promote interconnectedness, external knowledge connections, socio-cultural, infrastructure, technologies, and business support organisations. These factors are defined in the International Trade Centre (2019a) report as crucial in supporting SMEs' competitiveness but mostly reside outside the SMEs' traditional domain. Notably, manufacturing SMEs depend on short-term strategies and plans centred around their firm-level capabilities (Temtime, 2008). Understanding manufacturing SME ecosystem-level factors and developing the capacity to leverage internal and external opportunities seems to be a significant step towards enhancing SMEs' competitiveness. This idea may create more employment opportunities, thus contributing to socio-economic growth.

2.4 Ecosystem-level thinking

Previous research supports the need for improving socio-economic conditions to enhance productive entrepreneurial ecosystems (Sheriff and Muffatto, 2015; Audretsch and Belitski, 2016; Theodoraki et al., 2017; Bhawe and Zahra, 2017; Spigel and Harrison, 2018; Roundy et al., 2018). As shown in Figure 2.1, in 2017, Botswana Innovation Hub introduced the innovation fund with a systemic objective to build a national innovation ecosystem. The fund was intended to provide seed capital to inter-firm collaborations (BIH, 2020). Here the Government is starting to recognise the need to adopt systemic approaches to innovation. Oh et al. (2016) suggest that money and intellect are insufficient to promote innovation at regional levels, rather a well-connected innovation system is needed.

Many countries now recognise the significance of investing in ecosystems rather than in supporting a single actor. This idea is partly because knowledge combinations and partnerships across firms may lead to more innovation output (Lucena and Roper, 2016). Most manufacturing SMEs in Botswana still lack the understanding of how to leverage capabilities outside their firms (Mutoko and Kapunda, 2017). Given the widely acknowledged barriers to SMEs’ competitiveness, e.g., lack of access to funding, lack of access to skilled labour, and lack of access to markets (Temtime, 2008; Rapitsenyane et al., 2014; International Trade Centre, 2019a; Mutoko and Kapunda, 2017), developing an ecosystem-level approach to innovation may promote manufacturing SMEs’ interconnectedness, thus leveraging social capital to improve competitiveness. Ecosystem-level capabilities may assist less-resourced SMEs to augment their firm-level capabilities in innovation processes.

2.4.1 Why is context-based ecosystem thinking important?

Looking back at the history of Botswana in terms of material and social practices, there are specific mechanisms that defined local community structures. These mechanisms shaped social connections that were deeply enshrined in Botswana culture and manifested strongly in cooperation, exchange of gifts, sharing of tools and food, and social gathering, amongst others. However, this thinking seems to be vanishing in the modern-day manufacturing practices in Botswana. As astutely stated in (Moalosi et al., 2008), the country needs to leverage these socio-cultural practices to contribute to socio-economic development. In (Moalosi et al., 2008), the authors argue that while borrowing from other countries is good, people need to use their resources and culture to promote innovation that will shape their future.

The subject of ecosystems in the Botswana context is not entirely new because certain activities in the past can be explained in the context of ecosystems. Since ecosystems in this thesis are defined as networks of actors working together and dependent on each other for survival and growth, this concept seems to resonate with Botswana's historical, socio-cultural practices and connotations where people were known for their generosity to share and assist others in the community (Moalosi et al., 2007). The sharing was accomplished through socio-economic mechanisms such as "*Mafisa"* in Setswana language, which means cattle that are loaned to other people for their use and caretaking (Parson, 1981). This mechanism allowed destitute persons to access cattle from wealthy households. Collective craftsmanship was also common and anchored on the spirit of *"botho"*. The *"botho"* principle works on the idea that all actors in the community need to add value to community development. This value can be achieved through "*reciprocity, mutual assistance, a sense of responsibility, respect and recognition to all"* as elaborated in (Modie-Moroka et al., 2019).

Ploughing was treated as a collective responsibility amongst communities through a socio-economic mechanism called *"letsema"* in Setswana language, which means volunteering time on behalf of family members to do farm work in exchange for farm produce. Hunting was also done in clusters, where the benefits were shared amongst the hunters. All socioeconomic mechanisms were designed to leverage social capital based on the principle of *"botho"*. This social capital seems to be eroding in Botswana (Seleka et al., 2007), where it could be fortifying local ecosystem structures within the modern-day manufacturing spaces. It is important to consider how contextual socio-cultural and economic factors affect local manufacturing ecosystems to augment ecosystem-level capabilities.

2.5 The role of design in supporting manufacturing SMEs in Botswana

The role of design in manufacturing SMEs is less understood in Botswana (Rapitsenyane, 2019). Although there are several pedagogical studies which aimed at promoting design conceptualisation into the curriculum at secondary and tertiary levels (Moalosi et al., 2016; Olakanmi et al., 2016; Moalosi et al., 2012), it seems very little has been achieved in transforming design principles out of school settings into the realm of manufacturing SME systems. Rapitsenyane et al. (2014) developed a framework to promote design-led product-service systems in leather manufacturing SMEs to promote competitiveness in Botswana. Moalosi et al. (2008) developed a culture-oriented design model to aid product designers in creating culturally oriented innovations. Therefore, more SME innovation ecosystem design research is now needed to expand on these previous works. This is important to promote context-specific designerly ways of innovation by focusing on ecosystem-level approaches.

2.6 Conclusions

This chapter discussed significant milestones and challenges in policies for enhancing SME ecosystems in Botswana. Although the Government is showing commitment towards building entrepreneurship in the country, little effort is aimed at growing manufacturing SMEs through ecosystem-level approaches. Most policy initiatives have focused on firm-level capabilities until the recent innovation fund, targeted at growing the ecosystem level capabilities for entrepreneurs. Even so, manufacturing SMEs from the crafts and indigenous technology domains are lagging. More attention seems to focus on information technology-related entrepreneurs who account for a small number in localised SME ecosystems. Therefore, these challenges require a design approach focused on an ecosystem-level understanding and interventions amongst manufacturing SMEs and key stakeholders, e.g., policymakers in Botswana, and how they might enhance the understanding of local SME ecosystems to promote entrepreneurship.

3 Literature Review

In the previous chapter, the thesis discussed opportunities and challenges for enhancing SME policies towards socio-economic development. This chapter critically discusses the shared value, disruptive innovation, and ecosystem metaphor. Then focuses on where this thesis sits in design research and how disruptive innovations, collaborative design, and visualisation techniques might be useful in promoting the understanding of entrepreneurial ecosystems. The chapter concludes by outlining gaps and the need for further empirical research.

3.1 Introduction

Enabling entrepreneurial ecosystems can be a life-changing endeavour in underserved markets (Ndemo and Weiss, 2017), that notwithstanding, organisations continue to experience challenges, e.g., scarce resources and limited capabilities in facilitating and managing ecosystems (Adner, 2017b; Jacobides et al., 2018). The manufacturing industry in industrialised nations is evolving rapidly (Nagy et al., 2018), which is possible partly because of the advent of new capabilities such as digital information and fabrication tools and how these capabilities shape innovations ecosystems (Granstrand and Holgersson, 2020). Therefore, it is believed that future manufacturing SMEs might benefit from leveraging networks and digital tools to shape their systems (Foresight, 2013; Ghobakhloo and Ching, 2019; Sniderman et al., 2016).

This chapter provides an overview of the literature review framework by drawing relationships between important keywords in design and innovation ecosystems. Figure

3.1 highlights the relationship between design, entrepreneurial ecosystems, and creating shared value, leading to socio-economic development. Several significant relations emerge from this approach (Figure 3.1), but SMEs have three main routes to follow to create shared value. First, they may use route 1 to pursue social innovation to create shared value or use social innovation to create new business models leading to shared value. Second, SMEs can use route 2 to build innovation ecosystems to create shared value or create conditions to promote serendipity for disruptive innovation, which may create shared value.

Third, and most relevant for this thesis, route 3 shows an alternative for SMEs to exploit design capabilities to create new roles, leading to disruptive innovation and shared value. This route can also lead to catalytic innovations, disruptive innovations, and serendipity for disruptive innovation ecosystems and shared value. The chapter discusses these synergies and more in the following sections, highlighting key literature that supports the value of design in the innovation ecosystem domain.

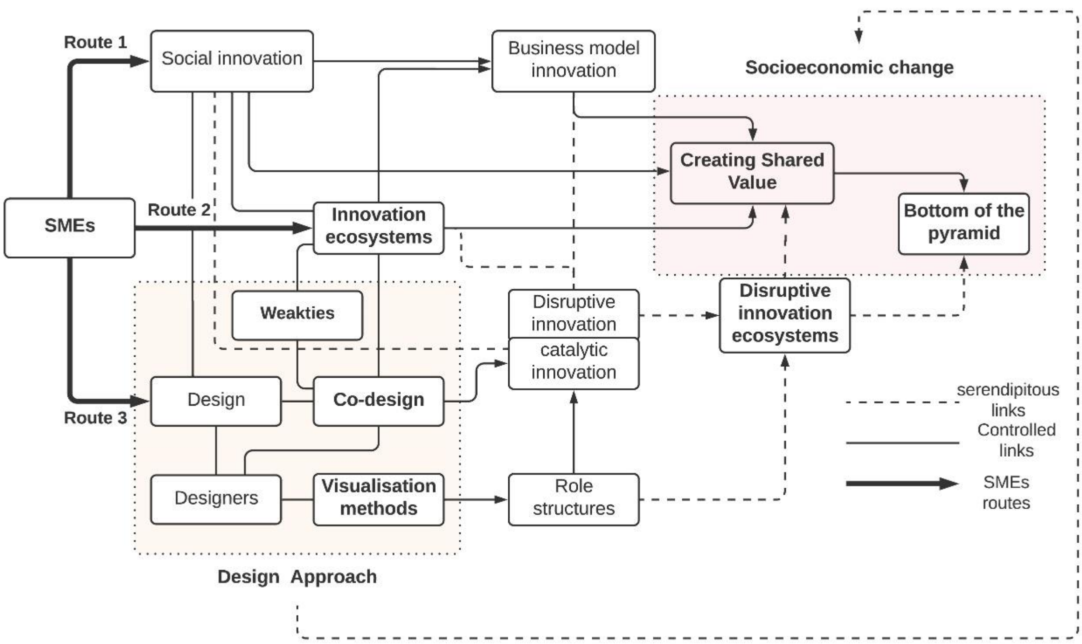


Figure 3.1: Literature review approach

3.2 Creating shared value for SME ecosystems

The idea of creating shared value emerged from corporate social responsibility. As shown in Figure 3.2, by plotting the key historical highlights of social responsibility and shared value in a timeline, the chapter provides analysis and synthesis of how creating value evolved with time. Figure 3.2 shows that social responsibility became prevalent post-World War II.

Although aligning corporate decisions with society's values has been in academic publications since the 1950s, little has been achieved to create sustainable value for the underserved communities (Ramani and Mukherjee, 2014). In the early and mid-2000s, social responsibility authors like Lantos, Chandler, and Werther started discussing social responsibility as a strategic imperative which they claimed led to sustainable competitive advantage (Chandler and Werther, 2006). In 2006, Porter and Kramer also started exploring social responsibility as a way of creating shared value. Later in 2011, the authors advocated for shared value as a novel idea to replace social responsibility (Porter and Kramer, 2011). Some even claimed that social responsibility would slow down in the future because of concepts like creating shared value (Latapí Agudelo et al., 2019).

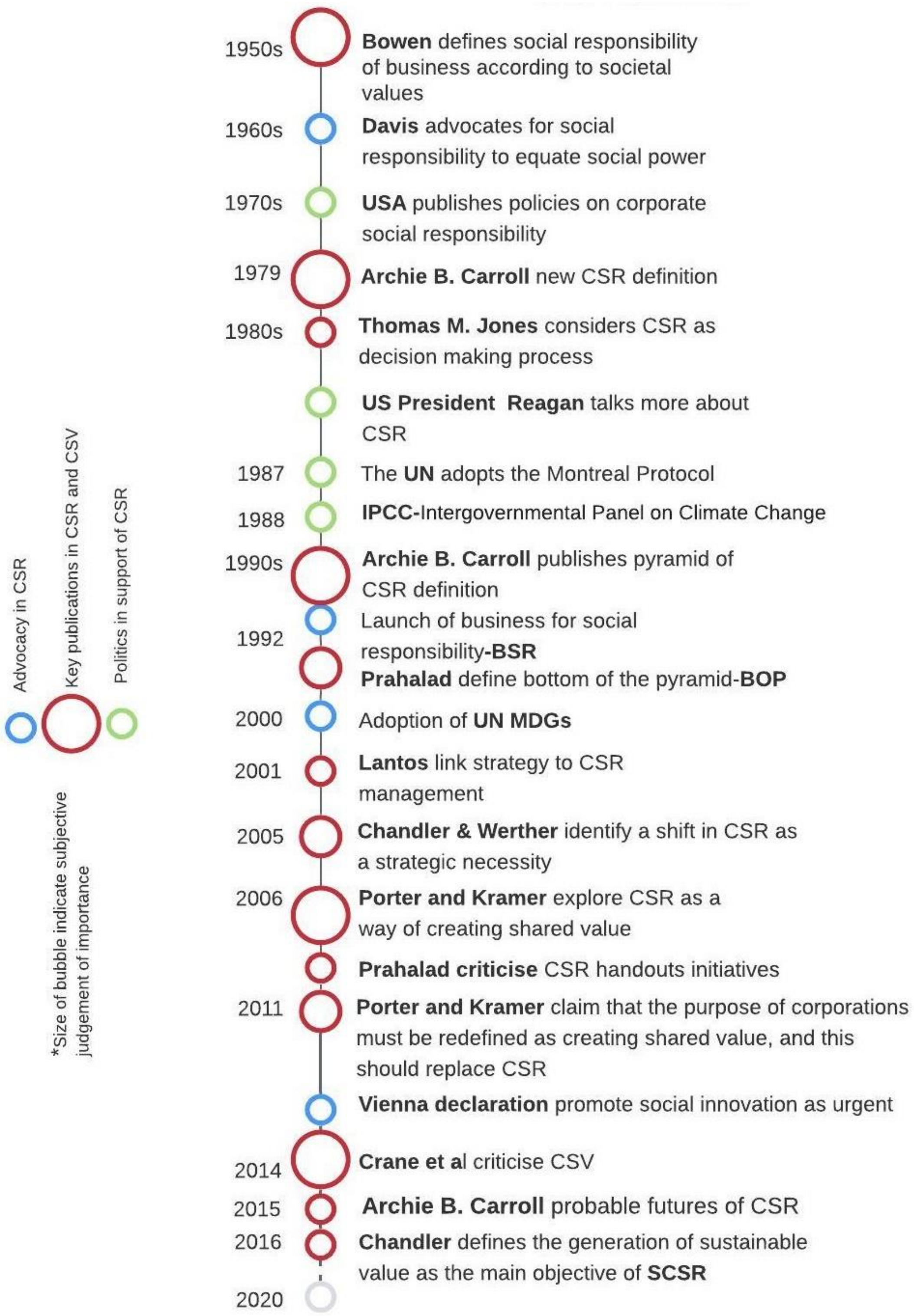


Figure 3.2: Historical highlights of Corporate Social Responsibility leading to Creating Shared Value

Creating shared value is defined as follows:

> *"Policies and operating practices that enhance the competitiveness of a company while simultaneously advancing the economic and social conditions in the communities in which it operates. Shared value creation focuses on identifying and expanding the connections between societal and economic progress" (Porter and Kramer, 2011, p.66).*

The above quote implies that shared value is about turning social problems into business opportunities, thus tackling societal problems while achieving great profitability. Although other scholars dismiss this concept as a 'seductive proposition' which ignores the prevailing tensions between social and economic goals (Crane et al., 2014), Porter and Kramer (2011) argue that the framework is widely embraced by many and acknowledged as useful. It is rather challenging to balance corporate interests with solving social needs (Crane et al., 2014), despite Porter and Kramer's arguments. Hossain (2017) argues that the fundamental dimension of sharing value with external partners is receiving little attention from innovation researchers.

Shared value is closely related to concepts like social innovation, i.e., generating new ideas that work to meet social goals (Michelini, 2012). Hence, the shared value concept is attracting much criticism as a novel idea. The key to the criticism is that while shared value presents a win-win opportunity, it fails to provide a framework to navigate misalignment situations between economic and social outcomes for multi-stakeholders (Crane et al., 2014). The debate seems to be stuck on the dualism between shareholder and stakeholder value.

Creating shared value is also closely associated with the bottom of the pyramid theory. In his theory, Prahalad (2009) argues that people living in poverty areas need to be treated as a potential market instead of using approaches such as corporate social responsibility, e.g. handouts. This idea may lead to sustainable social change and poverty eradication (Walsh et al., 2005). Some authors long called for a rapid move by corporations to use the bottom of the pyramid strategies that engage in co-invention and co-creation to bring business actors closer to communities (Simanis et al., 2008). However, corporations seem to be lagging in engaging the community actors in creating social and economic outcomes, particularly in Botswana.

The key features of shared value, social innovation, and the bottom of the pyramid are the involvement of social actors in the firm's economic activities, e.g. civic organisations, mayors, and politicians (Kanter, 1999). Support from these actors may facilitate prompt systemic changes in society. Innovation typically emerges from combining existing business models in new ways, but this does not always translate into new value. In (Nicholls, 2006), value is achieved if people can reach their potential by investing less to solve complex problems. To effect change, Michelini (2012) adds that firms face different market dynamics that need new business models to tackle. This idea is also buttressed in (Prahalad, 2012; 2009), where the author points to the need to develop context-specific bottom of the pyramid strategies instead of using generalised techniques to solve bottom of the pyramid unmet needs.

The most compelling argument for social innovation is that it recognises unmet needs and effectively acts on them (Nicholls, 2006). In SME ecosystems, the interconnected diversity of SME business models adds to the complexity of creating shared value (Sánchez and Ricart, 2010). However, Sanchez and Ricart (2010) argue that the heterogeneity in business models present more benefits than a single firm and may induce a systemic change in the ecosystem (see appendix 1). Chesbrough (2010) and Cruickshank (2014) support this argument by emphasising that open business models allow firms to create more value through leveraging external assets, resources, and positions of others.

Tackling social problems while achieving great profitability for SMEs may require focusing on aligning SMEs business models with unmet needs at the bottom of the pyramid. Firms often argue for new ideas and technologies, yet they lack business model innovations (Chesbrough, 2010). Teece reasons that platform leaders need enhanced dynamic capabilities to design appropriate business models (Teece, 2018). Few studies looked at business model innovation in developing economies (Hossain, 2017). M-Pesa, a mobile payment ecosystem in Kenya, is a notable example of impacting people’s lives while simultaneously achieving great profitability for the organisation in an underserved market (Sadoulet, 2014). Therefore, a contextual understanding might support productive local SME ecosystems through creating shared value.

3.3 Disruptive Innovation

The Oslo manual defines innovation as follows:

> *"An innovation is a new or improved product or process (or a combination thereof) that differs significantly from the unit's previous products or processes, and that has been made available to potential users(product) or brought into use by the unit (process)" (OECD/Eurostat, 2018, p.20)*

The above definition gives reference to a 'unit' which describe the actor responsible for innovation, e.g. SMEs, and the successful application of products and processes places innovation in the context of need. Innovation is also about identifying new connections and opportunities and exploiting them (Bessant and Tidd, 2007). Innovation can either be incremental or radical. Incremental is improving on what is already existing by making slight variations on the product (Shi et al., 2020). A good example of this is the television because it continually improves in shape and function while the core idea and components remain. In contrast, radical innovations develop new ideas through revolutionary technologies and new business models (Souto, 2015). Examples of these are personal computers and the internet that are now ubiquitous and transforming the entire world. Incremental and radical innovation spaces are illustrated in Figure 3.3 below.

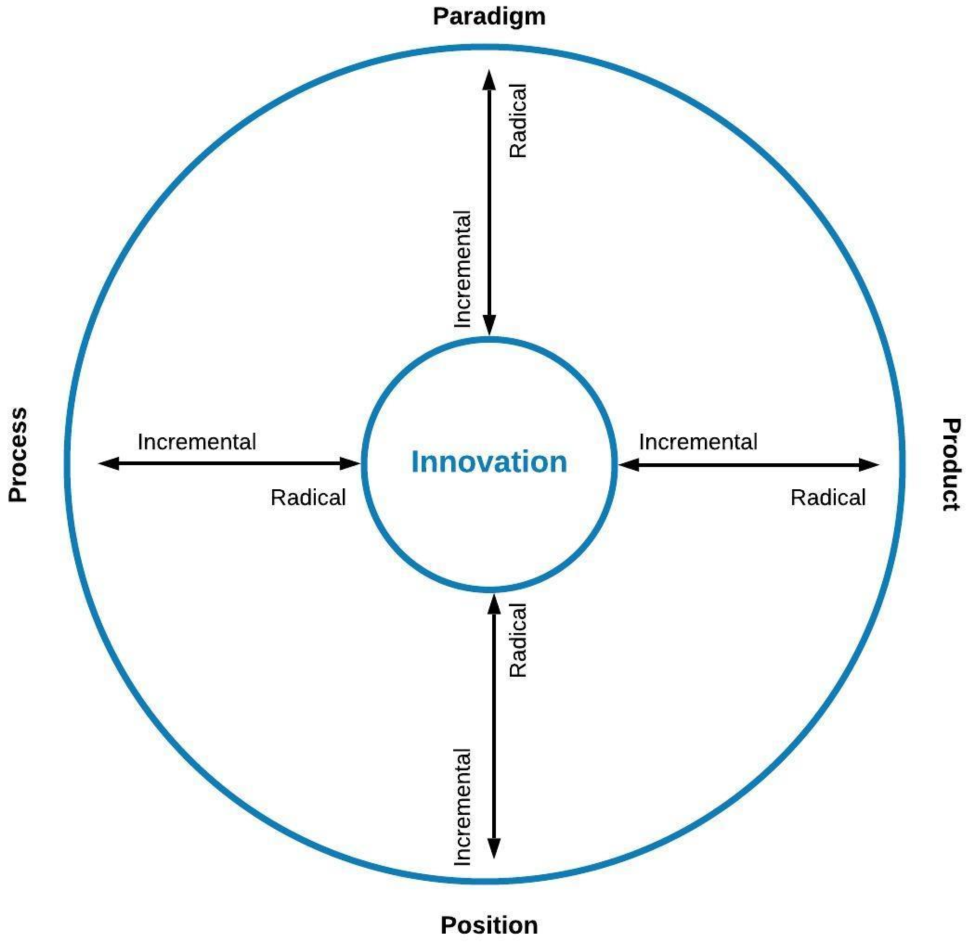


Figure 3.3: Innovation spaces (Bessant and Tidd, 2007)

Aside from incremental and radical innovations, there are also sustaining and disruptive innovations. Sustaining innovations exist in the current markets instead of new value networks and aim to improve and sell more products to their most profitable customers (Christensen et al., 2017). This is achieved by meeting the needs of existing customers. An example of sustaining innovation is the iPhone. This product thrives on releasing new versions of the phone, which seem to appeal to the same set of high-value customers, leveraging on the pre-existing value networks (Son et., 2018). Contrarily, disruptive innovation means creating a new market by providing a different set of values, which ultimately (and unexpectedly) overtakes an existing market (Christensen, 1997). Disruption, in this case, refers to the process whereby a new or smaller firm with fewer resources successfully challenge established firms for markets (Christensen et al., 2015). This is normally achieved by providing simpler, cheaper and good-enough alternatives to the underserved group of customers (Christensen et al., 2017). SMEs provide the driving force to disruptive innovation, vital for socio-economic growth (OECD, 2017). This is so because incumbents are usually less attracted to these small profit markets. It is not worth their time and resources. Therefore, they instead focus on providing for their most profitable and demanding customers (Christensen et al., 2015). For example, although Xerox Palo Alto Research Centre (PARC) was the first to develop inventions such as the ethernet, a prototype of a modern PC, graphical user interface, mouse and laser printers, executives failed to see the commercial value in these inventions (Viki, 2017).

Not all new technologies are disruptive (Christensen et al., 2018), but it is the business models that the technology shape that sometimes creates disruptions (Hopp et al., 2018). Additionally, disruptive innovations are often hampered by technological and market uncertainties, weak value propositions and resource scarcity (Hossain, 2017), particularly in developing economies. An example of this is the “M-PESA” mobile money ecosystem in Kenya. Although the ecosystem project later became a success, it faced hurdles such as unbanked, unconnected, and semi-literate users and other contradictory regulatory requirements (Hughes and Lonie, 2007).

Christensen et al. (2006) introduced a notion of catalytic innovation alongside the disruptive innovation concept, which appears as a promising approach to shared value. Catalytic innovation is considered a subset of the disruptive innovation model but offer solutions to inadequately solved social problems. The MinuteClinic is an example of a catalytic innovation in the USA, where they offer services that incumbent health providers do not offer because of limited profit (Christensen et al., 2006). Christensen et al. (2006) argue that although disruptive innovation has led to social changes, these changes are mostly serendipitous and by-products of business pursuits.

The main goal of catalytic innovation is social change. The example of MinuteClinics brings essential health care services to many who are otherwise unable to access doctor’s offices. This is because the innovation is affordable to uninsured people more than visiting the doctor’s office and similarly convenient for insured clients (Christensen et al., 2006). Incumbents firms may be reluctant to pursue simpler, less expensive, more accessible services and products to capture the bottom of the pyramid markets, hence the need for catalytic innovators. Targeting manufacturing SMEs aiming at contributing to social change may create shared value for the bottom of the pyramid community. Finally, disruptive innovation seeks to increase competitiveness, whilst catalytic innovation seeks to solve social problems. How might SME ecosystem actors combine these capabilities to create value?

3.4 The innovation ecosystem concept

It is not surprising that business researchers have always used metaphors from the natural systems to explain organisational and innovation systems (Read, 2016; Shaw and Allen, 2018). This is because there is no comprehensive theory to address the complexity and emergence of ecosystems in entrepreneurship and innovation domains (Roundy et al., 2018). Complex adaptive systems have been used in some cases to explain the dynamics of interconnected firms (Palmberg, 2009; Iñigo and Albareda, 2016). Nonetheless, organisations continue to experience challenges in understanding, facilitating and managing innovations in interconnected, everchanging ecosystem milieus (Rosli et al., 2017; Jacobides et al., 2018; Adner, 2017b), and this is becoming a bigger challenge for entrepreneurs with limited capabilities and resources (OECD, 2017; Buckley and Davis, 2018; Von Stamm and Trifilova, 2009; Motoyama and Knowlton, 2017).

Understanding SME ecosystems is necessary for developing economies to reinvigorate local ecosystems to promote disruptive innovations (Xu et al., 2018) and social change (Figure 3.1). When local ecosystems do not have adequate knowledge about disruptive innovations in developing nations, they rarely tap into these sustainability potentials (Khavul and Bruton, 2013). Ecosystems are explained as complex adaptive systems because of the unpredictable patterns, behaviours, and structures exhibited that influence other processes and the system's overall behaviour (Roundy et al., 2018).

The word ‘ecosystem' originates from the domain of biology, and it defines the interaction and interdependence of living organisms within the environment (Jucevičius & Grumadaitė, 2014; Ferdinand & Meyer, 2017; Su, Zheng & Chen, 2018). The biological concept is widely adopted metaphorically in the industry and academia to explain business and innovation processes (Iansiti and Levien, 2004; Howkins, 2010). There are three broad aspects of ecosystems that are often used interchangeably: business, innovation, and platform ecosystems (Adner, 2017a; Jacobides et al., 2018; Gawer and Cusumano, 2014). The difference between business and innovation ecosystems is that the latter emphasises the system of innovations, i.e. value creation

(Adner, 2017b), while the former focuses on individual firms and a community of actors that impact the firm's business performance, i.e. value capture (Iansiti and Levien, 2004). The platform ecosystems focus on technology-based platforms where platform hubs and complementors create value for customers (Gawer and Cusumano, 2014). This thesis uses the innovation ecosystem construct, emphasising interdependent actors and how they interact and create benefits to the entire ecosystem (Adner and Feiler, 2019; Jacobides et al., 2018).

The innovation ecosystem defines a set of actors and processes that cooperatively and competitively interact to co-evolve and innovate (Christensen, 2013). The actors collaborate to offer new networks, new products, technologies and services to customers and business models (Smith, 2010). Adner (2017) highlights the ecosystem as an alignment of interconnected actors to create value. Although a large part of the innovation ecosystem is self-evolving, part is shaped by coordinated and conscious actions (Abel et al., 2011). Another key difference is that firms can rapidly change their business strategies, unlike biological species constrained by genes (Fransman, 2018). While this metaphor has been widely accepted as useful, some researchers have rebutted the notion of using natural ecosystems as analogies to explain innovation and business systems and labelled the process as flawed when used as a rigorous construct (Oh et al., 2016). Oh et al. (2016) emphasise that innovation ecosystems are designed and engineered with teleology much different from natural systems. Others long abandoned the idea (Haynes, 1971). Although Moore (1993) was the first to introduce the ecosystem metaphor in meticulous detail, the author also cautions against its overzealous use as a theory.

This thesis finds the metaphor useful, particularly in exploring entrepreneurial ecosystems. Appreciating how biological species are configured in terms of interconnections, co-existence, natural selection, survival, and growth (Su et al., 2018), may inspire the understanding of ecosystems (Moore, 1993). This thesis also appreciates the distinction between natural and innovation ecosystems, where natural species survive one day at a time (Hwang and Horowitt, 2012), while firms depend on business model innovations for survival (Oh et al., 2016). Wal-Mart, Amazon, ALIBABA, Apple, eBay and Microsoft are some of the few examples of the entities which excelled in the past due to their business model innovations (Lyman et al., 2018; Iansiti and Levien, 2004).

In areas where there is an acute scarcity of resources, e.g. developing economies, businesses are confronted with contextual challenges such as low access to capital, low-income consumers and low access to technologies (Hughes and Lonie, 2007; Webb et al., 2009). Because of these challenges, there is a need to shift from isolated operations to distributed processes or dependence on other organisations and people (Zulu-Chisanga et al., 2020; Songling et al., 2018). Firms are now becoming part of a broader network of organisations (Chesbrough et al., 2006). Consequently, SMEs are also seen as actors within this broader ecosystem complex. Most SMEs to large firms have limited capabilities in understanding and managing inter-organisational relations within their milieu (Schoemaker et al., 2018; Jacobides et al., 2018). Adner highlights the importance of understanding ecosystems as thus:

> *"Success in a connected world requires that you manage your dependence. But before you can manage your dependence, you need to see it and understand it. Even the greatest companies can be blindsided by this shift" (Adner, 2012, p.16)*

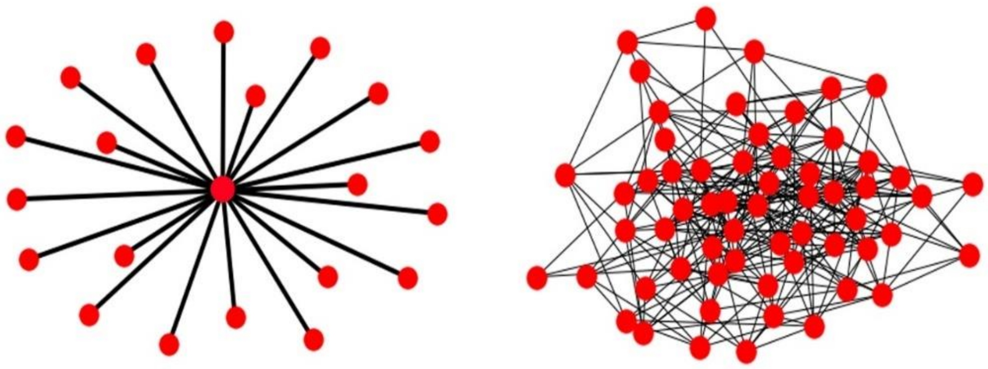
Some researchers emphasise the need to understand interrelationships and complementarities between different ecosystem actors and how these might be leveraged to create shared value (Adner and Feiler, 2019; Dedehayir et al., 2017; Iansiti and Levien, 2004; Jacobides et al., 2018; Rosli et al., 2017). The evolving interconnectedness of firms in ecosystems remains unclear due to different organisational logics (Gratacap and Isckia, 2013). Understanding behaviours and practices of different firms might lead to the success of emerging ecosystems (Jacobides et al., 2018). Some suggested how loosely formed ecosystems might be developed into productive ecosystems (Shaw and Allen, 2018). Adner (2017) found that identifying factors that shape ecosystems was paramount, and this was buttressed by Pankov et al. (2019), who identified different contextual factors that may influence the exchange of ecosystem resources.

Contextual factors may vary from an industrialised and a developing economy. The firm's abilities to reconfigure competencies to meet changing inter-firm relationships influenced by different contexts and actors is essential (Teece et al., 2016). The key issue here is understanding the local ecosystem contexts to create shared value, which requires an ecosystem-level capability and knowledge. Knowledgeability is seen as a continual process constituted in everyday practice and provisional instead of given (Orlikowski, 2002). Therefore, this thesis seeks to establish what capabilities are required by SMEs for continual learning and understanding of local ecosystems. Then explore how actors might gain those capabilities through a design approach to understand and continuously reshape the local ecosystem.

3.5 Disruptive innovation ecosystem: reconceptualising innovation ecosystems

The thesis conceptualises a disruptive innovation ecosystem as an innovation ecosystem capable of delivering disruption, where disruption is about smaller businesses combining their resources and coordinating their capabilities to successfully challenge large ecosystems for markets, as discussed on page 27. This concept is discussed in this thesis as a conceptual lens to investigate local ecosystems, which may lead to disruptive solutions with the potential to create social change (Figure 3.1). Although James Moore introduced the ecosystem concept to understand business strategy and competition, the conceptualisation was later adapted in exploring social networks and community structures (Ansari et al., 2016; Gratacap and Isckia, 2013; Galateanu and Avasilcai, 2016). In industrialised economies, there are good examples that appear as disruptive ecosystems, e.g. Uber and Lyft in the taxi business, Airbnb and Breather in the hotel business (Libert et al., 2014; Smith, 2016), and Apple iPhone in the telecommunication business (Valkokari et al., 2017). Some of these examples are discussed later in this chapter.

The idea of disruptive ecosystems appears useful for developing solutions to social problems. It would be vital to design disruptive ecosystems from scratch, but the dynamic behaviour of disruptive ecosystems can be challenging to understand (Roundy et al., 2018; Christensen, 2014). For purposes of appreciating the structure of ecosystems, it is generally explained in terms of either a hub-centred star or flat mesh-like structures (Mazhelis et al., 2012). It seems ecosystem structures are defined by how actors interrelate with each other. As shown in Figure 3.4 (A), by plotting nodes connected to a single central node, the thesis simply demonstrates how a hub-centred star structure look. An example of this is the Uber ride-sharing ecosystem. Also, as shown in Figure 3.4 (B), by plotting nodes connected to many other nodes without a hub centre, this thesis shows how a flat mesh-like structure look. This is associated with entrepreneurial ecosystems, where there is no hub leader.



A. hub-centered star structure generated using Erdos Renyl Model in Python networkX: The centre red node is associated with a keystone,hub or dominator role depending on the innovation ecosystem design.

B. Flat mesh-like structure generated in Python networkX: The innovation ecosystem structure is associated with connections between enterpreneurship partners with no hub or dominating actor.

Figure 3.4: A typological visualization of innovation ecosystems: Showing A (star-shaped structure) and B (flat mesh-like structure).

While hub-based ecosystems might be manageable through platform-based strategies and roles, flat-mesh like ecosystems, e.g. SME ecosystems, may be difficult to manage due to lack of a structure to manage many diverse actors possessing distinct characteristics and motivations (Masys and Bennett, 2016), e.g. contrasting socio-economic and interdependent business models (Barile et al., 2016; Russell and Smorodinskaya, 2018; Mortati et al., 2012).

There is an opportunity for SMEs to create disruptions in underserved markets because incumbent firms find it risky to evolve their ecosystems to attract these markets (Christensen et al., 2015). Entrepreneurs find underserved markets intriguing to develop disruptive innovations (OECD, 2017). Microsoft Zune seems to be a good example of a failed ecosystem that was expected to disrupt the iPod ecosystem by offering cheaper and competitive pricing (Woody, 2013). Users had little motivation to opt for Zune over their established iPod ecosystem; the marketing and advertising were not enough to overcome the iPod (Lombardi, 2013). The challenge is on how SMEs tackle local unmet needs to create the much-needed disruption.

3.5.1 The Strength of weak ties

Identifying the right factors and resources to support the development of disruptive ecosystems seems to be a challenge confronting SMEs interested in leveraging low-end markets. To create shared value within SME ecosystems, leveraging the theory of weak ties, albeit old (Granovetter, 1973), may aid SMEs in identifying and using resources outside their traditional domains. The theory suggests that acquaintances are more influential than close friends, particularly in social networks (Granovetter, 1973). In this case, social networks are not necessarily computer-based (Facebook, Twitter) but also involve in-person interactions. Exploring weak ties may help SMEs identify key bridges that lead to new resources and information they might not otherwise reach. This theory seems relevant because it may support SMEs to connect to different information from that which they receive (Granovetter, 1973), thus increasing serendipity for disruption in local ecosystems (Figure 3.1).

It is challenging for Manufacturing SMEs to innovate in isolation without involving other players, e.g. knowledge centres (Universities), Government, financial institutions (David and Anastassios, 2008). Interactions amongst small groups sometimes aggregate to form macro-level patterns spontaneously, which often becomes more complex to understand (Granovetter, 1973). Other researchers concluded that mixing unreliable ties (weak ties) with reliable and established ties (strong ties) provide new avenues for disruptive innovations (Cruickshank, 2010). Recently, it was reported that developing innovations is shaped by creating an ecosystem where actors such as firms, people, sectors can foster value creation and collaboration (Granstrand and Holgersson, 2020). Finding useful ways to take advantage of social networks is a great challenge and opportunity for designers. This challenge calls for new ways to leverage networks.

3.6 Design

This section discusses how the thesis relates to design research, emphasising the role of design in empowering non-professional designers to use design capabilities to build productive local ecosystems.

3.6.1 Design inspiration

As explained in section 3.4, part of the innovation ecosystem is self-evolving; conscious decisions shape part of it. According to Papanek (1972, p.4), *“Design is the conscious and intuitive effort to impose meaningful order”*. Papanek emphasises that understanding our existence requires us to seek order in it continuously. The works of Victor Papanek emerged in tandem with the late 60’s radical discourses around the subject of social design, social enterprise and interest in involving more actors in design decisions (Lie, 2016). This idea was later propounded in his book entitled *“Design for* *the Real World".* Before then, the term 'design' was mostly associated with products, from the arts and crafts, this is still predominantly the case in developing economies, e.g. in Botswana (Moalosi et al., 2016), but in most industrialised nations, e.g. the UK, design is mostly seen as a process of change (Kah, 2019).

Papanek explains design and architecture as tools for people to adapt to their environment (Papanek, 1983). Thus implying that design functions as a process of understanding and can also function to shape the ecosystem configuration. Papanek's definition of design highlight the process as a controlled and conscious activity, where designers engage in imagining, creating and iterating systems to serve specific market needs. However, ecosystems are partly organic, less controlled, and influenced by all the ecosystem actors and not just a single 'designer'. This kind of setting resonates with participatory approaches to design, which actively engage all key stakeholders in the design process (Dell'Era and Landoni, 2014).

There is a need to identify a more nuanced approach in understanding local ecosystem configurations, particularly entrepreneurial ecosystems. Since human actions and choices reconfigure the ecosystem (Reed and Lister, 2014), manufacturing SMEs and other decision-makers seem to be better placed to design the local ecosystem.

3.6.2 Design research and entrepreneurial ecosystems

According to Hernandez et al. (2017, p.702), design is most valued by SMEs, although they still lack the skills to determine where and how design can create value. Bolland and Collopy (2004, p.4) argue that managers are designers and decision-makers in organisations, albeit more emphasis has been placed on decision making. The authors emphasise that by assuming the role of designers, managers can develop new solutions rather than being stuck in default alternatives and organisational cultures. The knowledge of existing systems also inhibits new thinking and attitudes (Huang et al., 2018, p.248). In connected environments, systemic design approaches emphasise tools to design and manage energy flows between system components, thus bringing diverse actors to co-create new solutions (Nohra and Barbero, 2019). Koria and colleagues (2020) highlight that systemic thinking is concerned with integrating resources to connect service areas. Other systemic designers call for a virtuous circle of relations between system actors in the collaborative design of services (Selloni and Corubolo, 2017).

Therefore, designers undertake complex organisational challenges mostly through service design and co-design to create value in enterprises (Salmi and Mattelmäki, 2019). However, it seems most designers encounter complex challenges such as understanding and managing policies. Design methods arguably make policies visible and tangible (Kimbell and Bailey, 2017). Consequently, design has been recognised as an essential factor in fostering innovation in enterprises, particularly in Europe (Whicher and Walters, 2017). Design also helps organisations explore and manage innovation in different and new ways (Hernandez et al., 2021). Acklin (2010) long highlighted that future design research needs to focus on how design methods can be developed to support SMEs in integrating design in their innovation processes. This is important to tackle local problems while maximising profit for enterprises, as discussed on page 24.

The role of design and who does the design is undeniably changing (Komatsu, Kaletka, and Pelka, 2020). In ecosystem environments, design is now acting as a conduit of heterogeneous stakeholders across firms, thus redefining the modern-day designer (Bryant, Straker, and Wrigley, 2020). Furthermore, Cairns (2017) looks at design as attitudes that require owners of the problem to be engaged throughout the problem-solving process, and in Sun and Park (2017), participatory experience is seen as a mindset about people. A healthcare study found that although healthcare designers possess design and co-design skills, they still lack early design engagement of other stakeholder groups, e.g. patients (West, 2020, p.267). Pedersen (2020, p.60) further highlights that design research helps shape and stage encounters in multiple actors in a system. Therefore, design is important in facilitating mindset shift through inflows and outflows of knowledge across actors. Consequently, design seems to be a useful process for capturing knowledge and attitudes embedded in entrepreneurial ecosystems (Cesário et al., 2017).

With that in mind, there is limited research in defining exchanges between local entrepreneurial actors, making it challenging for policymakers to nurture entrepreneurship at the local level (Cavallo et al., 2020). Literature on entrepreneurial ecosystems focuses on high-growth firms (Spigel, 2017; Audretsch and Belitski, 2016), ignoring the networks of micro-businesses critical for developing local ecosystems (Aljarwan et al., 2019). Scant literature looks at how less developed entrepreneurial ecosystems emerge (Pustovrh, Rangus, and Drnovšek, 2020).

Furthermore, there is still a need to explore the role of contexts in entrepreneurial ecosystems (Kansheba and Wald, 2020). Spigel (2017) examined three examples of ecosystems where they found that differences in ecosystems' cultural, social, and material attributes influence entrepreneurs differently. In areas where resources are scarce, SMEs struggle to access capital, technologies, and markets (Webb et al., 2009). Similar challenges were highlighted in a design study with early-stage entrepreneurs in Brazil's low resource settings (Koria, Vasques, and Telalbasic, 2020). Several entrepreneurial ecosystem models propose a paradigm shift from traditional approaches to firms and markets to people, networks, and institutions (Audretsch and Belitski, 2016; Stam, 2015; Isenberg, 2010; Pugh et al., 2019). This shift calls for more design research and how design can add value in promoting and supporting entrepreneurial actions in local ecosystems (Figure 3.1).

The design role has been deployed through service design, design for social innovation, open design and policy design to contribute towards systemic methods (Karadima and Bofylatos, 2019). Extant literature shows how design research facilitate and shape the understanding of connections between key actors involved in a system (Ballantyne-Brodie and Telalbasic, 2017; Pérez et al., 2019; Hyvärinen, Lee, and Mattelmäki, 2015). Design approaches have also been discussed as support mechanisms for collaborative creations across organisations (Simonsen and Robertson, 2013). Minder and Lassen (2018) highlight that collaboration between designers and other actors facilitate boundary-spanning innovation. In other related studies (Hyvärinen, Lee, and Mattelmäki, 2015; Steen, Manschot, and Koning, 2011), design plays a significant role in creating effective platforms to enable diverse actors to collaborate in innovation. However, design needs to integrate sustainable ecosystems and the world around us to build local communities' responsibilities (Phillips et al., 2020).

The design focus is gradually shifting from user-centred design approaches, i.e. a user as a subject (a US-driven phenomenon), to participatory approaches, i.e. a user as a partner (mostly led by Northern Europeans) (Sanders and Stappers, 2008; Dell'Era and Landoni, 2014). These authors further espouse that design is no longer just about designing products for users but developing the meaning of future experiences in interconnected communities. Therefore, the emerging role of design in ecosystems is developing methods and tools that promote collaborations amongst diverse entrepreneurial actors. This role positions the designer as a facilitator of innovation, empowering people with tools to develop new opportunities beyond the presence of a trained designer (Ballantyne-Brodie and Telalbasic, 2017; Cruickshank et al., 2016; Manzini, 2015). This form of empowerment also depends on how the whole network of relations in ecosystems changes (Zamenopoulos et al., 2019, p.4). Design researchers acknowledge the design efforts by non-designers and seek to improve methods and tools to support them (Sangiorgi and Junginger, 2015). Therefore, practitioners are challenged to characterise and exploit local ecosystems defining value in networks (Bianchi and Vignieri, 2020).

Collaborative design refers to “the creativity of designers and people not trained in design working together in the design development process” (Sanders and Stappers 2008, p.6). Co-design empowers actors to engage beyond traditional business boundaries (Steen et al., 2011). This idea involves applying designerly tools to facilitate collaborative exploration of problems and solutions (Brandt et al., 2012; Manzini, 2015; Trischler et al., 2018). This view shifts from acknowledging a designer as a creative expert to a designer as a stager and facilitator of dialogue and negotiations during the co-design process (Pedersen, 2020). The decisions and actions of ecosystem actors are innately reconfiguring the ecosystem, sometimes without deliberate action. By employing co-design methods, the thesis attempts to exploit the “dialogic cooperation” as noted by Manzini (2015), where diverse actors may engage, share, and communicate openly about local ecosystems' present and probable futures.

Design research has been deployed in various ways to empower businesses to realise their potential. Thus coupling design visualisations with conversations to move past abstractions and help participants see and better understand the inner workings of their ecosystem attributes (Zweifela and Van Wezemaela, 2012). For example, Mortati et al. (2012) developed a design tool called NETS for SMEs to exploit social networks through visualisations. The NETS allows users to activate social networks to create SMEs competitive advantage (Mortati et al., 2012). The Ecosystem Pie Model was also developed to help businesses in modelling their existing ecosystems as a strategy tool to influence the behaviours of firms (Talmar et al., 2018). An interactive visualisation design tool was developed called dotlink360, which aimed at assessing the interconnectedness of business ecosystems and decision making (Basole et al., 2013). Basole et al. (2018) later designed the ecoxight tool to discover, explore, and analyse business ecosystems.

Jan et al. (2020) recently proposed a tool called the ‘Circularity Deck’ to help firms to analyse, ideate and develop circular innovation ecosystems. Therefore, this thesis extends these design attempts using participatory design principles to explore ways to empower connected entrepreneurs to consciously influence the evolution of their networks of networks. The concept of exploring visualisation methods is discussed later in this chapter (Section 3.7). Next, the thesis discusses the conceptualisation of possible design elements and factors that may influence the evaluation and understanding of local ecosystems.

3.6.3 Conceptualising elements and factors for disruptive ecosystems

Ecosystem elements and factors are challenging to understand (Dedehayir et al., 2018). Rabelo and Bernus (2015) also identified the gap in ecosystem literature on how innovation ecosystems are built or emerge and the need for a broader analysis in this area.

Moore (1993) proposed a four-phase life cycle (birth, expansion, leadership, and self-renewal) focused on developing business ecosystems for value capture. Hwang and Horowitt (2012) explain the building of the innovation ecosystem in three phases (i.e. see, cultivate and nourish), thus treating the ecosystem like a rainforest. Other authors also propose similar ecosystem phases with different phrases such as connect, inspire and transform phases (Kaplan, 2012). Rong et al. (2015) extend Moore’s four-phase life cycle by introducing emergence, diversifying, converging, consolidating, renewing ecosystems. Since this is based on the notion that ecosystems are continually changing and require continual learning, exploring more contextually based meanings of entrepreneurial ecosystems is important (Spigel, 2017, p.50).

Many ecosystem models emerged in recent years to define elements of entrepreneurial ecosystems, but there is still limited knowledge of assessing local ecosystems (Cavallo et al., 2020). Isenberg (2010) highlights culture, policies, leadership, finance, human capital and markets as important elements. This model is designed around what entrepreneurs view as important. Stam (2015) developed ten elements to measure the entrepreneurial ecosystem outputs, but he also acknowledges that context-specific measurements are crucial. The World Economic Forum recently proposed eight pillars (Markets, human capital, funding, support systems, Government regulations, education, Major universities and cultural support) of building a successful ecosystem (Pugh et al., 2019). All the above entrepreneurial ecosystem models emphasise the need to understand the context and place-specific characteristics of ecosystems.

As shown in Figure 3.5, by plotting ecosystem phases and synthesising this in the form of links between ecosystem levels and factors, this thesis provides a summary of possible factors for understanding conditions for disruptive ecosystems based on different ecosystem models (Rabelo and Bernus, 2015; Hwang and Horowitt, 2012; Kaplan, 2012; Rong et al., 2015; Moore, 1993; Stam, 2015; Pugh et al., 2019; Isenberg, 2010). At each stage, key factors are suggested which may influence how ecosystems are initiated, developed, managed, sustained and die.

As shown in Figure 3.5, ecosystem initiation is based on trust, shared value, accepting failure, tolerance, experiments, and new ideas. Ecosystem development is based on openness, coopetition, self-organisation, new markets, policies and contracts. Management is based on shared resources, niche roles, interrelationships, governance and data sharing. Business sustainability depends on creating new visions, resilient and healthy ties, adaptation and evolving relationships. The death of ecosystems is created by the migration and liquidation of ecosystem actors. These factors make ecosystems complex but may also create serendipity for disruption.

The question is how design might influence a better understanding of these factors to create an environment for innovation in the local SME ecosystem.

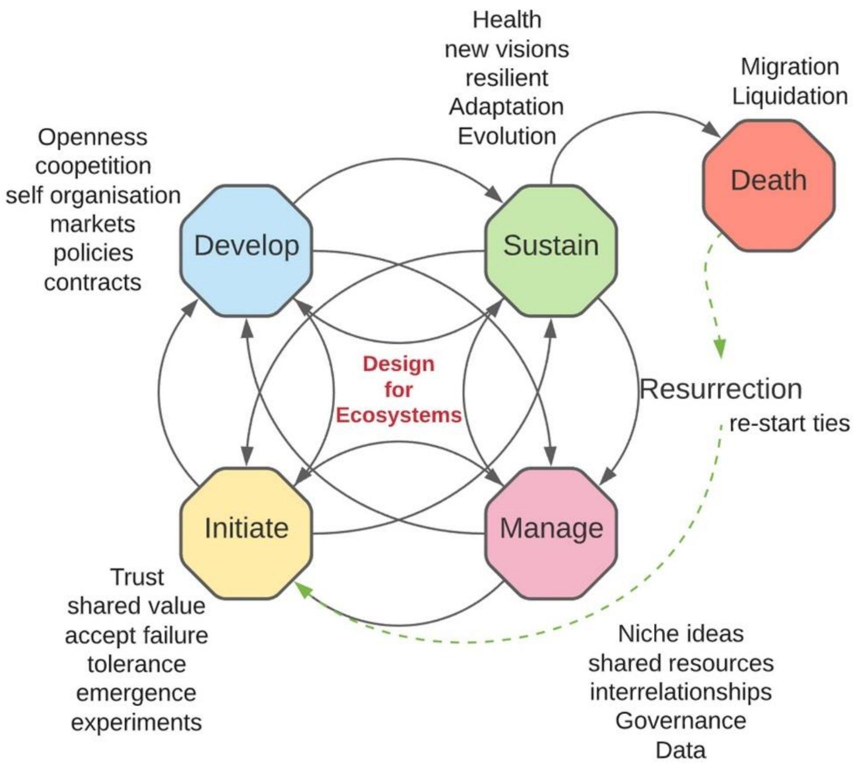


Figure 3.5: Conceptualising factors for disruptive innovation ecosystems

3.6.4 Rethinking role structures in ecosystems

Although ecosystem role structures are sometimes naturally emergent rather than prescribed (Dedehayir et al., 2018), there is a need to understand how the ecosystem configurations may affect the actor's roles in local SME ecosystems. To guide the conceptualisation of role structures in local SME ecosystems, this section discusses Iansiti and Levien (2004) strategic roles, i.e. keystones, dominators, hub landlord and niche. Second, the thesis synthesises and discusses different role structures to guide the understanding of innovation ecosystem structures. Third, the section also discusses existing examples that better fit this role typology. This idea is important because it may highlight how to reconfigure relations and strategies in local SME ecosystems.

3.6.4.1 Keystone role structure

A keystone player in the ecosystem structure occupies few positions yet profoundly influences stability, health, and sharing of resources (Iansiti and Levien, 2004). As shown in Figure 3.6, this thesis represents keystones as large nodes occupying a central role and few positions, thus allowing other actors, e.g. third-party developers and users to come in and provide niche services by occupying other spaces in the network.

Therefore, this role may be key in promoting disruptive ecosystems because power and authority are dispersed across the ecosystem, thus allowing horizontal value creation. Less dominance from keystone actors may allow entrepreneurial actors to experiment and innovate through leveraging the keystone resources.

Example- Keystone-based ecosystem

The growth of Amazon digital innovations is attributed to its disruptive innovation ecosystem approach (Isckia, 2009). Amazon resembles a keystone actor in its digital retail ecosystem because it focuses on creating opportunities for other actors to access and leverage almost unlimited resources (Mazhelis et al., 2012; Gratacap and Isckia, 2013) without contributing to huge platform-specific investments (Zhu and Liu, 2018). Therefore, Amazon is a relevant example of the need to sacrifice profit for growth by creating value for the entire ecosystem.

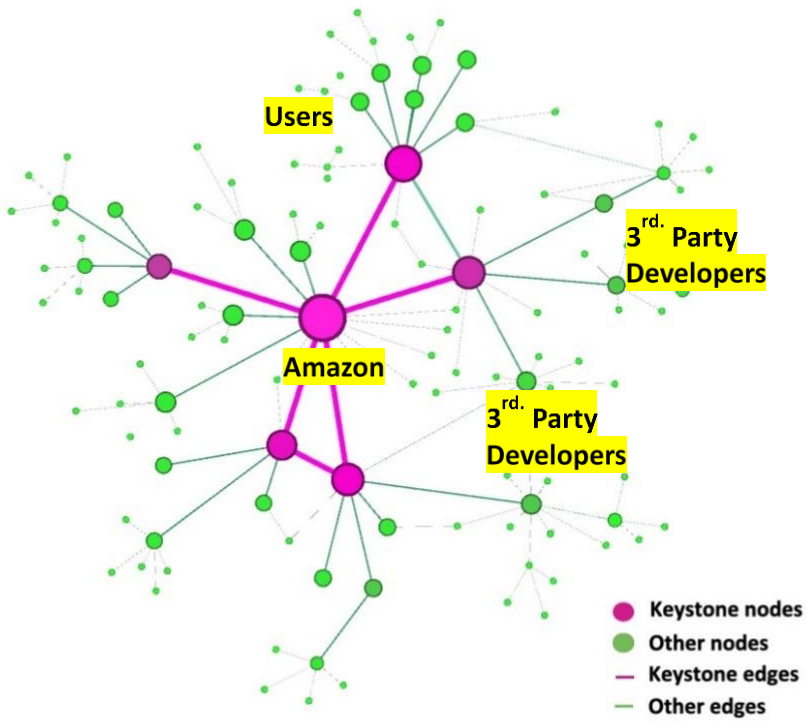


Figure 3.6: Example of a visualised Keystone-based ecosystem role structure

3.6.4.2 Dominator role structure

Unlike a keystone role, a dominator in the ecosystem occupies all value-creating and extraction positions. As shown in Figure 3.7, by plotting the dominator nodes all over the network, this thesis demonstrates in a simple way that dominators are distinguished from keystones through metrics of physical size. A dominating actor occupies all positions indicated in large nodes. This dominated structure may limit diversity and niche creation from other actors (Dedehayir et al., 2018). Consequently, dominators may be tempted to extract most of the value, thus starving the entire ecosystem.

Example- Dominator-based ecosystem

Unlike Amazon, Apple may be extracting more value from the ecosystem by dominating most of its ecosystem structure. This behaviour is highlighted in other studies as a dominating role (Valkokari, 2015). Apple appears to be controlling the ecosystem by inhabiting most of the value-creating nodes, as visualised in Figure 3.7. Distinct from the Amazon ecosystem, Apple has been consistently reluctant to share value with other actors, i.e. through licensing third-party developers over the years (Valkokari, 2015). However, the company recently started supporting third-party apps (Zhu & Liu, 2018). Although Apple has managed to sustain its innovations and niche market through its smartphone ecosystem and its incumbent services (Back, 2014), it may be even more beneficial to open its ecosystem further to support and create value in underserved markets.

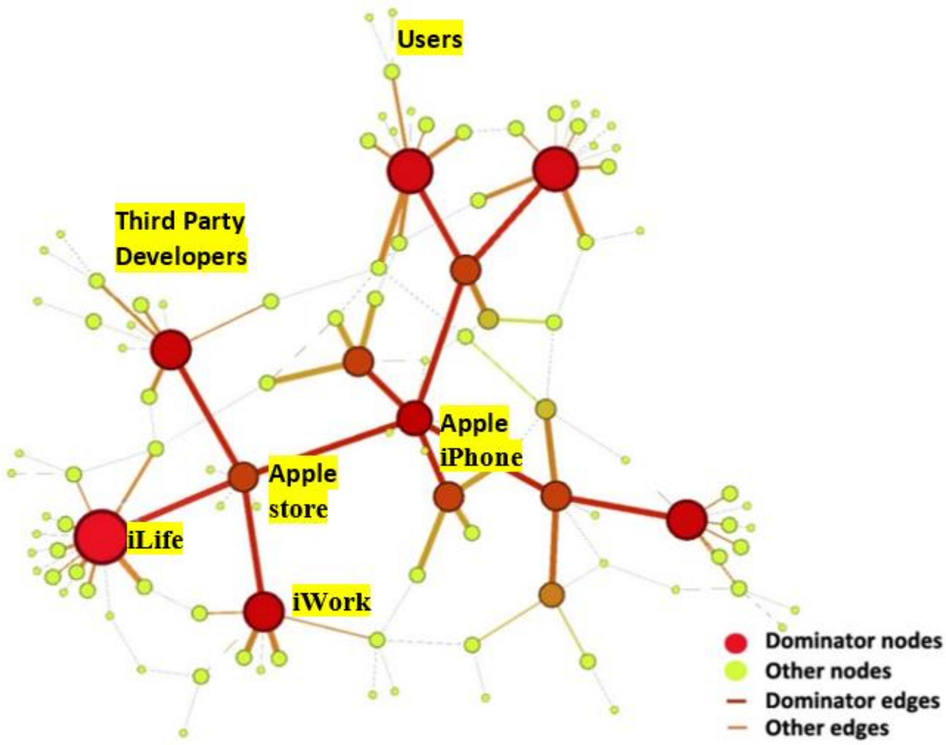


Figure 3.7: Example of a visualised Dominator-based ecosystem role structure

3.6.4.3 Hub landlord role structure

Hub landlords invest in value extraction only (Iansiti and Levien, 2004). As shown in Figure 3.8, by plotting all nodes connected to a big single node but not each other, the thesis demonstrates that hub landlords occupy a central position in the entire ecosystem structure. It is crucial for actors connected to this kind of ecosystem structure to see their dependence and risks associated with this. Actors holding hub positions are often faced with temptations to exploit their central hub role for short term gains because they have access to everyone else’s information and data (Iyer et al., 2006). Unlike Dominators, hub landlords choose not to participate in the value creation, instead eschews control of value extraction (Song, 2010).

Example- Hub landlord-based ecosystem

Uber mostly relies on other people’s automobiles by providing the hauling app to facilitate the sharing of assets (Libert et al., 2014; Smith, 2016). Although Uber appears as a keystone actor at first glance, previous research work done on the ecosystem suggests that most of the value generated by drivers and customers go to Uber (Bensinger, 2017; Berger et al., 2018). Drivers and riders are resentful of Uber’s value extraction and its inability to improve their well-being within the ecosystem (Ridester, 2018; Bensinger, 2017). Although Christensen et al. (2015) disqualify Uber as a disruptive ecosystem, they point out that UberSELECT is disrupting the traditional limousine business by offering better prices to the low-end limousine market.

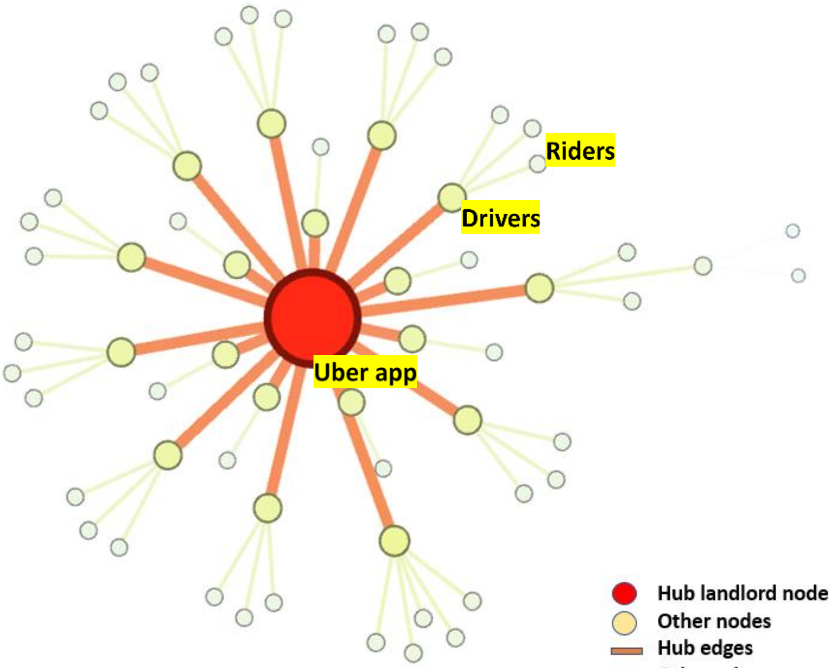


Figure 3.8: Example of a visualised Hub landlord-based ecosystem role structure

3.6.4.4 Niche role structure

While keystones provide a platform for innovation and experimentation, niche actors add value to the ecosystem by innovating (Iansiti and Levien, 2004). This idea was later supported in (Rong et al., 2015). As shown in Figure 3.9, by plotting niche nodes occupying positions in a keystone structure, this thesis demonstrates that niche actors have a meagre physical presence but leverage keystone resources to create high-value solutions. As discussed earlier, keystones rely on the presence of niche actors to remain sustainable. Niche actors may develop disruptions through keystone support (Elena and Avasilcai, 2016).

Example- Niche-based ecosystem

Adidas and Siemens are forming something similar to a niche-based ecosystem to build an intelligent manufacturing speed factory. The factory is intended to build the ecosystem around customising shoes faster than using conventional methods (Lyman et al., 2018). Adidas, as a keystone, is leveraging the specialized services of Siemens within its ecosystem to transform their factory. By digitizing the factory, the ecosystem may produce new technological innovations and customizations faster than ever before

(Adidas, Siemens Partner in Digital Production, 2017). In the Adidas speed factory ecosystem, Siemens occupies a niche position.

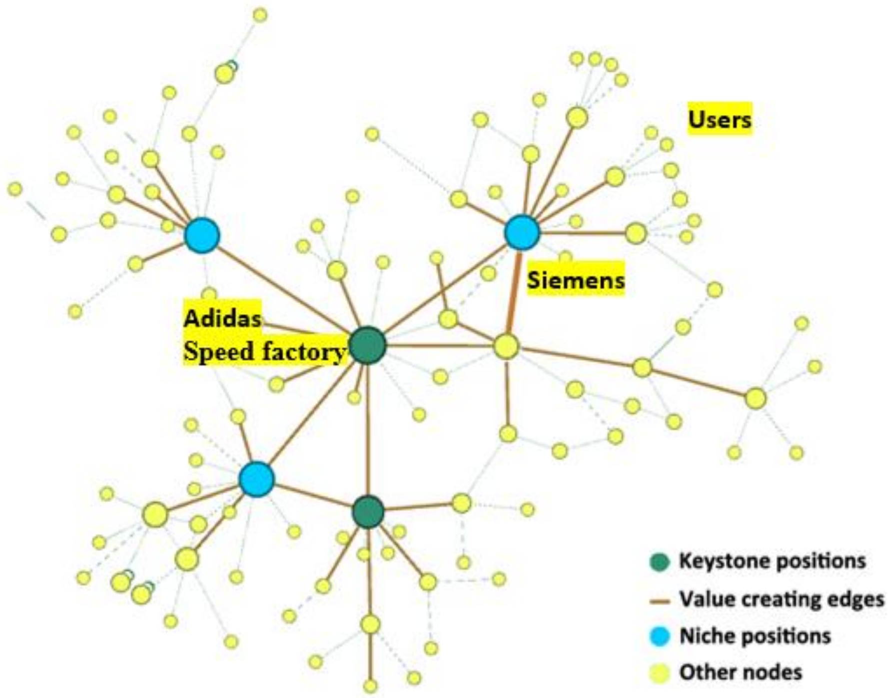


Figure 3.9: Example of a visualised Niche-based ecosystem role structure

Given the re-conceptualisation of ecosystem role structures and how this may influence decision-making, further work is needed to explore how the role structure can influence the understanding of local SME ecosystems in Botswana which this thesis seeks to explore through design and visualisation methods.

3.7 Visualisations as artefacts or mental models for understanding ecosystems

This thesis refers to the simplified definition of visualisation in (Evans, 2011, p.245), as thus; *"The act of creating an image, diagram or animation to enable communication"*. Using co-design approaches to develop visual representations of ecosystems draws from the tenets of constructionism, where knowledge is regarded as socially constructed by actors (Mascolo and Fischer, 2005) and seen as a continuous construction of mental representations of the real world that is and that could be. Visualisations function as representations that promote understanding through the actor's interpretations (Sheridan et al., 2014). This approach has advantages because it enables actors to create and recreate mental images of their ecosystems as artefacts, then analyse them and discuss possible future scenarios (Padilla et al., 2018; Lurie and Mason, 2007; Burnay et al., 2019; Evans, 2011). Mental images of ecosystems may help reduce complexities by acting as heuristics in understanding local ecosystem structures (Vink et al., 2019). Sanders and Stappers (2014) posited that artefacts elicit discussions amongst actors because the phenomenon is visible to the actor's eyes. The tacit knowledge is made visible (Evans, 2010).

Designers use visualisations to reveal insights and communicate experiences (Lengler and Eppler, 2007; Banissi, 2014). Therefore, in this thesis, the research seeks to leverage visualisation methods in a designerly way to scaffold meaningful dialogue and interactions between SME ecosystem actors.

Next, data visualisation methods are explored to demonstrate different affordances in data exploration. This underpins the design visualisation approach necessary to develop the understanding of local SME ecosystems, situating visualisations as an exploratory method to which this thesis seeks to contribute.

3.7.1 Visualisation methods

There are three fundamental intentions for data visualisation, which portray data as either explanatory, exploratory or an exhibition (Kirk, 2012). This thesis is more inclined towards the visual exploratory function of data to promote discovery and new insights (Krzywinski et al., 2012). In contrast to explanatory approaches, visual exploratory techniques are about visual analysis than just the visual presentation of data. Kirk (2012) summaries the value of exploratory visualisation as thus:

> *"Exploratory solutions aim to create a tool, providing the user with an interface to visually explore the data. Through this, they can seek out personal discoveries, patterns, and relationships, thereby triggering and iterating curiosities. It also opens up the possibility for chance or serendipitous findings caused by forming different combinations of variable displays" (Kirk, 2012, p.35)*

The above insights highlight the value of exploratory visualisations, which resonates with the constructionist view to promote interpretation and knowledge discovery. This view is important because co-design tools may enhance the process of sensemaking and decision support in local innovation ecosystems. So, there is a vast array of data visualisation techniques available (Kirk, 2016), and each offers different affordances. Since innovation ecosystems are made up of interconnected networks of actors, using visualisation methods to study these actor-networks may enhance the understanding of local ecosystems. Visual network analysis techniques are usually adopted to make sense of network structures by exploring retinal attributes, e.g. nodes, links, clusters, colour, size, and position (Börner et al., 2019; Venturini et al., 2015). Some researchers from interdisciplinary fields such as bioinformatics (Zhou and Xia, 2018), engineering (Koochaksaraei et al., 2017), computer science (Long et al., 2017), sociology (Healy and Moody, 2014), transportation (Cheong and Si, 2019), and more have shown how important visual network interfaces are in enhancing understanding and managing complex systems.

In genetic data visualisations, researchers reported that they favour the use of Sankey layouts over pie charts and bar charts for exploring gene sequences and detecting key species (Platzer et al., 2018). Pie and bar charts are mostly usable in explaining data than exploration. However, it has been observed that analysing high volumes of data may lead to more visual cluttering in Sankey layouts (Maurits, 2019). Parallel coordinates are widely used for exploring multidimensional data (Zhou et al., 2018), as shown in Figure 3.10(A), although the methods experience visual cluttering with an increase in data volumes. However, this approach is sometimes preferred for exploring insights on the overall picture of clusters and outliers (Zhou et al., 2018; Healy and Moody, 2014). Recently, biologists prefer the use of web-based 3D visualisation tools to make better sense of molecular interactions. They take advantage of interactive graph features and multiple 3D layouts to avoid visual cluttering and enhance discovery and exploration (Zhou and Xia, 2018; 2019). This is illustrated in Figure 3.10(B). 3D tools have affordances in rotating and zooming to explore finer details.

There has been a great deal of work in developing force-directed layouts, which are arguably the most used in visual network exploration (Mei et al., 2018; Jacomy et al., 2014). These layouts are applied in exploring networks in complex biological systems (Heberle et al., 2017; Zhou and Xia, 2018; Ralf et al., 2016), sensor networks (Efrat et al., 2010), space information networks (Shaobo et al., 2018) and social media data (Palmer and Udawatta, 2019). However, this layout often lacks consistency for comparative analysis. Chord layouts explore the hierarchies of nodes and ties (Börner et al., 2016), but visual cluttering is also a challenge here when handling big data, as shown in Figure 3.10(C). Chord layouts were recently proved useful in mineralogy by exploring pairwise occurrences and locating co-existing species (Hazen et al., 2019). However, due to the vast amount of links in a small space, this layout shows little concrete path connecting single points (Koochaksaraei et al., 2017), so interactive features help filter connections and make it easy to see ties.

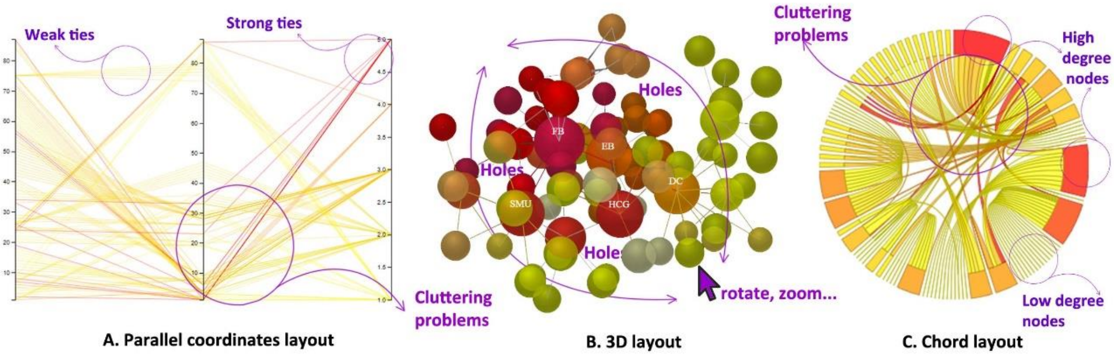


Figure 3.10: Examples of some visualisation methods

Therefore, there are different affordances in these methods which can help characterise ecosystems. There is little evidence in the literature regarding the use of open-source visualisation tools to support the understanding of local SME ecosystems. Within these visualisation methods (and many others), this thesis seeks to understand the methods necessary to support SMEs. The thesis seeks to contribute knowledge on what type of exploratory visualisation tools and methods might be useful for understanding local SME ecosystems.

3.8 Conclusions

In section 3.2, the chapter discussed shared value to tackle social problems while achieving great profitability for entrepreneurs. Creating shared value was discussed with enabling disruptive innovations in section 3.3, where new markets may be created by providing offerings that may ultimately overtake existing markets. This idea may be achieved by providing alternative solutions to unmet needs, underserved markets of a fringe group of customers. This chapter identified gaps in the innovation strategy literature on how interdependent firms may enhance their capabilities to design appropriate independent yet interdependent business model innovations.

This chapter also discussed the usefulness of the ecosystem concept in explaining the limitation of existing strategy literature, e.g. resource-based view, and how resources existing at the system-level influence the firm's capabilities (section 3.4). The chapter also discussed 'disruptive innovation ecosystems' as an idea of innovation ecosystems capable of delivering disruption (section 3.5). Incumbent ecosystems find underserved markets less attractive, thus giving room for SMEs to experiment with these unmet needs of the bottom of the pyramid communities. This thesis seeks to contribute to mainstream innovation and strategy research by exploring local ecosystem-level capabilities required in SME ecosystems and how actors might gain these capabilities to understand and reshape their local ecosystems through design research.

The chapter discussed possible approaches that may complement the overarching goal of enhancing the understanding of local SME ecosystems in a developing economy. The strength of weak ties was highlighted as key in exploring external resources (section 3.5.1). To develop ecosystem design capability, mixing weak and strong ties within ecosystems is key for ecosystem designers and decision-makers. It is still not clear from previous literature on how interconnected SMEs might leverage the concept of weak ties to understand local SME ecosystems.

The thesis also discussed how design research might fit within the envisioned process of understanding innovation ecosystems. Co-design approaches are also discussed as possible processes to develop local SMEs ecosystem design capabilities. There was little evidence in the literature regarding the use of design visualisation approaches to support the understanding of local SME ecosystem structures. The chapter also discussed the possible benefits of using exploratory visualisation methods in enabling SME ecosystem actors to explore and recreate mental models of local ecosystems (section 3.7). These ideas underpin the design visualisation approach proposed in this research, to which this thesis seeks to make a major contribution.

4 Methodology

The previous chapter presented findings from the literature review, which discussed the key concepts that underpin this research. This chapter discusses the methodology and rationale of the thesis. This is achieved by discussing the philosophical worldview that underpins this research, followed by the research approach, the conceptual lens, research questions, case study selection and data collection techniques. Finally, data analysis techniques, validity strategies, ethics and a summary of the methodologies are discussed.

4.1 Research philosophy

Research philosophy is a belief system about how knowledge is created (Saunders, 2016). In order to rationalise the best position for the thesis, this section discusses i) ontology, ii) epistemology and iii) axiology (Creswell, 2009; Saunders, 2009).

The ontological assumptions raise questions on beliefs and views about reality (Richards, 2003; Bryman, 2012; Saunders, 2016; Bell, 2019; Denscombe, 2010; Tashakkori and Teddlie, 2010). It is critical to start the genesis of research by establishing this position. Richards (2003) discusses ontology as the study of being, Saunders (2009, 2016) posit that ontology is the nature of reality, and Bryman (2012) introduces the concept of social ontology, which is about understanding reality from social entities (Bell, 2019). The central question of whether social entities should be viewed as having reality external or internal to the social actors has been extensively discussed (Bryman, 2012; Saunders, 2009; Crotty, 1998; Bell, 2019). The ontological worldview can be discussed into objectivism and subjectivism or constructionism (Saunders, 2016; Bell, 2019). Objectivism implies that entities' social context and meaning are independent of their social actors and are closely related to realism (Saunders, 2016; Bryman, 2012). In contrast, subjectivism means that social reality is created by people’s actions (Saunders, 2016), also known as constructivism (Alvesson, 2009; Bell, 2019).

The epistemological assumptions raise questions on how knowledge is interpreted (Richards, 2003; Bryman, 2012; Crotty, 1998) or the best tools for research (Denscombe, 2010). Epistemology is also concerned with how valid knowledge is constructed (Richards, 2003), and what can be known about something (Tashakkori and Teddlie, 2010). This also depends on the kind of knowledge viewed. If knowledge is based on objectivity, the researcher will likely take the natural science approaches (Bryman, 2012; 1989; Saunders, 2016; Dalcher, 2007; Crotty, 1998). Whereas, if knowledge is viewed as subjective and unique, the author is likely to reject the natural science approach and embrace the constructivist or subjectivist approach (Bryman, 1989; 2012; Crotty, 1998; Mason, 2002; Dalcher, 2007; Saunders, 2016).

Amid the ongoing debate on which position to settle for given positivism and constructivism (Mkansi and Acheampong, 2012), pragmatism suggests that research questions are the most important in determining how research is conducted (Saunders, 2016; Denscombe, 2010) and in getting the desired results (Dalcher, 2007). Positivism and objectivism posit the meaning of realities existing outside human consciousness and out there waiting to be discovered (Crotty, 1998). Constructivism and interpretivism emphasise exploring, understanding and interpreting the social world phenomenon (Mason, 2002; Bryman, 2012; Richards, 2003; Denscombe, 2010). Though it is not a watertight distinction between the two philosophies, it can be used as an initial assumption to distinguish the two worldviews (Denscombe, 2010).

The interpretivist viewpoint implies that the subject matter of social sciences, which include studying people’s actions and their institutions, is very much different from the natural-scientific way of viewing the world (Bryman, 2012; Saunders, 2016; Maxwell, 2013). Unlike in the positivists epistemological position where the investigator’s influence is supposedly distant from the findings, in interpretivist position, investigators interpret meaning based on their participant's views and are not detached from findings, but they largely influence the findings through their participation, perceptions and values (Bryman, 2012; 1989; Crotty, 1998; Richards, 2003; Saunders, 2016). This thesis interprets the meanings of what others have about the world instead of depending on the theory as in research approaches guided by the philosophy of positivism (Creswell, 2009; Richards, 2003; Crotty, 1998; Bryman, 2012; 1989).

Positivism is mostly intended to explore knowledge based on existing theory rather than building theory (Crotty, 1998; Bryman, 2012). This thesis followed constructivism and interpretivist epistemology (Denscombe, 2010; Creswell, 2014) to engage social actors in constructing and interpreting knowledge. While scientific methods are useful in conducting social-related studies, they are arguably less effective in disentangling social phenomena (Bryman, 2012; Crotty, 1998; Maxwell, 2013; Creswell, 2009). This thesis investigated the ecosystem phenomena from the constructivist position. This is because innovation ecosystems are composed of interactions and interdependences of actors, and in this thesis, network structures are regarded as structures of ecosystems, giving ecosystems form and function. This complex phenomenon is like what Manzini (2015) referred to as ‘cosmopolitan localism,’ i.e. the society in which places and communities are connected nodes in various networks.

Axiological assumptions raise questions on the extend people’s values influence the research process (Saunders, 2016; Leavy, 2014). Axiology questions how researchers and participant’s values are dealt with during the research process (Saunders, 2009). Objectivists claim to detach their values and beliefs from the research process (Saunders, 2016); however, constructivists use their values and beliefs (Maxwell, 2013). For example, a constructivist choosing the in-person interviews as a technique of gathering data means that he/she values personal interactions with respondents more than using online surveys (Saunders, 2016).

To conclude this section, the ontological position of this thesis was informed by people's knowledge and descriptions of how they understand their local innovation ecosystems. This ontological position grounded this present thesis (Denscombe, 2010). The epistemological viewpoint allowed exploring the ontological properties through interactions with ecosystem actors and listening to their construction of discourse

(Mason, 2002; Saunders, 2016). The axiological position used social interactions and engagement with social actors to choose the research methods and techniques (Saunders, 2009) discussed in the next sections.

4.2 Research approach

The philosophical position led to the use of a qualitative approach which reflected this thesis's methodological assumptions. This thesis explored manufacturing SME ecosystems in Botswana and the UK. Amongst different research approaches, i.e. quantitative, qualitative and mixed methods, the qualitative approach was adopted to evoke inductive means of constructing data and interpreting meaning in social settings (Saunders, 2016; Creswell, 2014; Dalcher, 2007; Bell, 2018; Silverman, 2016). Researching local innovation ecosystems was regarded as an emerging innovation and strategy research field, lacking a well-established theory (Roundy et al., 2018). In such instances where there is a conspicuous lack of theory, several researchers show that qualitative methods offer an opportunity to contribute to theory generation (Eisenhardt, 1989; Bell, 2019; Leavy, 2014; Creswell, 2014). Considering diverse viewpoints associated with qualitative methods, this made the approach most suitable for exploring interactions amongst actors such as firms, people and sectors. The social actors within innovation ecosystems held in-depth knowledge about their contexts, such as ecosystem views and experiences. The knowledge was also augmented through co-creation activities with ecosystem actors and the researcher's presence in the research process (Creswell, 2009; Saunders, 2016).

The qualitative methods provided a thick description of the phenomenon described by Geertz's interpretivism approach (Tracy, 2013), where there was a conspicuous lack of understanding in local SME ecosystems in Botswana. Quantitative methods are mostly applied to test relationships between variables or approve or disapprove existing theory (Maxwell, 2013; Creswell, 2014; Bell, 2018). These methods were unsuitable for this present thesis. The research valued the tacit and implicit knowledge and diversity of the participants and the researcher. The researcher's reflexivity and the variety of transformational data collection methods adopted in the present thesis were also valuable to construct an in-depth, rich knowledge about local SME ecosystems.

4.3 Case study design

To explore the local ecosystems, the significance of the context and the potential for discovering new factors relevant to understanding ecosystems, a case study design was adopted for this thesis. Although a case study design is mostly associated with qualitative approaches (Yin, 2012), they are also useful in testing theory through quantitative approaches (Eisenhardt, 1989; Yin, 2012). What is key in this research is not whether or not case studies are qualitative or quantitative, but a focus on a particular setting to provide a rich and detailed account of what is happening there that is important (Yin, 2012; Silverman, 2016; Denscombe, 2010; Dalcher, 2007; Richards, 2003). This thesis sought to understand how the researcher and the participants in different contexts perceived and interpreted the ecosystem phenomenon and how they co-constructed the understanding of the cases (Bell, 2019).

The case study was adopted over other qualitative designs for three main reasons. First, it allowed exploring local SMEs ecosystem phenomenon in specific locations, i.e. both in Botswana and the UK, thus generating in-depth knowledge about an unclear and subtle phenomenon within its real-life state (Denscombe, 2010; Yin, 2003). This design seemed highly relevant to adopt for exploring cases with limited existing knowledge (Yin 2012). Second, case studies were important to study contextual ecosystem factors, mechanisms and how these affect the understanding and shaping of local SME innovation ecosystems.

An innovation ecosystem is an emerging phenomenon for crafting strategies in developing economies (Mei et al., 2019), let alone in Botswana. Emmel (2013) also emphasise the need to take advantage of contextual activities to allow in-depth inquiry into a phenomenon. Third, case studies are most suitable for exploring social interactions and people’s understanding of phenomena (Dalcher, 2007). Following Yin (2003), a set of research questions and the problem statement were established before exploring case studies to guide the inquiry. Before investigating a case, the formulation of research questions was intended to focus the research and filter the information necessary to be collected (Yin, 1994; 2009; 2003).

Other research designs, such as grounded theory and action research, were not considered. First, because the grounded theory design is normally adopted to develop metatheory from data, no preconceived ideas are adopted before research, e.g., a predetermined sampling process (Strauss and Glaser, 1967). However, this present thesis aimed to develop an understanding of local innovation ecosystems by exploring two contexts, i.e., the UK and Botswana, presenting the opportunity to compare an industrialised and a developing economy. Therefore, a case study design seemed more relevant than grounded theory to conduct a comparative understanding of two contexts. Second, action research was not considered because of its intervening approach to diagnose a problem and provide solutions through repeated cycles to effect positive change in a particular context (Lorelei et al., 2008; McDonnell, 2016). This thesis sought to understand rather than change the local SME ecosystems. Hence, the case study was the most suitable research design for this present thesis.

4.3.1 Case studies selection

When selecting cases, researchers opting for a single case study are often tempted to overstate data, and this may lead to inconclusive findings (Yin, 1994). Yin (1994), Emmel (2013), Creswell (2009), and others argue that while high risks do exist in multiple case studies, they are reduced using cross-case analysis. The target of case selection in qualitative research is at the achievement of depth in investigating a phenomenon rather than breadth of coverage (Emmel, 2013; Denscombe, 2010). This present thesis did not follow the tabula rasa grounded theory approach (Strauss and Glaser, 1967); instead, the study adopted the purposeful sampling approach where preconceptions about the phenomena were made prior, and the insights from the literature were used to preconceive research questions (Emmel, 2013; Yin, 2003). Huberman and Miles (2002) also show that prior conceptualisation can shape the initial design of theory-building research.

Amongst the typology of case studies discussed in Yin (2003), a multi-case study seemed suitable because it allowed the researcher to compare the local innovation ecosystem cases in the UK and Botswana. Cases selected in both the UK and Botswana presented the opportunity to explore the existing local SME ecosystems in these contexts. A similar data protocol is used in a multi-case approach to collect data from the case settings (Yin, 2003). The study followed a theoretical replication strategy where the multiple cases selected were expected to give contrasting results but for anticipatable reasons (Yin, 2009; 2003), e.g. due to contextual differences, size of ecosystems and different settings. The purpose of this case selection was not to sample a part of the entire population but to carry out an in-depth investigation of a unique ecosystem phenomenon (Denscombe, 2010), occurring in a bounded context (Miles and Huberman, 1994; Creswell, 1994). In multi-case scenarios, there are no strident rules in the number of cases to be used to satisfy replication strategy because multi-cases are not meant to emphasize logic used in survey methods (Yin, 2003). Therefore, theoretical replication allowed the researcher to identify patterns in the data and make constant follow-ups to develop the data based on the identified patterns.

4.3.2 Data collection methods

The choice of research methods was influenced by the time-bounded study, which was scheduled to be completed within a period of three years. Another factor was the type of data collected guided by the research aim and research questions. Appendix 2 shows the multiple methods adopted to explore the local innovation ecosystem in an accessible, appropriate and quick way to provide adequate data for the study. Several scholars emphasise the need to use multiple data collection methods in a case study approach to generate rich data (Denscombe, 2010; Silverman, 2000; Saunders, 2016; Yin, 2012; Maxwell, 2013; Creswell, 2014; Silverman, 2016). Maxwell (2013) elucidates the former view by noting that mixing research techniques brings complementarity in all aspects of the studied phenomena.

Based on the axiological position that guided this methodology, personal interactions were valued when constructing data than virtual interactions or quantitative methods (Saunders, 2016). Semi-structured interviews and visualisation activities were done on-site through collaborations with participants. Before the interviews, the researcher made visits to the participants' workplaces to forge relationships with them. This approach was preferred to allow the participants to feel comfortable around the researcher and share their experiences and perceptions during data construction (Creswell, 2014).

In this thesis, semi-structured interviews, workshops and visualisation techniques were the main data collection methods. Websites and documents about the settings were also used to supplement the data. Using interviews and workshops was preferred for several reasons. First, because these approaches generate rich data about the perspectives and lived experiences of the actors in an interactive manner (Maxwell, 2013; Mason, 2002), much more transformational, as opposed to observational. This approach was key to understand how actors views and values influence local ecosystems. Second, using in-person interviews and workshops followed a dialogic exchange between the researcher and participants (Brinkmann, 2018) to bring out relevant data to answer the research questions. Specifically, semi-structured interviews allowed the researcher to use a preconceived guide with open questions and develop ideas during conversations with participants (Saunders, 2012). Third, to generate relational data on local ecosystems, the researcher also used a mapping tool shown in appendix 5 during the in-person interviews to visualise SME ecosystem structures from the interviewee’s perspective. This approach allowed the researcher to capture more rich details on the relational data and how the participants judged their strength of connections with stakeholders, e.g., the reciprocity of services (Granovetter, 1973).

There are also many limitations to using interviews and workshops. One is that these methods include biased responses due to the researcher’s presence (Creswell, 2009). This was addressed by allowing participants enough time to discuss amongst themselves, i.e. during the workshop parts, without the interference of the researcher. Some respondents were not articulate enough to provide relevant data, especially during interviews, this was countered by using the visualisation tool, where feasible. Maxwell (2013) explains that using additional sources such as field notes, mapping tools, and documents enable the study to draw inferences about the information captured from interviews and workshops, thus reducing biases. Therefore, this thesis used website data and field notes to supplement visualisation, workshop and interview data on ecosystems. These data collection methods allowed the co-construction of data between the researcher and participants rather than just collecting data stored somewhere (Mason, 2002), thus reaffirming the exploratory nature of this thesis.

4.3.3 Conceptual lens

As suggested by Yin (2003), formulating research questions and a theoretical framework before exploring case studies was useful in guiding the inquiry. The thesis started with a review of the literature to develop the aim, research questions, and conceptual framework that contributed to understanding SME ecosystems. Figure 4.1 shows a conceptual lens synthesised from existing innovation ecosystem literature. Although several studies have attempted to explore how ecosystems are formed and evolve (Adner, 2017b; Dedehayir and Seppänen, 2015; Ozgur and Marko, 2015; Iansiti and Levien, 2004; Rabelo and Bernus, 2015; Kaplan, 2012; Rong et al., 2015; Moore, 1993), there is a need as discussed in chapter 1 to 3 to understand how the contextual factors influence the understanding of local SME ecosystems. Also, it was important to explore how actors might gain design capabilities to understand and reshape local SME innovation ecosystems.

The ecosystem design conceptual lens shown in Figure 4.1 highlights important stages and factors in the innovation ecosystem process that may influence how manufacturing SMEs understand local ecosystems. This lens was used as a guide to focus the thesis (Huberman and Miles, 2002; Yin, 2003).

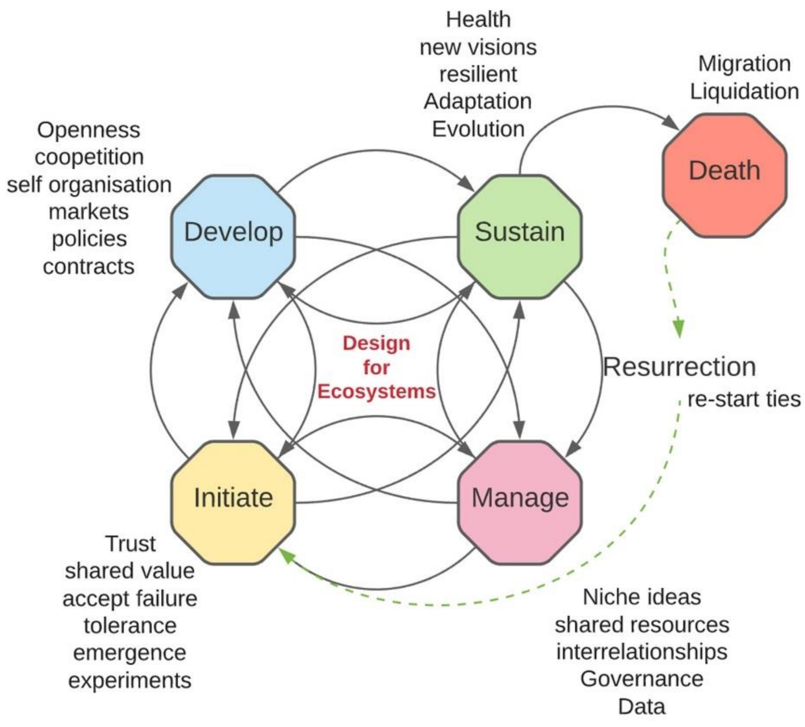


Figure 4.1: Ecosystem design conceptual lens

4.3.4 Research phases

As shown in Figure 4.2, the exploratory study was divided into four phases within a multi-case study design.

Phase 1: Understanding. This phase was about reviewing and understanding the status of SME support in Botswana (chapter 2). In chapter 3, the thesis focused on reviewing the literature around creating shared value, disruptive innovation, innovation ecosystems, design research, co-design and visualisation approaches. The literature review identified gaps in entrepreneurial and innovation ecosystem literature and formulated the research questions to address these gaps. As emphasised by Yin (1994, p. 28), *"theory development prior to the collection of case study data is an essential step in doing case studies".* The following research questions were developed to focus the thesis:

1. What is an innovation ecosystem, and how does this fit within the manufacturing SME environment in Botswana in terms of contributing to socio-economic development?
2. In what ways might local manufacturing ecosystems in SME environments be supported to create shared value?
3. How might insights from decision-makers in innovation ecosystems in the UK be augmented to support the understanding of manufacturing SME ecosystems in Botswana?
4. How might ecosystem design and visualisation approaches support and enhance the understanding of local SME ecosystem structures in Botswana?
5. Where could the design visualisation approach be improved to enhance the understanding of local manufacturing SME ecosystems?

Phase 2: Tools development and UK study

This phase was made up of two exploratory studies.

1. **Pilot Project and Tools Development**

The first phase of the exploratory case studies was to test the data collection techniques with three ecosystems in the UK, i.e. the artist, the FabLab and the 3D printing bureau ecosystems. The focus was on 3D printing technology-based cases to explore how disruptive technologies shape different ecosystems in the UK and how these insights may augment the understanding of manufacturing SME ecosystems in Botswana. The early findings from the pilot study contributed to the re-design of the research approach to study makerspaces as ecosystems.

2. **Makerspaces as localised ecosystems**

This research shifted to exploring makerspaces as localised manufacturing ecosystems for the following reasons. It was revealed that the ecosystem around manufacturing SMEs is important than the technology of 3D printing itself. The major shift was from focusing only on 3D printing as a disruptive technology to exploring how these tools and makerspaces influence and shape local SME innovation ecosystems. This research focused on exploring how makerspaces as local ecosystems are structured in the UK. Findings from the makerspaces were used to compare with incubations in Botswana.

Phase 3: Main case study

1. **Incubators as localised ecosystems**

This case study explored manufacturing SME incubators as local ecosystems in Botswana. The case used in-person interviews and exploratory visualisations with manufacturing SMEs and incubator managers. Findings from this phase were used to compare with the UK local ecosystems. This case study proposed a framework for understanding the local SME ecosystem in Botswana.

Phase 4: Evaluation

This phase had two exploratory co-design and evaluation activities. The evaluation addressed the question of how design and visualisation approaches might support the understanding of the local SME ecosystem.

1. **In-person co-design workshops**

The first evaluation work had three in-person co-design workshops held in Botswana. These co-design workshops used the framework developed in phase 3 to evaluate the understanding of local manufacturing SME ecosystems.

2. **Virtual co-design workshops**

Due to the COVID-19 pandemic, the second evaluation work was transformed into a virtual co-design workshop and conducted at the Design Research Society virtual conference. This virtual workshop focused on evaluating the framework with a group of design researchers.

The evaluation feedback from the in-person and virtual workshops was used to improve the Jigsaw design framework (discussed in Chapter 7) to address the last research question on where the design visualisation approach might be improved to aid SME ecosystem actors in making sense of local ecosystems.

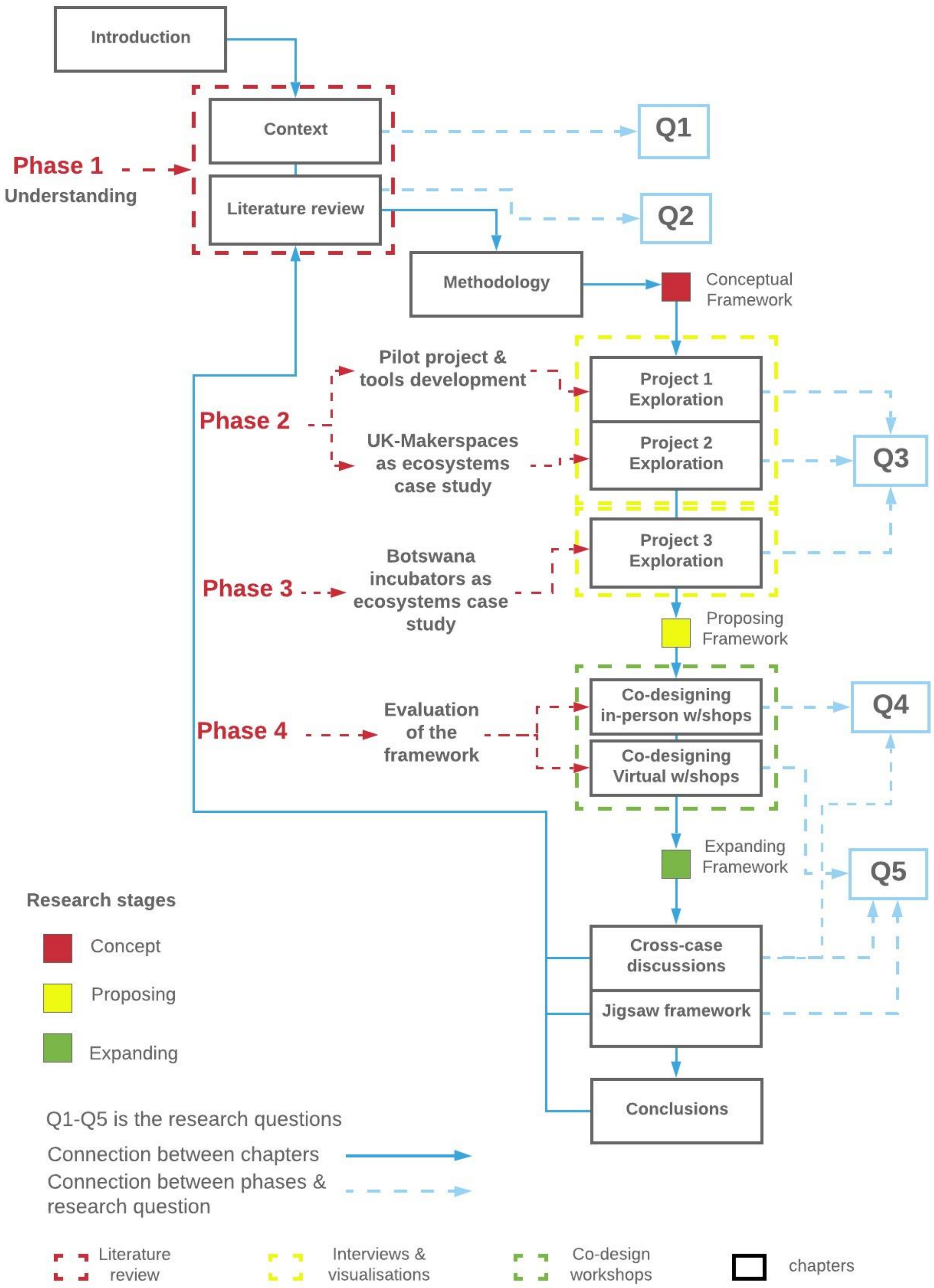


Figure 4.2: Research phases

4.3.5 Research Cases

This section discusses the research conducted in two countries, i.e. Botswana and the UK, and the rationale for selecting the units of analysis.

4.3.5.1 The rationale

Selecting cases is important in determining the quality of the overall research (Creswell, 2014). For this thesis, it was significant to select based on information-rich cases (Yin, 2009). All cases were selected for a specific purpose (Kvale, 1996) and based on a theoretical replication approach to allow the researcher to identify patterns in the data and adjust the research design (Yin, 2009). The case study aimed to explore how decision-makers in ecosystem cases in the UK and Botswana understood their ecosystem and how this might be augmented and extended to benefit manufacturing SMEs in Botswana.

Pilot and tools development

As argued by others (Kitzinger and Barbour, 1999), piloting the research design and methods is essential to provide the researcher with a clear focus on the research and develop the data collection instruments. The UK cases were selected for several reasons. First, they adopted modern technology, e.g. 3D printing, to transform the manufacturing industry (Hague et al., 2016; Hauser, 2014). Second, all the cases were distinct yet using similar technologies, thus providing an opportunity to compare and document a process of understanding the influence of disruptive technologies, e.g. 3D printing in different ecosystem contexts. Third, the three cases were in the Northwest of England, hence accessible and feasible to carry out in-person inquiries since the researcher was based in Lancaster. Finally, looking at the odd number of cases provided the opportunity to explore an outlier within these distinct ecosystem categories to learn something new.

The study selected cases based on three distinct categories; i) the Artist, ii) the FabLab and iii) the 3D printing bureau, which formed embedded units within the multi-case study design. The thesis was interested in 3D printing technology, i.e. the ceramic artist using 3D printers, the FabLab, where SMEs used 3D printers for developing and testing prototypes and the 3D printing bureau service using 3D printers to service customers. It was important to select key decision-makers in these settings. Participants included the ceramic artist, the FabLab director, and a 3D printing bureau service director. These high-profile informants were expected to provide rich information about their understanding of ecosystems where they are embedded.

Makerspaces as localised ecosystems

Based on the UK pilot study findings, the thesis shifted the focus to exploring local SME ecosystems, thus selecting three makerspaces in the UK to understand their local ecosystem structures. During the pilot project, the study found that within the three ecosystem cases, the FabLab ecosystem was the most appropriate case to compare to Botswana SME incubators since the main aim of the thesis was to enhance the understanding of local SME ecosystems in Botswana. The Fablab ecosystem case had more potential to create shared value than in other cases. Therefore, the research focused on exploring makerspaces as local SME innovation ecosystems because makerspaces are associated with less profit-oriented approaches and more community-focused programs (Bedford and Detsch, 2018). The makerspace case explored how directors as high-profile informants understand and shape local ecosystems and how this might be augmented and extended to benefit the understanding of manufacturing SME ecosystems in Botswana. Further details on the rationale of selecting cases is provided in chapter 6 of this thesis.

Incubators as localised ecosystems

The third phase of the study was conducted in Botswana as the main focus of this present thesis. The project used a case study with multiple embedded units, just like in the UK, to clarify the context and the phenomena of SME ecosystems across different contexts. The study selected four incubation spaces (13 SMEs and two incubation managers) and five SMEs located outside incubators as units of analysis to compare with makerspaces in the UK. The selection of these cases was made based on several reasons. First, the cases were part of Botswana’s priority areas and commitment to promoting manufacturing SMEs towards economic diversification, as discussed in chapter 2. Second, these four incubators are also part of Botswana government’s strategic plans to promote the entrepreneurial ecosystem. Third, incubation spaces were treated as innovation ecosystems because the Government uses these spaces to assist SMEs and start-up businesses through incubation programs and entrepreneurial initiatives (BIH, 2020; LEA, 2020), thus making this case study important to explore. Forth, manufacturing SMEs located outside incubators were also selected to explore their understanding of local ecosystems and to compare with those located inside incubators. Further details on the rationale for selecting Botswana cases is provided in chapter 7.

Evaluation

In-person workshops

Regarding evaluating the framework developed in the exploratory case studies, a series of in-person co-design workshops were developed. This approach was preferred to assemble key actors in the local SME ecosystem to explore their understanding of SME ecosystem structures.

In this phase, the first evaluation study involved three in-person co-design workshops held in Botswana. In line with the Government priority areas, the research organised the first workshop with the leather incubator involved in developing the framework in phase 3. The second workshop had 65 participants from Lancaster University's Recirculate project, and the final workshop was conducted with 20 entrepreneurs from Botswana Innovation Hub. Therefore, these participants were all relevant and appropriate to evaluate the ecosystem design framework proposed in this thesis.

Based on the workshop design presented in appendix 13, the in-person workshop activities were arranged in three parts. The first part of the co-design activity was an icebreaker, where participants were expected to visualise their position in the innovation ecosystem and introduce themselves using a tool shown in Figure 4.3. This was important to help deal with frozen relations and allow participants to start conversations based on trust and openness (Verma and Anand Pathak, 2011).

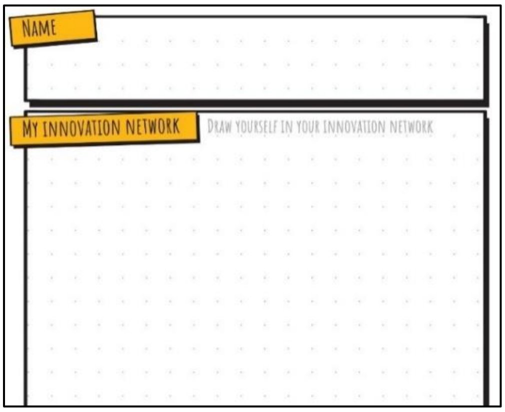


Figure 4.3: Icebreaking tool

The second part was for individual co-design activities, where participants from different entities visualised their local ecosystems and then shared them with others for review. The third part was about bringing different actors together to explore their connections, design and review new connections as an idealised ecosystem. These were important to help participants link existing possibilities of the present with the future state of local ecosystems. When participants link the present state of ecosystems with the future, it becomes possible to plan a course of action (Metzker et al., 2006).

To evaluate the framework developed in phase 3, three workshop parts were arranged in consecutive order, such that the first part outputs linked into the next part activities to form a coherent meaning of the ecosystem design process. This aided participants to use the learnings from the first part outputs as prompts to design the understanding of ecosystems in the subsequent parts.

In order to facilitate engagements, the thesis developed a mapping tool based on the framework for understanding ecosystems, as shown in Figure 4.4. The mapping tool was intended to simplify the operationalisation of the proposed framework shown in appendix 10. To ensure that the tool was appropriate for the study, the researcher conducted a pre-test assessment of its functionality. This was done through a focus group of design researchers with vast experience developing and using co-design tools at Imagination Lancaster research centre. Based on the feedback received, the tool was re-designed before use in these workshops. Visualisation outputs generated at the workshops were used as objects for design (Zamenopoulos and Alexiou, 2018) to enable dialogue and understand local innovation ecosystems.

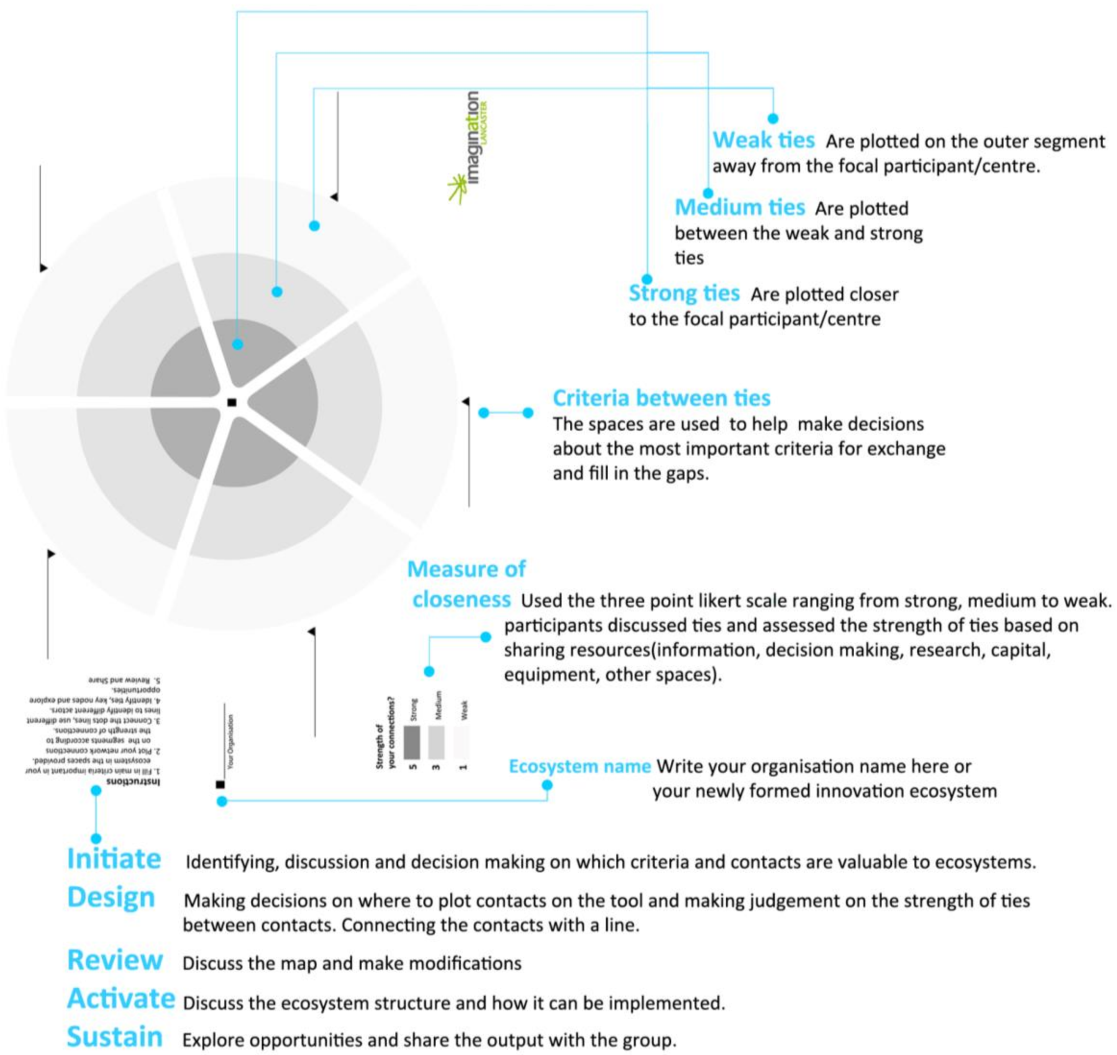


Figure 4.4: The innovation ecosystem design tool

Virtual workshop

The virtual workshop evaluated the ecosystem design framework with a separate set of participants instead of actors connected to the manufacturing SME ecosystem in Botswana. This approach was important to explore the framework useability to other ecosystem contexts to enhance its validity. This workshop aimed to explore how design researchers might use the Jigsaw framework (discussed in Chapter 7) to enhance the understanding of their research ecosystems. Due to the COVID-19 outbreak, it was impossible to run in-person workshops as scheduled in August 2020. This workshop was initially planned to happen at the Design Research Society (2020) conference in Brisbane, Australia. The workshop was scheduled to take up to 105 minutes. However, this had to be re-designed into a 60 minutes virtual workshop following the new Design

Research Society (2020) online conference requirements. To effectively deliver an online co-design workshop, the thesis re-designed the in-person plan into a virtual online plan.

Planning online activities

Changing time allocated to a virtual activity affected the workshop design from the initial three in-person workshops. Although the change in the workshop duration was a conference requirement, it was also a way to reduce information overload as the workshop was part of a full-day virtual conference. The MIRO whiteboard platform was selected to support the online workshop for several reasons. First, because other professional designers and researchers widely used it during the conference to exchange knowledge with participants. It seemed to be an appropriate choice to support this workshop because of prior knowledge about it. Second, the tool did not require advanced skills to operate, such as learning new digital skills like coding. Third, it allowed participants to work and chat on the same whiteboard in real-time. The Design Research Society 2020 conference also provided the Microsoft Teams platform for communication through videotelephony.

Regarding the icebreaker (see Fig 4.3) used to introduce the concept of ecosystems during in-person workshops, this was planned into a virtual activity, where participants were expected to pick any object, or 'thing' laying in their physical spaces and talk about that in 10 seconds, and nominate another participant to do the same to find connections between these physically distant things. These activities also aimed to encourage people to talk, move them around and provide fun at the beginning of the virtual workshop.

Designing interactive resources

Unlike in-person workshops where the planning of design activities involved procuring well-established tools, e.g. sticky notes, whiteboards, printed canvases, in virtual workshop planning, much time was invested in honing virtual design spaces. This was done to lessen the difficulty of using virtual whiteboards and make participants with low digital literacy less worried about learning new skills during co-design interactions. The workshop had to break down the framework into different spaces to help participants make sense of ecosystem activities. The workshop was limited to four design spaces, with customised icons and tools to ease the co-design activities.

The thesis designed a table with fifteen spaces for participants to fill in their criteria, including five boxes to agree on five main criteria and fill in the boxes. Participants actions were to click and type in spaces provided, as shown in Figure 4.5. Activity-2 was designed in the form of a virtual notepad, and again the participants only needed to click and type in their key contacts. Activity-3 was the main mapping tool space, and this provided participants with node icons to copy and paste on the co-design tool, connection line tools to connect nodes, and a text tool on the left to type in their labels. They also had an option to use sticky notes to add reviews. Activity-4 was the evaluation of the tool. The thesis used a combination of questions, node icons, boxes and emojis because participants were much familiar with these from the realm of social media, it was more relevant to use them. Participants' actions were to copy their node icons and paste them in their preferred boxes to answer the questions.

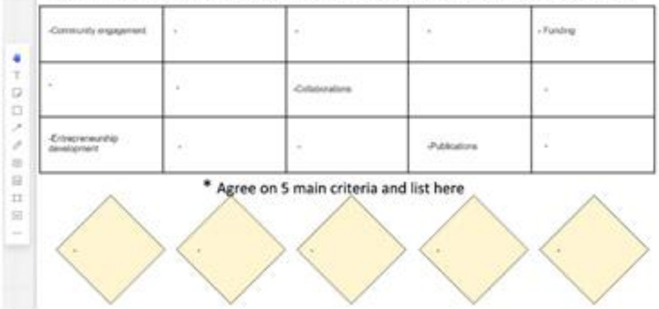
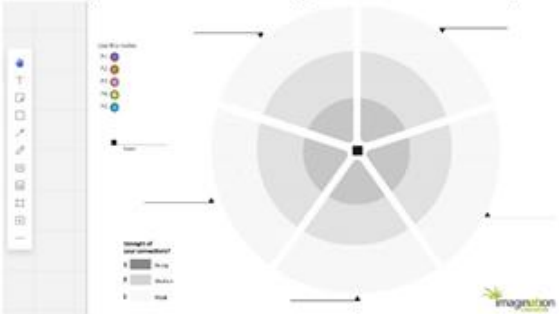
Activity	Design space	Action
1	In 5 minutes, can you list the main criteria in your research ecosystem? 	Click and type in spaces provided
2	In 5 minutes, can you list the key contacts in your research ecosystems? 	Choose your pad and colour then Click and type in spaces provided
3	In 20 minutes, fill in the criteria on the spaces and plot contacts on the ecosystem tool. *note the strenght of connections between yourself and contacts. 	Using the same colour from activity 2 copy and paste your node icons on the tool. Use pen or connection line tools on the left to join nodes Click text tool and type node labels
4	In 3 minutes, react to question by filling in your colour on the boxes provided. 	Using the same colour from activities 2 & 3 copy and paste node icons on the boxes provided to answer the questions.

Figure 4.5: Virtual workshop design spaces

4.3.6 Data collection

In order to increase the reliability of data generated from the field, the thesis used multiple data collection methods, as described in section 4.3.2. This approach also acted to triangulate data to confirm the study's validity (Yin, 2003). This research used the following data collection methods; i) semi-structured interviews, ii) visualisations, iii) websites and documents, iv) evaluation workshops.

Semi-structured interviews

Although there are three main types of interviews, i.e. i) structured, ii) semi-structured, iii) unstructured, semi-structured interviews were preferred because they are widely adopted for collecting data in qualitative inquiries (Simon and Fin, 2013) and other reasons described in section 4.3.2. During phases 2 and 3, the main data was elicited through semi-structured interviews, which involved three stages, i.e. pre-interviews, during interviews and post-interview activities. Before conducting interviews, the thesis developed open-ended questions based on the conceptual lens and research questions. The interview protocol guided the researcher to remain in control of the interview process (Gani et al., 2020). Then the researcher conducted a test run on the interview protocol with a colleague to check if the questions made sense (Jacob and Furgerson, 2012). The research instrument was made up of open-ended questions of a semi-structured interview to allow the participants to have the freedom and a high level of flexibility to speak about anything relevant to the subject (see appendix 4).

On the interview day, the researcher visited the participants at their settings at least an hour before the start of the interview. This allowed time for informal chats and to tour the setting to allow the participants to relax. The participants were allowed to decide where to carry out the interviews, and they all preferred their quiet office spaces. At the start of the interviews, the researcher explained the purpose of the study using the participant information sheet shown in appendix 15. The researcher also reiterated the confidentiality of the data being sought and the rights of the participants before they signed the consent form.

In most cases, participants gave the researcher permission to audio record the interviews; however, there were instances where some participants did not want to be recorded. Therefore, in such instances, the researcher made field notes (Guest et al., 2012) and used the visualisation tool to capture the data. Most interviews took 60 minutes to complete. Further information on the interview protocol for phases 2 and 3 is found in Appendix 4.

In the post-interview stage, all the data from phases 2 and 3 were transcribed verbatim. The interview transcripts were shared with the participants, and clarifications were sought through email correspondences.

Visualisations

As shown in Figure 4.6, using a mapping tool adapted from the position generator technique (Lin et al., 2001), the thesis captured participants' views on the strength of connections with partners in terms of reciprocity of resources. The visualisation activity was also done during the interview sessions. The position generator was used to explore the characteristics of the participant’s ties, often used as a brokerage between separate groups (Maness, 2017). This is important to expand ecosystem diversity and information. Where it was not possible to capture actors' positions during the interview, the researcher used additional sources, e.g. websites, to search for ecosystem actors’ relationships. An example of how the tool was used is shown in appendix 5.

The benefits of this approach were in two-folds. First, it generated a graphical representation of data which improved understanding and communication of participants experiences about the ecosystem structures. Second, the tool also helped participants recall the forgotten relationships between actors (Lin et al., 2001). The co-designed visualisation data was later transformed into edge list datasets for further analysis using open-source visualisation methods. The case study datasets can be found online (Nthubu, 2020c). These datasets can be loaded into various network visualisation tools for analysis.

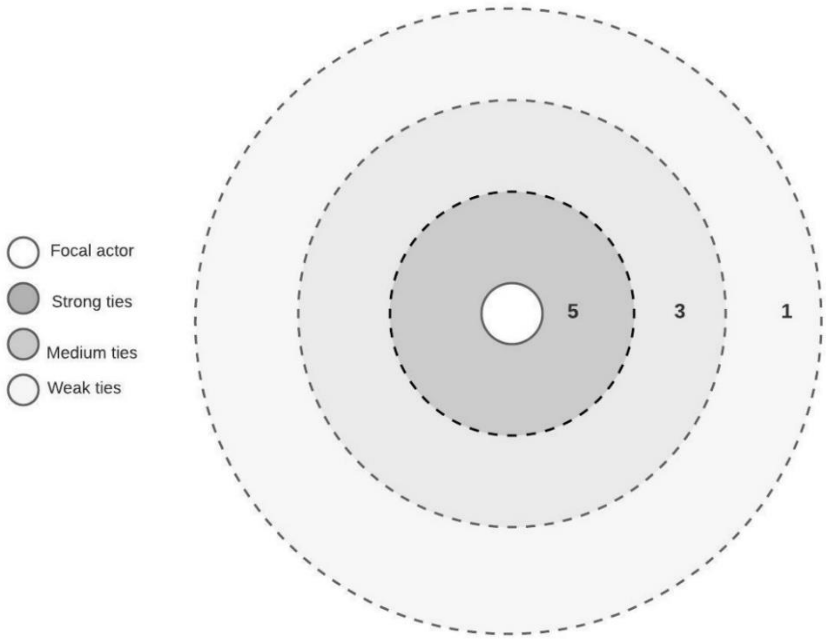


Figure 4.6: A mapping tool

Desk research

The researcher used websites for additional data to supplement the interviews and visualisation data in phases 2 and 3. This data included more information on relational data, which was not mentioned during the interviews or not captured through the ecosystem mapping. During the site visits, the researcher collected printed pamphlets and flyers with key information about the cases. Although documents and website data were available to the public, and the researcher did not require permission, participants were informed about this during the interview, and they granted the consent for the data to be used in the thesis and as part of reporting results in other platforms, e.g. conferences and journals.

Workshops

The type of data collected from the co-design workshops is as follows. First, all the presentations done by participants during workshops were audio recorded. This was important to capture the exact words and expressions used by participants. Second, the researcher also took pictures of visualisation models produced during the workshop for further analysis and reporting. Third, the researcher collected notes on reflections made about the use of the tools. Forth, in all workshop parts, the researcher collected evaluation feedback using the form in appendix 12.

Regarding the virtual workshop, the virtual design spaces shown in Figure 4.5 captured all design activities done by participants, i.e. visualisations and comments for further analysis. Also, discussions and ideas shared by participants were captured by the researcher as notes during co-design activities.

4.3.7 Data analysis

Since the project generated two main types of data, i.e. transcripts and visualisations, the thematic analysis method was used to analyse transcripts and field notes, and then visual network analysis techniques were used to explore datasets for insights. In the following sections, the thesis discusses the two analysis techniques in detail.

Thematic analysis

There is no agreed definition of a theme, as emphasised in (Braun and Clarke, 2016), meaning that how researchers conceptualise and arrive at themes vary. However, this project followed the conceptualisation of the 'organic theme' applied by Braun and Clarke and other qualitative researchers. In Braun and Clarke (2016), the conceptualisation of an organic theme is like baking a cake instead of the discovery of diamonds. Like baking a cake, the research used a thematic method to make sense of voluminous and complex data (Creswell, 2014), thus requiring the researcher to engage deeply in an iterative thematic analysis process, i.e. systematic, repetitive, and recursive, much earlier in the data collection cycle.

Choosing the thematic analysis methods over other forms of analysis in a qualitative study, e.g. discourse analysis and narrative analysis (Braun and Clarke, 2016), was done based on several reasons. First, it allowed the researcher to explore richness and depth in the qualitative data by revealing patterns through organising, interpreting and reporting emerging themes. Second, thematic analysis was useful for exploring different perspectives from participants and summing up important features of large qualitative data (Nowell et al., 2017). Third, the thematic analysis provides a flexible approach that can be modified to suit many research settings.

This thesis referred to Miles and Huberman (1994) principal proposition for data analysis which combined the use of reduction strategy, visual techniques, pattern identification, conclusions drawing and verification to ease the analysis of complex ecosystem data (Figure 4.7).

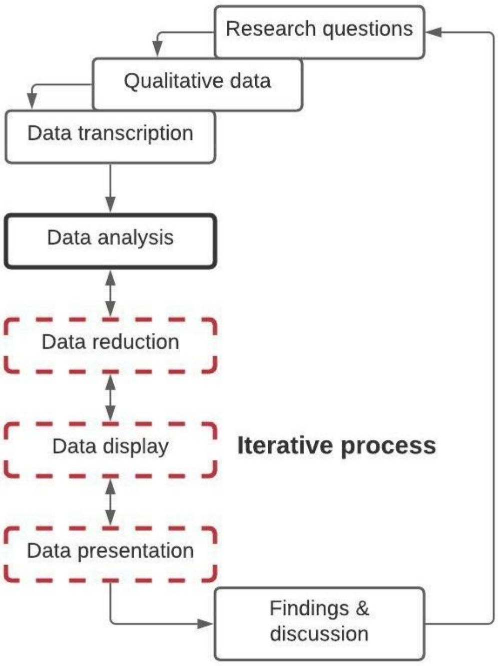


Figure 4.7: The data analysis iterative process (redrawn from Miles and Huberman, 1994)

The data was interpretively and reflexively read to get the meaning of a phenomenon (Mason, 2002). The audio data from the field study were transcribed verbatim immediately after data collection and pre-coded to generate initial codes as part of the reduction strategy. The coding process is defined as assigning a label to chunks of data (Creswell, 2014), thus aiding data reduction by breaking down large chunks of data into smaller bits. As shown in Figure 4.8, although the research mostly used an inductive approach to data analysis by open coding, theory-driven codes from the conceptual framework on page 59 were also used in the analysis as anchor codes and initial codes. These combinations of data and theory-driven codes formed part of the coding structure used in this research's thematic analysis. Examples of excerpts of a mix of initial and anchor codes with descriptions are shown in Appendix 7.

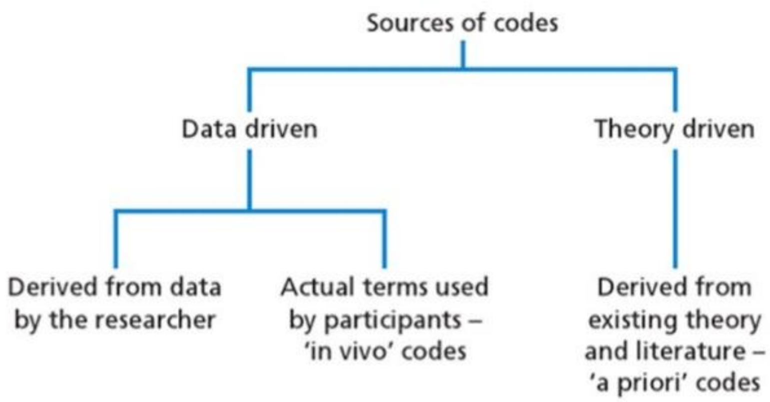


Figure 4.8: Sources of codes (Saunders, 2016)

Following the iterative data analysis process shown in hidden details (Figure 4.7) and thematic analysis structure (Appendix 6), pre-coding involved a repeated reading of transcripts and highlighting of interesting ideas before formal coding was conducted to reduce the volume of data and get a holistic view of ideas across transcripts. The transcripts were then loaded into NVivo 12 software for coding. Open coding was conducted for each script to allow new codes to emerge from the data, i.e. the researcher read the scripts line by line to make sense of data and identify initial ideas related to initial codes or new ideas emerging from the data (Creswell, 2009). Since the study was investigating participant's innovation ecosystems, the research used emotion coding to capture participants emotions, value coding to capture attitudes, beliefs and uncertainties, themes to describe the meaning of an aspect of data and evaluation coding to capture the perception about ecosystems.

In conducting the thematic analysis, for each case transcript loaded in NVivo 12, the data file was read individually, noting interesting items within the text and cutting and dragging chunks of data into relevant node containers, i.e. initial codes or new codes, and assigning labels that capture what is interesting or emerging from the data through open coding. The coding process was coupled with taking notes of thoughts about the codes using memos (Figure 4.9). The labels were created as nodes in NVivo 12 or code containers where each relevant chunk of data was dragged and dropped. Figure 4.9 shows an excerpt of how the code, clusters and themes were hierarchically linked during the pilot study data analysis.

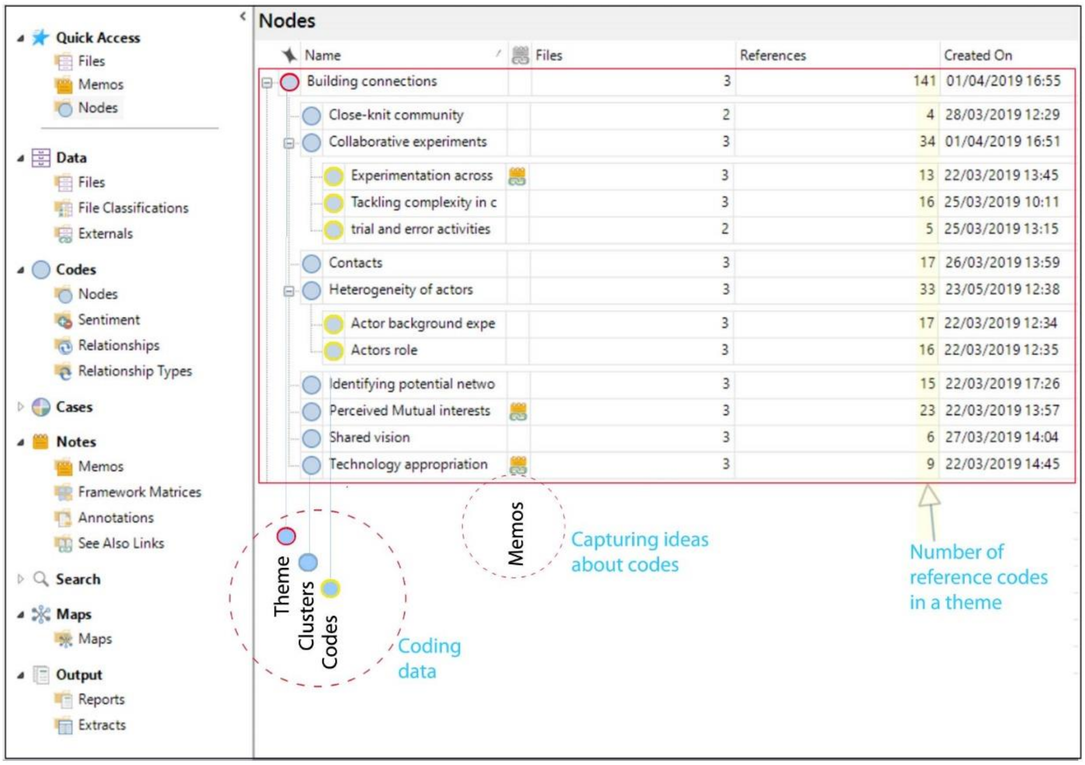


Figure 4.9: Example of a hierarchical structure of themes, clusters and codes created in NVivo 12 during the pilot project in phase 2.

After coding, an assessment of the characteristics of each code was done to determine the dominant codes. The next step was the categorisation of codes into clusters. The thesis used the cluster analysis function in NVivo 12 to cluster codes in terms of word and node similarity (Figure 4.10). Visualising codes in graphical layouts made it easy to locate similarities by observing the code cluster patterns formed. However, additional manual clustering of code was done by going through the code references and reading through the interview statements to check if the text reflected similarity in terms of meaning to other codes. Some codes were moved to other clusters or renamed. Pattern coding is suggested as a quick way to make sense of relationships between codes (Miles and Huberman, 2012). Clusters were labelled with a generic name to reflect the codes. The labelling process was done in alignment with the research questions, as suggested by Braun and Clarke (2016). The authors highlight that pattern identification needs to be in line with research questions to test the phenomena under inquiry. To reduce the number of categories (Creswell, 2009), the research summed-up clusters into main themes to draw up conclusions.

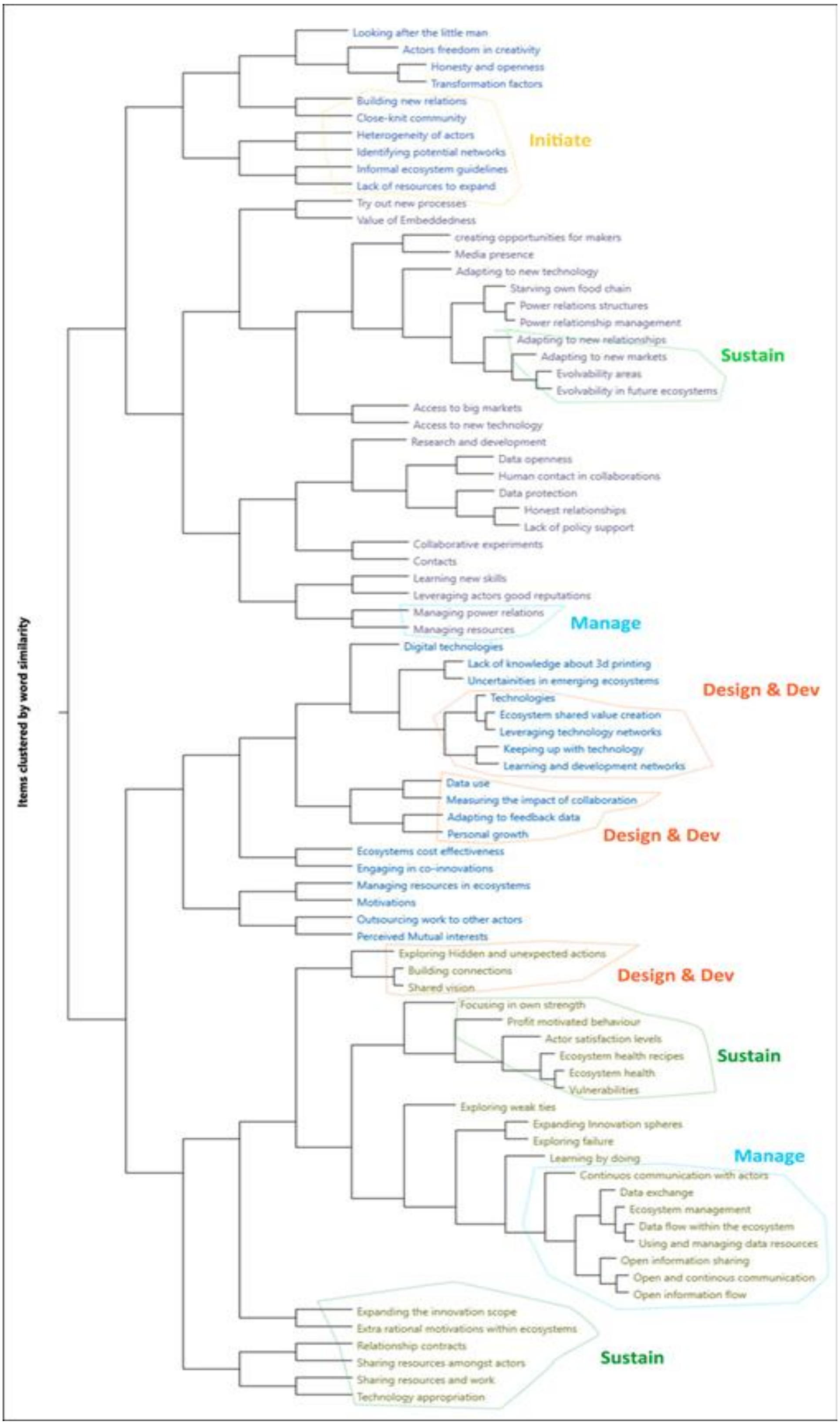


Figure 4.10: Example taken from the pilot study analysis : Clustering codes by similarity analysis in NVivo 12

In line with Miles and Huberman (2012), data was displayed in the form of tables showing main themes, subthemes and key questions representing an assembly of information that is logically explainable and conclusions drawn from it. This idea was important because it summarised how ecosystem actors thought about their ecosystems, what was common amongst them and where they contrasted. Therefore, data display made voluminous data manageable and explainable (Creswell, 2014). The book of codes was developed throughout the coding process to explain the meaning of each code. An excerpt from the book of codes from the pilot study is shown in Table 1 below. This scheme guided the second coder to establish inter-rater reliability (Braun and Clarke, 2016). Since generating themes was an iterative process throughout the project, tables of code descriptions for each transcript were developed to communicate the distinction between findings from each participant meaningfully and logically.

Table 1: An example of the definition of themes and codes from the pilot study book of codes

Themes & codes	**Description**	**Typical reference**	**Participants**
Initiate	This theme explores how actors initiate ecosystems	1.	2.
3. **Enabling trust**	The actor expresses the significance of trust in interrelations but also expresses uncertainties	"I mean we have lost a really large customer to xx [referring to a 3D printing manufacturing firm] and so … that made life difficult for a little while but then you know we have been able to find new customers, but there is nothing stopping that happening again you know, we are running on trust you know, which is very difficult sometimes"	3D printing bureau

Develop	This theme explores how actors understand ecosystem value, and how they are creating it		
Building collaborations	The actor highlights the need to engage other actors in the ecosystem, to develop more collective capability. Also expresses challenges of identifying key roles	"We don't want to do it all, because we are not experts in all, we are experts in our small part of it, but we work within an ecosystem of experts in all different perspectives, …sometimes it's challenging to get the right expertise to assist."	FabLab
Manage	This theme explores how actors manage their inter-firm resources		

Managing actors' roles	The actor highlights how roles are shared in their relations. However, he also expresses the downside of not handling some of the roles because of the relational contracts.	"They [refering to the gallery] are responsible for choosing which fairs to attend, which curators, which museums to speak to, which private collectors to speak to when I bring out some new work, when I have an exhibition, they put together the list of invitees to private views, you know…"	Artist
Sustain	This theme explores how actors understand ecosystem health, and how they create it		
Enabling the health of ecosystem relations	The actor expresses an unhealthy climate in their relations with other actors who are all trying to get more out of the value created in the ecosystem. Also lack clarity of how and when these aspects will be improved.	"I feel like we are quite tied down and its almost like trending in waters a lot of the time, so the investors are keen to see return on investment, the resellers and manufacturers want to make a good profit, and we are just trying to sought of getting by"	3D printing bureau

This thesis also used a matrix table to organise main themes, subthemes and questions to show the relationship between ecosystem design concepts, how the participants interpreted their ecosystem in terms of subthemes, i.e. factors influencing how ecosystems are shaped in each level of the innovation ecosystem structure. Organising and displaying information using the matrix and tables display data for easy understanding makes concluding the findings much easier. In the last step of the iterative process (Figure 4.7), the thesis made sense of the data display in relation to understanding the innovation ecosystem. Data display was done in line with recommendations from Miles and Huberman (2012). The presentation of results was displayed in a graphical framework, showing the levels and factors affecting the understanding and shape of ecosystems under study.

In order to establish the rigour in a thematic process, few things were done. First, the transcripts from semi-structured interviews were verified by the participants before the coding was done. This verification ensured that the data was a true reflection of what the participant wanted to communicate. Second, the researcher engaged a colleague to code the data following the book of codes generated from the first coding process. This process was important to provide rigour in the quality of codes, reduce the level of negative bias on the interpretation of the data, and increase the trustworthiness of the thematic results. At the end of the coding process, conclusions were drawn from the thematic findings. Next, the thesis discusses the visual analysis techniques and related theories used to characterise SME ecosystems.

Visual network analysis

Visual network analysis was used to explore hard to understand ecosystem attributes such as node hierarchies, clusters, bridges, structural holes, tie size and role structure. Since the thesis was studying the understanding of the local ecosystem, these attributes were key factors that influenced the level of the actor’s understanding. Focusing on ecosystem attributes was based on the results from the pilot study (see chapter 5), which indicated the difficulty in understanding complexities associated with these ecosystem attributes. Below, the thesis discusses the visual network analysis approach.

- Node hierarchy

  Node hierarchies represent how many stakeholders are connected to an actor compared to others regarding the degree of connection. Understanding highly connected actors in the local ecosystems is key for start-ups and entrepreneurs to leverage resources outside their core networks (Bounegru et al., 2017). The node hierarchy was analysed by observing the node size. The bigger the node, the more connected, and the more resources actors may have. Colour was also used to search for node influence, where red nodes had high influence, orange medium, and yellow represented low influence in the ecosystem structure. This method can be visualised, as shown in Figure 4.11 below.

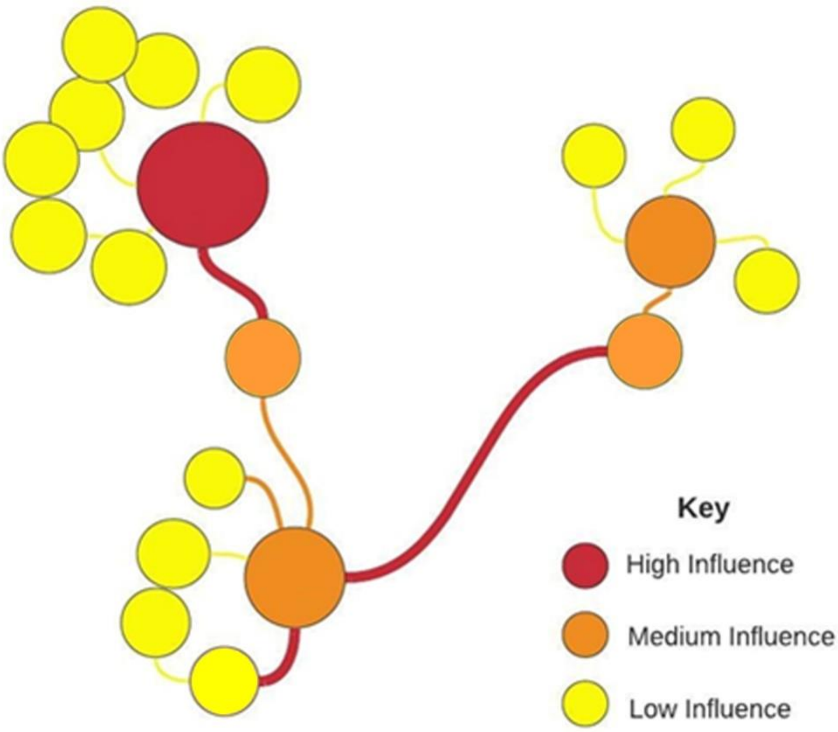


Figure 4.11: Visual display of node hierarchies

- Clusters & Bridges

  Clusters are a group of actors in a specific sector who may be connected or disconnected, cooperating or competing (Porter, 1998). Clusters in local ecosystems have an advantageous role anchored on geographic and social proximity. In Katarzyna and Krzysztof (2009), bridges are nodes that connect clusters with the peripheral nodes or clusters and with the rest of the network. This thesis defines bridges as key actors or clusters that connect distant actors or clusters in the ecosystem to allow resource flow across. All bridges are weak ties (Granovetter, 1973). Understanding these attributes might be useful in planning innovation activities between SME communities (Li et al., 2019). In this thesis, clusters were analysed by observing the number of nodes and visual density or cohesion of nodes. As shown in Figure 4.12, bridge-1(a node) connects clusters A and C, while bridge-3 (a cluster)-connects clusters A and B.

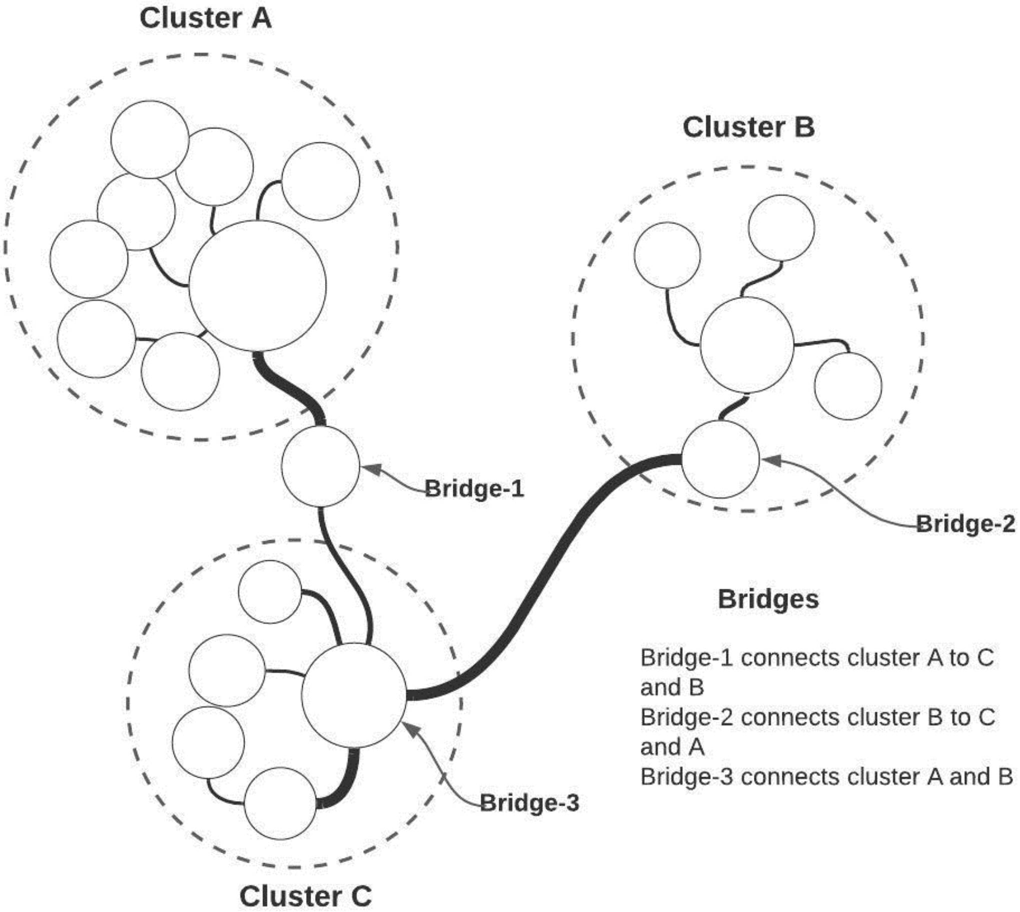


Figure 4.12: Visual display of clusters & bridges

- Structural holes

Ahuja (2000) defines structural holes as follows; "gaps in information flow between alters linked to the same ego but not linked to each other". By synthesizing the structural hole theory (Figure 4.13), the thesis demonstrates that A and B may decide to directly link if they know each other and if the link will lead to value creation. The structural holes in this thesis are opportunities for SMEs to leverage social capital, i.e. resources embedded in ecosystem structures. Social capital is not always measured by closeness but by the ability to leverage information and resources from disconnected environments (Latora et al., 2013). This formed the key arguments by Robert S Burt, who highlighted the advantage of occupying bridging positions between separate entities (Burt, 1992).

While cohesion may lead to social capital through increased trust levels between actors (Coleman, 1988), it can also lead to limited exploitation of innovative ideas because of redundant information embedded in closed networks. An actor can utilise the hole by acting as a bridge or broker between two clusters (Burt, 1992), i.e. between clusters A and B (Figure 4.13). Knowledge of structural holes is an opportunity to access and use the flow of resources and information. This may give actors greater exposure to the novelty of information, leading to great advantage.

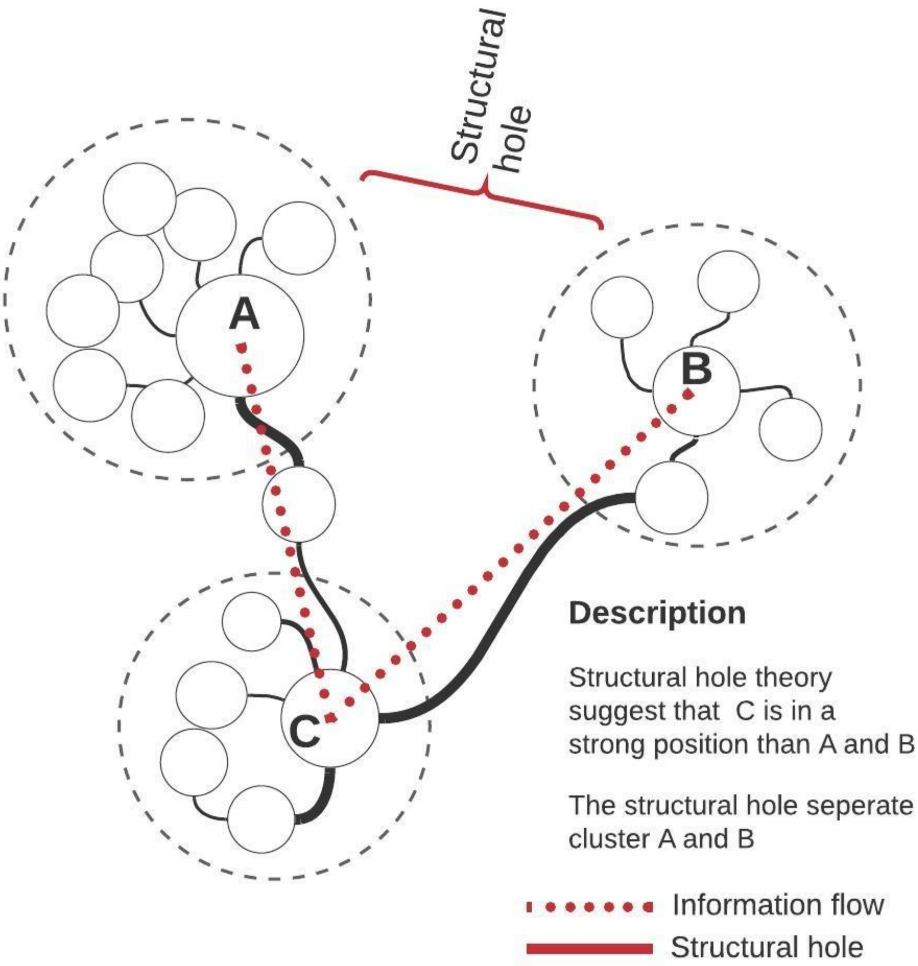


Figure 4.13: Visual display of a structural hole

- Weak ties

Weak ties may link actors from different groups than strong ties (Granovetter, 1973). By plotting nodes connected by strong and weak ties (Figure 4.14), the thesis demonstrates the value of understanding the strength of weak ties in an ecosystem. The thesis used reciprocity of services between actors from the participant's views to determine the strength of a tie using a mapping tool in appendix 5. Identifying strong and weak ties was crucial because a mix of external inputs with internal resources is vital for innovation (Chesbrough et al., 2014). This thesis analysed the tie size by observing visualisation structures based on the size of ties, i.e. thick represent high strength and thin low strength between relations. Colour was also used to represent high (red), medium (orange) or low (yellow) strength.

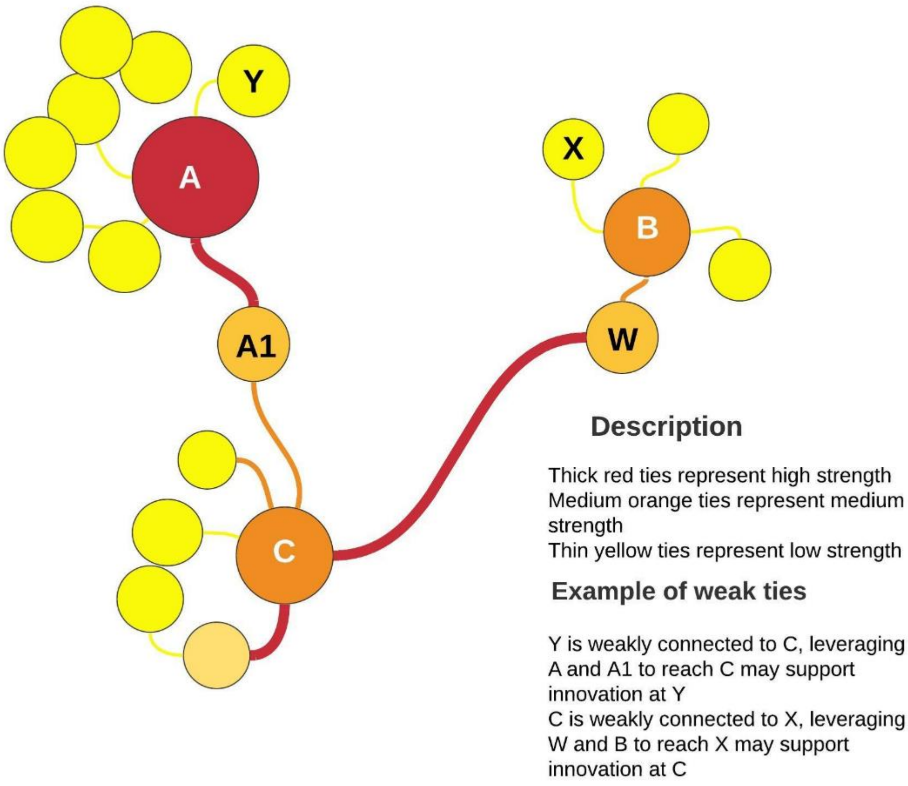


Figure 4.14: Visual display of strong and weak ties

- Role structure

  Role structures were analysed by how the ecosystem structures were arranged in terms of actor's positions, i.e. whether actors are located at the centre of the network (keystones, hubs), or located all over the network (dominators) or in specific areas of the network (niche actors). This method is important because identifying these roles may guide actors in developing collaboration, competition and governance mechanisms (Iansiti and Levien, 2004). These roles are fully explained in chapter 3 (pp.41-46).

This thesis used open-source visualisation tools to model qualitative data from the case studies to understand the above ecosystem attributes. Further details on open-source tools are presented in chapter 5.

4.4 Validity of the study

In Leung (2015), the validity of the research is about the "appropriateness of the tools, processes and data". In Maxwell (2013), validity issues revolve around how the study results and conclusions emerging from the data might be wrong? Maxwell (2013) reiterate that the concept of validity in qualitative research has been the centre of controversial debate for a long time, which led to other researchers abandoning the notion of validity in its entirety because of its link to quantitative methods and inappropriate to qualitative methods. However, Denscombe (2010) argues that validity addresses data accuracy and methods used to obtain data. Creswell (2013) suggest that using many data collection methods increases the rigour of research.

Therefore, this thesis adopted the use of multiple methods to collect data. Again, the study's validity was further reinforced using an iterative coding process, a continuously improving process from one case study to another. Using the same code structure facilitated comparison across different case studies. Further, codebooks provided easy access to code and themes' meaning for internal review; this increased the rigour of the research approach (Guest et al., 2012). Most importantly, the visualisation data was constructed with the participants and later analysed with different visualisation tools. This also increased the validity of the findings through triangulation of results from thematic analysis and visual network analysis. During visual analysis, the study used three different visualisation tools to explore the same datasets, thus improving the rigour of the findings. Below are a few validity threats which were associated with this thesis.

4.4.1 Researcher bias

This thesis was conducted following a qualitative approach, where data collection was done through engaging human participants. Because the researcher anticipated some level of bias in collecting data, varied data collection techniques were adopted to reduce the negative consequences of bias. Although it is impossible to do away with bias which comes in the form of the researcher's preconceptions, beliefs and theories (Maxwell, 2013), showing how these preconceptions have influenced the study was key (Creswell, 2009; Denscombe, 2010), which has been demonstrated through the conceptual framework and research questions used to shape the coding process. The study also demonstrated how the researcher's views were included in the data analysis through the coding and visualisation process. The negative researcher bias was further reduced by engaging a second thematic coder. The thesis adopted the subjective assessment of intercoder agreement (Guest et., 2012), where the researcher and the second coder reviewed their double coded text and reached an agreement in areas where they had a different definition of codes.

The researcher's influence on the setting been investigated is also identified as a validity problem (Denscombe, 2010; Maxwell, 2013). This research study reduced the negative influence of the researcher on the data construction process by using semi-structured questions, which encouraged the participants to give out an in-depth analysis of the setting. The researcher also avoided leading questions to minimize the negative influence on how the participants responded. However, the researcher's reflections were recorded as notes and included in the findings to meaningfully influence the study by factoring in the researcher's views. Other strategies used to improve the research rigour included allowing participants to look at the transcribed data to verify if it was a true reflection of their thoughts. Using workshops for the validity of the thesis output, i.e., Jigsaw design framework (discussed in Chapter 7), presenting the results to manufacturing SMEs, submitting some of the findings to refereed journals for peer review also reduced the researcher's bias by exposing the findings to a large audience of reviewers. This approach is proposed by Creswell (2014) and Silverman (2009) to reduce bias and increase the validity of the findings.

4.5 Reliability

Concerning reliability, explaining the research strategy in terms of how the data was collected and analysed from each case study for the replicability of the processes and the findings is important (Leung, 2015). Using verbatim accounts of participants in reporting themes increased the transparency of the thesis. Other researchers suggest this as crucial in making the findings of the study reliable (Silverman, 2016). The use of visualisations to provide a different approach to analysing qualitative data also increased the reliability of the results. Coding checks, verbatim quotes, triangulation and external reviews throughout this thesis made the research process transparent and reliable.

4.6 Generalizability

Generalizability is about extending the results of a specific study to a broader population. This thesis studied a specific phenomenon of SME innovation ecosystems in Botswana and the UK context, therefore generalizing to a wider population was not the intention of this study, but to focus on theoretical generalizability (Allen and Richard, 2012; Yin, 2012; 2014). This is explained further in the conclusions chapter, section 11.5.

4.7 Ethics

Since this was a qualitative research approach that engaged human participants in their workplaces and factories, ethical approval was applied for and granted by Lancaster University Ethics Committee before conducting the field research (see appendix 20). Following approval, the researcher sends the information sheet (appendix 15) and the consent form (appendix 16) to the participants who were interested in the study. This was important to ensure that participants privacy and identity is protected (Bell, 2019). This was also done to ensure that participants were aware of their rights to participate and withdraw at any time from the research. Also, to seek clarifications on the study before they participate, sign the forms and allow the researcher to access their data and guarantee their confidentiality (see appendix 15, for further details).

5 Pilot project and tools development

The previous chapter discussed the methodology and rationale for this thesis. This chapter presents findings from an exploratory study conducted in Lancashire, UK. This was the first phase of the case study approach to generate in-depth knowledge about how decision-makers understand innovation ecosystems. The pilot study tested the appropriateness of the research focus and methods, thus determining early suggestions on the validity of the methods.

5.1 Introduction

Although SMEs acknowledge the complexities of ecosystems, they seem to lack the tools to understand ecosystem dynamics (Jacobides et al., 2018; Adner, 2017). There is a need to understand ecosystems better and explore new opportunities for innovation (Su et al., 2018; Rong et al., 2018). This chapter addresses the following objective as part of answering research question 3:

> *To explore the 3D printing-based innovation ecosystem cases through engagement with experts to build an understanding of how they shape their innovation ecosystem structures.*

To develop this understanding, the thesis starts by exploring SME ecosystems associated with 3D printing technology. Also, the pilot study explores open-source visualisation tools to determine the most useable ones for analysing relational data. The cases were investigated through semi-structured interviews and a visualisation tool to capture relational data, i.e. data on stakeholders connected to the focal actor. The researcher visited participants at their workplaces for in-person interviews and visualisations. All interviewed participants were directors and founders. Below is the rationale for selecting cases.

5.1.1 Case selection

Case study selection was based on the potential of 3D printing technology to transform the economy (Hague et al., 2016; Hauser, 2014). The study considered selecting three cases based on three factors, i) creative industry, ii) public access, iii) manufacturing industry. These categories were considered relevant to be comparable to Botswana sectors.

Ceramic artist ecosystem case

This case study provided an opportunity to explore how the ceramic artist leverages external resources to create more value as a freelancer. This was considered relevant because the artist transformed from doing pottery to ceramic 3D printing to leverage the new technology. Some of the ceramic work produced in this case is shown in Figure 5.1. This case seemed to be embedded in a web of research on ceramic materials, collaborations with Universities and research centres outside the UK. The transition from the conventional to the digital realm of 3D printing ceramics made this case interesting. The ceramic artist was identified through a colleague at Lancaster University and contacted through an email (see appendix 18).

Figure 5.1: Photo showing work from the ceramic artist ecosystem (Courtesy of Adrian Sassoon, London)

FabLab ecosystem case

This case study provided an opportunity to explore how FabLab (Fabrication Laboratories) spaces create value for makers and SMEs. Makerspaces as commons-based peer production spaces (Troxler and Wolf, 2010) were identified as relevant for manufacturing SMEs to experiment with digital fabrication tools such as 3D printers. The study selected one of the first makerspaces in the northwest of England because the director who participated in this study was involved with setting up makerspaces across England in the last ten years. This was an interesting case study because the FabLab resembles a local ecosystem, influencing how actors collaborate and turn rudimental ideas into potential business innovations. Figure 5.2 shows a co-working space at the FabLab. The research identified this FabLab through a colleague at Imagination Lancaster. The director was recruited through an email and agreed to participate in this study.

Figure 5.2: Photo showing co-working space from the FabLab ecosystem (Photo taken by the author)

3D printing bureau service case

This case study presented an opportunity to explore how bureau services create value. This 3D printing bureau case is located in the northwest of England in the Lancashire area. The study selected this case because of its niche clients, such as motorsport, aerospace, UK National Health Services, and others. Examples of work from this bureau ecosystem are shown in Figure 5.3. This case was identified through a referral from the FabLab case. This was followed by a formal email correspondence to the director who agreed to participate in this study.

Figure 5.3: Photo showing work from the 3D printing bureau service ecosystem (Photo taken by the author)

5.1.2 Data collection

Semi-structured interviews and visualisations

The main advantage of using semi-structured interviews is to provide a detailed account of the case in a relaxed open conversation. To achieve this, the researcher visited the first interviewee, i.e. the ceramic artist, at his home laboratory in the north Lancashire area. This approach allowed the researcher and the interviewee to chat over a cup of coffee before the interview. The chat was useful to build trust and confidence before the actual interview. During the interview, the researcher asked for permission to record the session, which was granted. The researcher started by moving from general introductory questions to more specific ones, using prompts to make follow-ups and re-direct the interview. This process was relaxed, and the interviewee felt free to share his experience. Details of the interview questions are shown in appendix 4. The researcher also used a visualisation tool (Figure 5.4) to collect relational data for further analysis with open-source tools. The mapping tool supported collaborative engagement with the interviewee; it also helped to recall contacts and links. This interview lasted for 65 minutes.

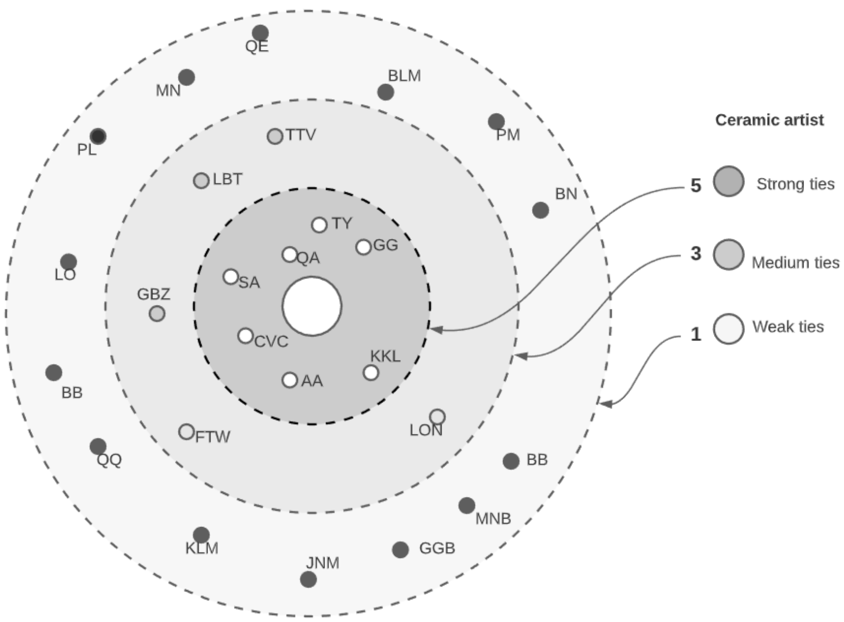


Figure 5.4: Example of how the mapping tool was used during the interview

Then, the second interview was conducted with the FabLab director. Before the interview, the researcher visited the FabLab to interact with the interviewee and FabLab users. This interview was done following the strategy on page 71 and appendix 4. The director opted to be interviewed in his office, where it was considered to be quieter. The research also used the mapping tool to visualise contacts and connections from the interviewee's perspective.

For the third interview, the researcher travelled to Burnley to interview the 3D printing bureau director. This event was also coupled with a tour of the factory. The director took the researcher around the factory floor to appreciate what the firm was doing. Then the interview took place in a conference room, following strategies in chapter 4 (p.71) and protocols in appendix 4. The researcher used the mapping tool like in the previous cases to further engage with the interviewee to generate relational data.

All the interviews were conducted in English language, and participants re-briefed about their rights to withdraw from the study at any time. Participants understood and stated their interest to participate in the study.

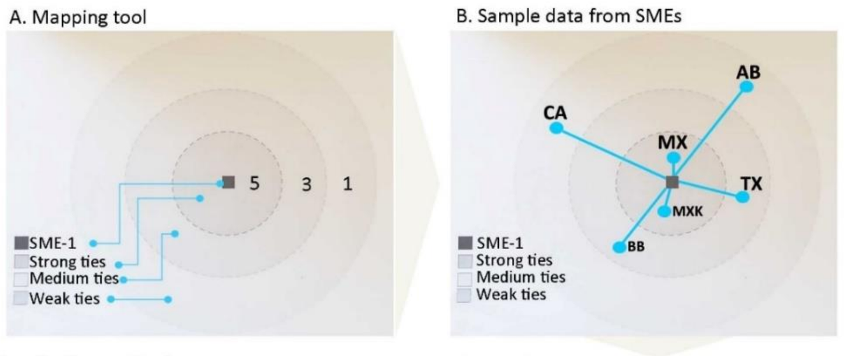
5.1.3 Data analysis

This study combined thematic and visual network analysis techniques to analyse qualitative data in transcripts, notes and relational datasets. Refer to the methodology chapter on how the thematic analysis was conducted.

Visualisations

Further to the thematic analysis, the study used visualisation techniques to explore relational data. This was achieved by firstly converting visualisation maps from the fieldwork into edge list datasets for each case following a procedure outlined in Figure 5.5. As shown in Figure 5.5 (B), a mapping tool from the field used to capture positions and strength of actors in the network was first used to generate datasets shown in Figure 5.5 (C), i.e. showing relations between actors and their strength of ties on a scale of 1 (weak ties), 3 (medium ties) and 5 (strong ties). Datasets were then analysed using different visualisation layouts, e.g. chord layout, force-directed layout and 3D layouts, as shown in Figure 5.5 (D).

These datasets were transformed into various formats, e.g. comma-separated-values, edge lists, JavaScript Object Notation depending on the tools used for analysis. These datasets can be viewed online at (Nthubu, 2020c). Also, see appendix 21 on how Gephi, google sheets and Omicsnet tools as main tools were used for further clarity.



D. Visualisation methods

Tools layout	Attributes tested
Chord layout	Strong &weak ties, Actors degree
Force Layout	Centrality & Bridging actors
3D layout	Structural holes & clusters
.....	.....
n	n

C. Sample Datasets

Source	Target	Weight
SME-1	MX	5
SME-1	TX	3
SME-1	AB	1
SME-1	CA	1
.....	......	.....
n	n	n

Figure 5.5: Process of transforming visualisation data into edge list datasets

Amongst many visualisation tools available freely online, the study randomly tested 20 open-source tools with ecosystem datasets. Then the researcher selected 14 visualisation tools for this pilot study because of several reasons. First, the tools were usable in modelling, and revealing ecosystem attributes described in chapter 4 (pp.82-87). Second, they required minimal coding skills to use. Third, the tools explored many attributes at the same time. Forth, tools were easily customisable in terms of colour. The following tools were selected; Gephi, NetworkX, Chord Snip, Sankeymatic, D3.js, Tableau public, SocNetV, R-Chie, OmicsNet, GraphCommons, RAWGraphs, Cytoscape, HighCharts and Zingsoft. These tools exhibited the potential to help decision-makers in the exploration and understanding of ecosystem attributes and the discovery of new insights. After selecting the tools and data formats, the researcher formatted the data according to each tool format requirement and started the modelling and analysis.

Next, the chapter reports findings from the thematic analysis followed by visualisations. Then conclude by reporting the research direction, tools limitations and practical implications for using open-source visualisation tools in understanding ecosystem structures.

5.2 Findings and discussions

From all cases, participants highlighted crucial factors that influence their understanding of ecosystems. The next sections report and discuss the main findings across three cases by looking at thematic findings followed by visualisation insights.

5.2.1 Thematic findings

By displaying data in a graphical framework, the thesis represents four core themes from the analysis to demonstrate the understanding of ecosystems across three cases (Figure 5.6). The first theme is the **Initiation** of ecosystems. Most participants described factors associated with knowledge exchange, such as enabling experimental work across firms, encouraging information sharing and open communication. The second theme is the **design and development** of ecosystems. Discussions were around the challenges of how to make sense of ecosystem configurations. Directors highlighted shared value, building collaborations, enabling key actors and roles, leveraging shared resources, accessing bigger markets and expanding ecosystem spaces as important. The third theme is the **management** of ecosystems. Here participants highlighted factors such as data use and interrelationships. The last theme is the **sustainability** of ecosystems. Participants raised key factors such as ecosystem health, trust, motivations, uncertainties and evolving relationships.

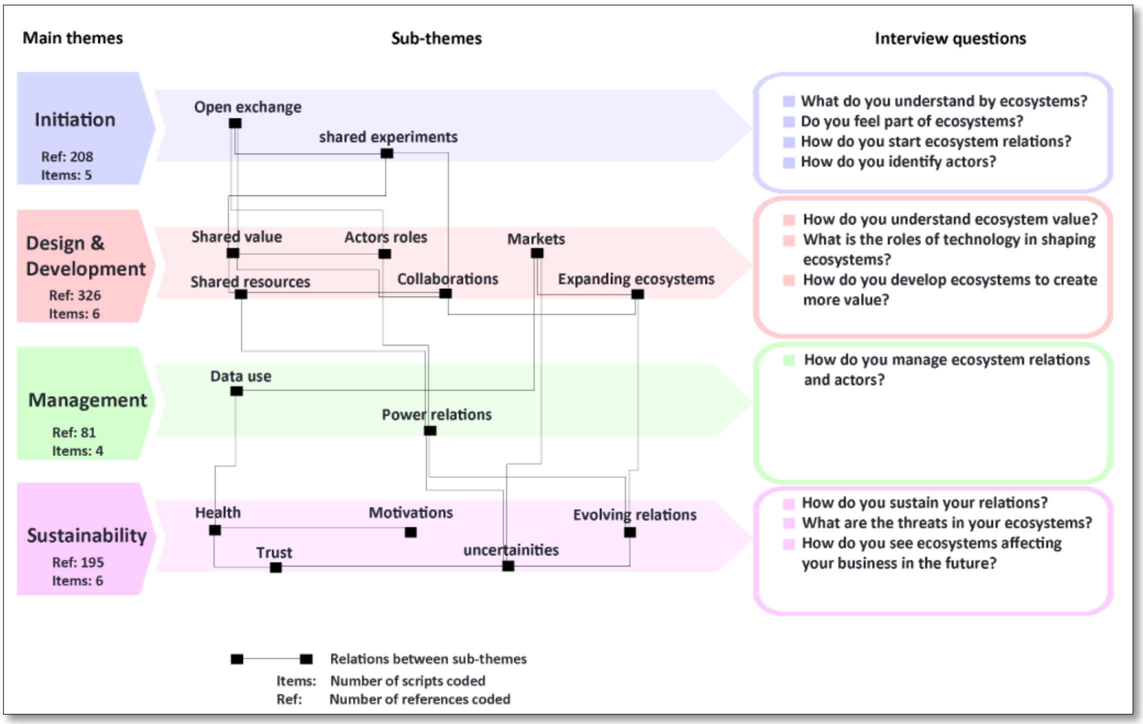


Figure 5.6: Findings from a thematic analysis process showing main themes, sub-themes and main interview questions.

5.2.1.1 Initiating ecosystems

When answering the questions on initiating ecosystems, all respondents highlighted the need to establish a rapport where knowledge might occur and expressly noted that engaging in collaborative experiments is key in initiating productive innovation ecosystems.

Open exchange and collaborative experiments

Directors in all cases reiterated that having an open exchange of knowledge and skills was crucial in understanding ecosystems, i.e. how knowledge flows across ecosystem actors to promote productive ecosystems. Since this case study was based on how 3D printing influences the shape of ecosystems, keeping up with recent 3D printing technologies was highlighted as important across three cases. One director added:

> *"Keeping up to date with advances in technology and exchanging contacts with companies who are using processes of developing, processes of materials that might be of interest to me is key" (Artist).*

The above quote also resonates with the FabLab environment, where the study found that sharing information and knowledge either through collaborating in tinkering or workshop activities was regarded as crucial. Having open labs for experimentation promote knowledge exchange amongst disconnected communities. Other scholars also found that experimental work across disciplines aggregated knowledge to support the ecosystem initiation (Walrave et al., 2018; De Silva et al., 2018). Open exchanges across clusters were more evidenced in the FabLab and artist ecosystems than in a 3D printing bureau case because of lack of trust. One director elucidated:

> *"I mean we have lost a really large customer to xx [referring to a 3D printing manufacturing firm] and so … that made life difficult for a little while, but then you know we have been able to find new customers, but nothing is stopping that happening again you know, we are running on trust you know, which is very difficult sometimes" (3D printing bureau).*

It appears the 3D printing bureau case depend on trust to collaborate with dominating manufacturers. Consequently, leading to some manufacturers taking advantage of their business contacts. Implications for abusing trust are that decision-makers may need trust-based mechanisms to protect their interest (Bernstein, 2016). Other authors also suggest creating non-hierarchical relational contracts to curtail unfair business practices (Kwak et al., 2018; Adner, 2017a), although this is challenging because of the uncoordinated interrelationships existing in the ecosystem structures (Ma et al., 2018; Masys and Bennett, 2016). In the long term, understanding conditions such as establishing shared visions within ecosystems and promoting a continuous exchange of resources may lead to more trust-based relations.

5.2.1.2 Design and development of ecosystems

In addressing how actors design ties and what factors affect their ecosystem understanding, participants agreed that establishing a shared value, building collaborations, understanding roles of actors, leveraging shared resources, accessing bigger markets and expanding ecosystem spaces were crucial.

Establishing a shared value

Participants identified shared value as an important factor in shaping formidable connections between ecosystem actors and the community. The study also found that value is cultivated around shared interests, based on the premise that interconnectedness creates value in support and access to resources. Participants agreed that having an open exchange promote perceived mutual benefits amongst ecosystem actors. One director added:

> *"We have leverage with the business and suppliers, the machine suppliers to say you know if you are going to put a new machine in the market, and you want to get to market, put one here, and we will show off for you…" (FabLab).*

From the above quote, the FabLab space and the equipment suppliers leverage social capital, i.e. trust based on mutual benefit and understanding. Trust is demonstrated in previous literature as a mechanism for building networks (Mortati et al., 2012). Other scholars also highlight that shared values unite actors around an ecosystem value proposition (Rong et al., 2018), thus creating favourable conditions for enhancing ecosystem understanding.

Building collaborations

Aside from creating value, it was found that actors need to collaborate in innovation processes for ecosystems to thrive. This was highlighted in the FabLab ecosystem, where the director espoused tinkering activities in open days as a source of inspiration for newcomers, entrepreneurs and established businesses to engage each other. Interestingly, a FabLab space promoted social activities and tinkering through free workshops and open days to facilitate ecosystem ties.

> *"Open days are our inspirational bits. That is where I want to let people see what is possible… have a play and start to kind of getting ideas forming and get the inspiration" (FabLab).*

The Artist and the 3D printing bureau cases also highlighted that collaborative experiments are cost-effective and allow them to test the relationships with other actors before committing resources. The artist elucidated:

> *"With any manufacturing system, ... things always go wrong, there is always trial and error, and in a way, ... it is far more cost-effective for me to have my work made by a 3D printing bureau" (Artist).*

Therefore, participants agreed that the emergence of effective ecosystems could be achieved through building collaborations. These findings corroborate previous studies, where collaborative experiments were used to manage uncertainties in entrepreneurial ecosystems (Gomes et al., 2018). Roundy et al. (2018) also found that entrepreneurial ecosystems use experiments to identify partners.

Key actors and roles

Identifying potential actors and their roles appeared to be widely acknowledged by the respondents as crucial. They highlighted the challenges of identifying key actors who can provide support and niche roles in building productive ecosystems. One director emphasised:

> *"We were very lucky to have a salesman who is very well connected in the industry, and he generally has a very good range of contacts, he knows where machines are, he knows where potential customers are likely to be, potential applications mainly just through communicating with lots of people in the industry" (3D printing bureau).*

As noted earlier, experimentation provides the opportunity to identify potential partners. This is common in a FabLab environment, where start-ups and individual makers identify important actors and roles during open activities. Identifying key actors to perform bridging or keystone roles within the ecosystem structure was highlighted as essential in leveraging the heterogeneity of ecosystem actors, albeit challenging. One respondent added:

> *"We do not want to do it all, because we are not experts in all, we are experts in our small part of it, but we work within an ecosystem of experts in all different perspectives, ...sometimes it is challenging to identify or get the right expertise to assist" (FabLab).*

Regarding the above, working in a diverse, interconnected milieu provide serendipity for innovation because actors can focus on their strength as a contribution to a whole.

The study found that understanding the actors and their ecosystem structure may aid strategic decisions. The more ecosystems grow in complexity, the more challenging in terms of understanding ties and roles.

Leveraging shared resources

The issue of sharing resources emerged as necessary in all cases. In a FabLab, bringing diverse actors together to try out new business ideas and technologies was highlighted as the main source of social capital. Respondents acknowledged the role of technologies, i.e. 3D printers, laser cutters, vinyl cutters, and others shaping the makerspace ecosystem. These digital fabrication tools were accessible to start-ups, SMEs and individual makers, thus making the FabLab a shared environment for tinkering and co-creation. This is elaborated:

> *"3D printing …transforms that whole process so that it is easy now to quickly create a design, prototype it, and then test it physically" (FabLab).*

Leveraging 3D printers hastens the product development process for makers. Similarly, the Artist said that the relationship with engineers in ceramic materials and 3D printers expediated the product development process. This was achieved by partaking in collaborative experiments to develop ceramic products with new materials and processes:

> *"Xx [3D printing equipment manufacturer] have developed what they call a resin ceramic, after their stereolithography system and they have successfully printed some pieces for me, and I saw some examples when I was over there in Boston, USA" (Artist).*

The implications for sharing resources such as 3D printers are in supporting start-ups with limited resources. This study found that in the FabLab ecosystem, actors such as start-ups and established SMEs leverage their networks to gain access to high-value tools, particularly 3D printers and laser cutters. Similarly, the artist ecosystem seemed to rely on a 3D printing bureau service to leverage high technology 3D printers to prototype and manufacture ceramic products. These findings validate previous studies, which posited that sharing resources, specifically digital technologies, significantly promoted the growth of innovation ecosystems (Kwak et al., 2018).

Accessing bigger markets

On the question of how ecosystems promote shared markets, respondents had different reactions. The FabLab as a makerspace highlighted the significance of actors to share business, particularly where SMEs have different capabilities and limitations. Having access to the FabLab space exposed actors to potential markets because of more than 700 registered users, entrepreneurs, schools and companies affiliated to the makerspace ecosystem. This is elaborated:

> *"We have now got I think over 600-700 registered users, who have gone through induction in terms of this labs, and we have about 4000/5000 businesses a year, that has grown over two years" (FabLab).*

Although the FabLab provided access to a large market, it seemed makers were not adequately taking advantage of the ecosystem to open new markets. The study found that equipment manufacturers were stifling the 3D printing bureaus in terms of diversity and growth. This is explained:

> *"It would depend on how the manufacturers [3D printing equipment manufacturers] want to operate, and now If the manufacturers sought of loosening things a bit and they were able to drop the costs it would open new markets for ourselves, our competitors and everybody down sought of the food chain would benefit" (3D printing bureau).*

The 3D printing bureau is different from the FabLab and the Artist ecosystem because they use tools from competitors, consequently leading to unfair business practices where manufacturers end up poaching customers from bureaus. As discussed earlier, this could be partly addressed through trust, albeit over long-term periods. The negative effects of having many dominators in a single ecosystem structure are also discussed extensively in previous studies (Talmar et al., 2018).

Expanding ecosystem spaces

Building collaborations, leveraging shared resources and markets are efforts towards expanding the ecosystem. The FabLab environment was highlighted as a platform where hobbyists and novice entrepreneurs turn their tinkering ideas into successful entrepreneurial ventures. This is captured below:

> *"You got a good idea, and we can take you through and help you and coach you, it's all aimed towards that building map network in that environment… We collaborate with even those with potential, but who really don't have money, we see a way we can work with them" (FabLab).*

In a 3D printing bureau case, expanding the ecosystem space seemed to be a challenge. The respondent highlighted that they spend most of their time developing ideas and less on growing the network. This finding was not a surprise because bureaus are typically about creating profit for investors. The study also found prevailing opportunities where bureau ecosystems might expand to other manufacturing sectors. This is supported in previous research, where other 3D printing bureau services actively seek alternatives to expand their options (Rong et al., 2018).

5.2.1.3 Management of ecosystems

Regarding how ecosystem actors manage their interrelationships, respondents raised the following factors as important; data use and power relations.

Managing data use

Managing relationships was noted as important, especially the use of data and power relations between actors. From the study, it was evident that minimal effort is channelled towards gathering and utilising ecosystem data. One director added:

> *"We don't have enough feedback data that we collect, we do have some, we do use it a little…yeah but we don't have enough to build on, that's sort of what we are working on to try and improve" (FabLab).*

There was limited data on users and how data might improve makerspaces. The same was observed in the Artist and 3D printing bureau cases. In the artist ecosystem, the gallery fully manages the business side, thus creating a structural hole between the artist and some customers. These structural holes may limit access to key data for innovation. The director elucidated:

> *"They [referring to the gallery] are responsible for choosing which fairs to attend, which curators, which museums to speak to, which private collectors to speak to when I bring out some new work when I have an exhibition, they put together the list of invitees to private views, you know…" (Artist).*

Respondents agreed that there is a lack of data collection and use in the innovation ecosystem. Implications for lack of data are that it becomes challenging to manage ecosystem relationships without knowing how the actors are configured in terms of roles and ties. For example, keeping records of people using the makerspace tools seems to be less useful unless the decision-makers can use the data to improve makerspaces. This finding broadly supports the work of other studies on managing effective innovation ecosystems (Dedehayir et al., 2018; Walrave et al., 2018).

Power relations between actors

Regarding power relations, respondents revealed that aligning business decisions and actions lead to the realisation of an ecosystem value proposition. In a FabLab ecosystem, the director has the autonomy from board members to manage the makerspace. But the Artist does not have the prerogative to decide on what idea ought to be manufactured and commercialised. Although the artist emphasised mutual benefits, he does not have the power to manufacture and sell. On the other hand, equipment manufacturers were identified as dominators in manufacturing 3D printers, selling them to bureau ecosystems and competing with them for markets. This is elucidated:

> *"I feel like a lot of the maintenance and things like that is overly expensive you know, and it makes it difficult for us to make a good profit … because when you got XX [equipment manufacturer] trying to make a lot of money, YY [another equipment manufacturer] trying to make a lot of money, the resellers trying to make a lot of money and then when you get actually to try to sell an application to a customer, it can be quite difficult" (3D printing bureau).*

Implications of this sought of dominating behaviour may eventually starve the resellers and bureau services, and by extension, the entire ecosystem. Previous literature point to a lack of a clear value appropriation logic for ecosystem actors (Rabelo and Bernus, 2015; Adner, 2017b), which often lead to the disgruntlement at the bottom of the 'food chain'. The use of relational contracts and trust as suggested previously in this chapter and highlighted by Dedehayir et al. (2018) and Adner et al. (2017) may help protect the bottom of the 'food chain'. So, understanding centres of power and influence within the ecosystem structure was considered crucial in managing ecosystems.

5.2.1.4 Sustainability of ecosystems

In responding to how directors sustain their existing ecosystems, respondents highlighted the following factors as important; ecosystem health, enabling trust, leveraging non-rational motivations, exploring uncertainties and surviving evolving relations.

Health

In interconnected environments, it is widely acknowledged that the decisions and actions of actors are intertwined (Adner, 2012; Iansiti and Levien, 2004). Respondents noted the need for collective capabilities in promoting a healthy ecosystem. So, they highlighted understanding the actor's roles and possible impact on other actors in the ecosystem structure as important.

> *"I was very happy to be fully represented by XX [referring to the gallery], …the advantage of been represented by XX is that they have introduced me to the world that I basically knew nothing about… so they do a fantastic job of promoting the work" (Artist).*

The above quote is an example of a healthy relationship between the Artist and the gallery. It seemed the two actors understood how their actions and roles impacted the ecosystem health. Understanding shared fate is crucial in sustaining ecosystems. Interestingly, a 3D printing bureau ecosystem seemed to present an unhealthy situation compared to the artist case. One director added:

> *"I feel like we are quite tied down, and it's almost like treading in the water a lot of the time, so the investors are keen to see return on investment, the resellers and manufacturers want to make a good profit, and we are just trying to sought of get by" (3D printing bureau).*

Given the above quote, recruiting niche actors into the innovation ecosystem to improve health is crucial in this case. This could be achieved by sub-contracting work to other specialised bureaus, where the 3D printing bureau case has limited capabilities.

Trust

Trust was highlighted as an important factor for developing relationships and initiating ecosystems on page 99. Similarly, under sustainability, trust was observed as a strong currency. It is sometimes challenging to operate with contracts in a networked environment because of the constantly changing relationships. Respondents agreed that trust was a necessary form of currency in sustaining ecosystem ties. One respondent shared:

> *"Being able to trust, completely trust and know that the relationship is symbiotic, that we are both gaining from that relationship, it's a lot to do with human contact and trust, and then I would say they are no boundaries" (Artist).*

The above quote emphasises the significance of trust in sustaining ecosystems. Other scholars also note that building trust and honest relations are crucial in sustaining ecosystems (Hwang and Horowitt, 2012; Presenza et al., 2019). Without trust, it is difficult for actors to work with strangers (Leung et al., 2019).

Motivations

The sustainability of ecosystems is also propelled by non-rational motivations such as friendships and volunteerism. The FabLab case reported having several volunteers engaged to assist community users and SMEs in tinkering activities. The director added:

> *"I have got two staff that are makers anyway, and they are makers at heart. Both have volunteered for a long time, and they both run businesses very well, so they are perfect for our objectives, they are so enthusiastic, and they stay long hours, they do this because they love doing it" (FabLab).*

Having people driven by altruism resonates well with a makerspace environment, obviously because of its non-profit orientation. Meanwhile, the Artist uses non-rational motivations such as friendship ties with other professionals to lower transaction costs of experimental work with 3D printers. Remarkably, the 3D printing bureau seemed to rely more on return on involvement by exchanging customers with other bureau services. The participant added:

> *"It's just almost like a friendship really in as much as they are passing work to us, and we also pass work to them sometimes" (3D printing bureau).*

This kind of transaction is solemnly based on trust. Following the present results, previous studies demonstrated the importance of non-rational motivations in sustaining ecosystems (Hwang and Horowitt, 2012; Presenza et al., 2019).

Uncertainties

About uncertainty in ecosystems, this study found that the asynchronization of diverse actors and roles lead to misaligned business choices and negative ecosystem performances. Furthermore, the FabLab director reported low adoption of 3D printing technology contrary to expectation as a major source of uncertainty. This was because of challenges with the design for 3D printing faced by makers. The director added:

> *"I think we need to simplify it, we almost need to produce a sketch, 3D model, … we had 3D SketchUp a few years ago, but it's still not as intuitive as it could be, we almost need something … haptic so that we can control and almost scoop things by hand and without having to do all the drawing and icons during the design" (FabLab).*

Although there was evidence that people were attracted to 3D printers in makerspaces, respondents highlighted that laser cutters were the most used digital fabrication tools in a FabLab environment. Lack of knowledge raised a lot of uncertainties and doubts on users directly interested in 3D printers. Rong et al. (2018) highlighted many uncertainties associated with low 3D printing technology knowledge and uptake. Other uncertainties include predatory behaviours as demonstrated in a 3D printing bureau ecosystem. The prohibitive costs of industrial 3D printers limit the capacity of a bureau service. Therefore, accessing other bureau services may increase the capacity to serve customers consistently, thus retaining confidence and loyalty to sustain the ecosystem.

Evolving relations

Changing relationships can sustain or lead to the death of a productive ecosystem. Since these ecosystems are based on the technology of 3D printing and other digital tools, technologies change, and so are business models across firms. The study found that the artist ecosystem stayed attune to the advances in technology by forging ties with equipment manufacturers. The director added:

> *"The technology is moving quickly, particularly in materials development, and I feel like I have to keep up, and I am interested as well because for me it's about the appropriation of technology" (Artist).*

As highlighted in the above quote, the participant's ability to keep up with new technologies is important for sustaining ecosystems. A 3D printing bureau case continually adopts new technologies but fails to open new markets to expand the ecosystem. It would seem that markets keep changing and influence how ecosystems change too. Rong et al. (2018) describe evolving ecosystems as adopting new parameters from changing markets. Therefore, increasing ecosystem ties to reach new actors might lead to the sustainability of ecosystems.

Highlights of themes

Initiation of ecosystems

The project found that initiating ecosystems start with creating conditions where communities of actors might connect through open exchange and collaborative experiments. Therefore, understanding the structure of ecosystems and seeing connections, roles and gaps within the structure were considered important.

Designing & developing ecosystems

Designing the understanding of ecosystems is about knowledge of factors that influence productive ecosystems. Establishing a shared value, building ties through collaborations, identifying key actors and roles are some of the key factors that influence the design of ecosystems. However, respondents expressed challenges associated with identifying important roles in the ecosystem, highlighting the risks of working with some of these actors. Knowing the ecosystem configuration may aid decision-makers in planning and expanding ecosystems.

Management of ecosystems

In terms of managing interrelationships within ecosystems, respondents agreed that they are underutilising ecosystem data in decision-making. This data can be used to explore how ecosystems are configured and even design future configurations. Identifying centres of influence in the ecosystem structure was highlighted as key in the decision-making and management of ecosystems.

Sustaining ecosystems

The study found that the health of the ecosystem can be enhanced by trust and non-rational motivations like friendships as sources of social capital. The study also found that evolving relations can sustain or lead to more uncertainties. It was important to identify and understand significant ties in the ecosystem.

Structural attributes such as clusters and bridges, actors, structural holes, relationship strength and ecosystem roles were challenging to identify and understand through a thematic analysis method. A lack of understanding of ecosystem attributes may affect decision-making. Next, the chapter presents findings from an exploratory study with open-source visualisation tools to test the above ecosystem attributes.

5.2.2 Visualisations

The study analysed data using open-source visualisation tools. Appendix 19 shows results from the visual network analysis, which are discussed in the following section.

5.2.2.1 Exploring ecosystem node hierarchy

By plotting the relational data from three cases using the chord layout and treemaps, the thesis reveals node hierarchies clearly (Figure 5.7). Amongst the 14 tools used, only nine had colour customisation capabilities, and it was challenging to do so in some tools, e.g. Sankeymatic (Figure 5.8). By observing the colour scheme, Chord layouts and treemaps show node hierarchies more clearly than in most layouts. For example, by looking at the artist case, the artist node is bigger than the gallery node, possibly because the Artist engages more in innovation activities than the gallery. Consequently, suggesting that the Artist has a greater influence on innovation activities. Meanwhile, a closer inspection of the FabLab ecosystem also indicates a consistent and similar pattern to the artist case (Figure 5.7), where the FabLab workforce node has a high degree of connection. Thus, revealing the FabLab staff as the most influential node across the layout, signifying its importance in the innovation process.

In a 3D printing bureau ecosystem, many actors appear to have high node hierarchies, and this could be because they are both involved in isolated innovation activities and only connected to few mutual customers like aerospace clients. Implications for these isolations are that competing manufacturers and bureau services highly dominate the ecosystem in a small niche market, which may lead to oversupply. Bureau services may explore alliances with equipment manufacturers to survive in these kinds of ecosystems.

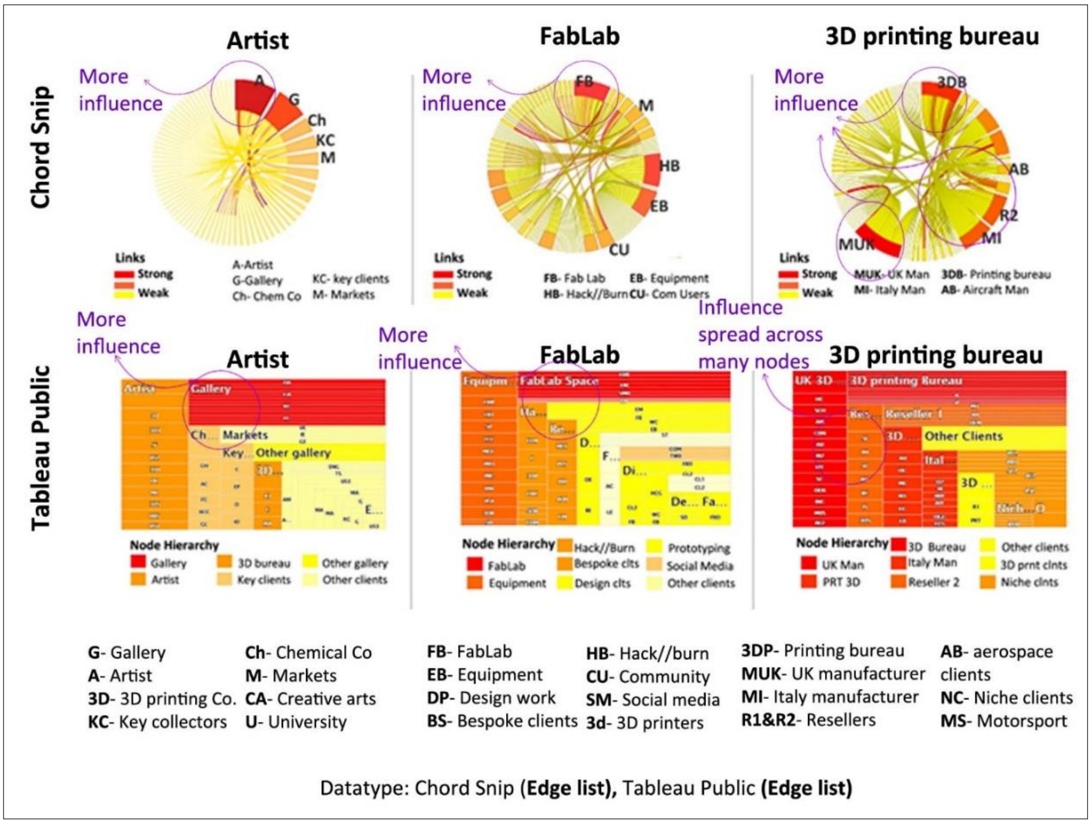


Figure 5.7: Examples of node hierarchy visualisations using Chord snip and Tableau public tools across three ecosystem cases.

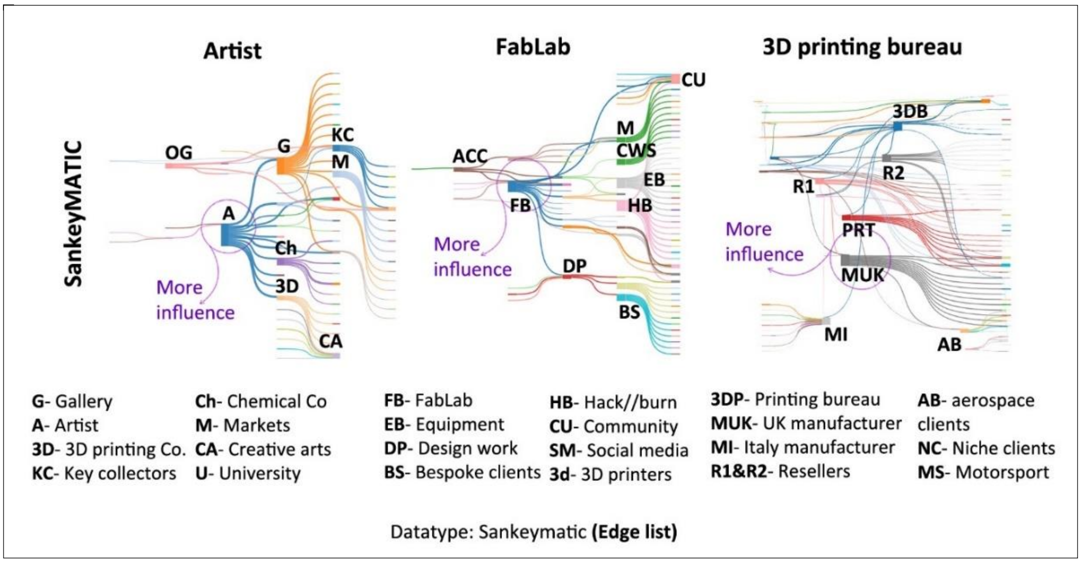


Figure 5.8: Examples of visualisations of node hierarchy using the Sankeymatic tool across three ecosystem cases.

5.2.2.2 Exploring ecosystem clusters and bridges

As shown in Figure 5.9, by plotting data using a force-directed and orthogonal layout in Gephi and Cytoscape, respectively, the thesis reveals ecosystem clusters and bridges more clearly. For example, under the artist ecosystem, the structure is divided into a two-sided network, i.e. manufacturing and business sides. By observing the thickness of the ties in Gephi and Cytoscape layouts, the gallery-artist link is identified as the main bridge connecting the two sides. This could be because the gallery provides the market for the artist products, thus allowing the Artist to focus on the manufacturing side of the ecosystem. It can be assumed that this bridge is the most critical in allowing information flow across, and its absence may completely cut off the Artist from leveraging the gallery market.

A similar arrangement of a two-sided ecosystem is observed in a FabLab network, with the workforce acting as a bridge between equipment booking and design and prototyping service clusters. This may indicate that the absence of self-motivated FabLab workers could create gaps between the FabLab users and equipment services, thus affecting the ecosystem health. FabLab workers play a key role in the makerspace, making it livelier and more enjoyable. Appreciating these bridges may aid the deployment of safeguarding mechanisms to motivate the workers. A low density of clusters is observed in the artist ecosystem compared to the FabLab, and this may be because the artist markets are sparsely distributed across the world, while the FabLab ecosystem high density could be attributed to the physical proximity of its actors; most of the FabLab users are from the same city.

Regarding the 3D printing bureau case, there are many clusters and bridges across the network, forming a group of small star-shaped communities appearing everywhere (Figure 5.9), suggesting that actors are connected to their hubs, possibly as customers or clients. These findings may help the ecosystem leaders to identify potential hubs and bridges by observing visual weights or densities of clusters, where high-density clusters may function as keystones or hubs. These findings corroborate previous literature on using visual weights of graphs to improve decision-making (Bradley, 2013).

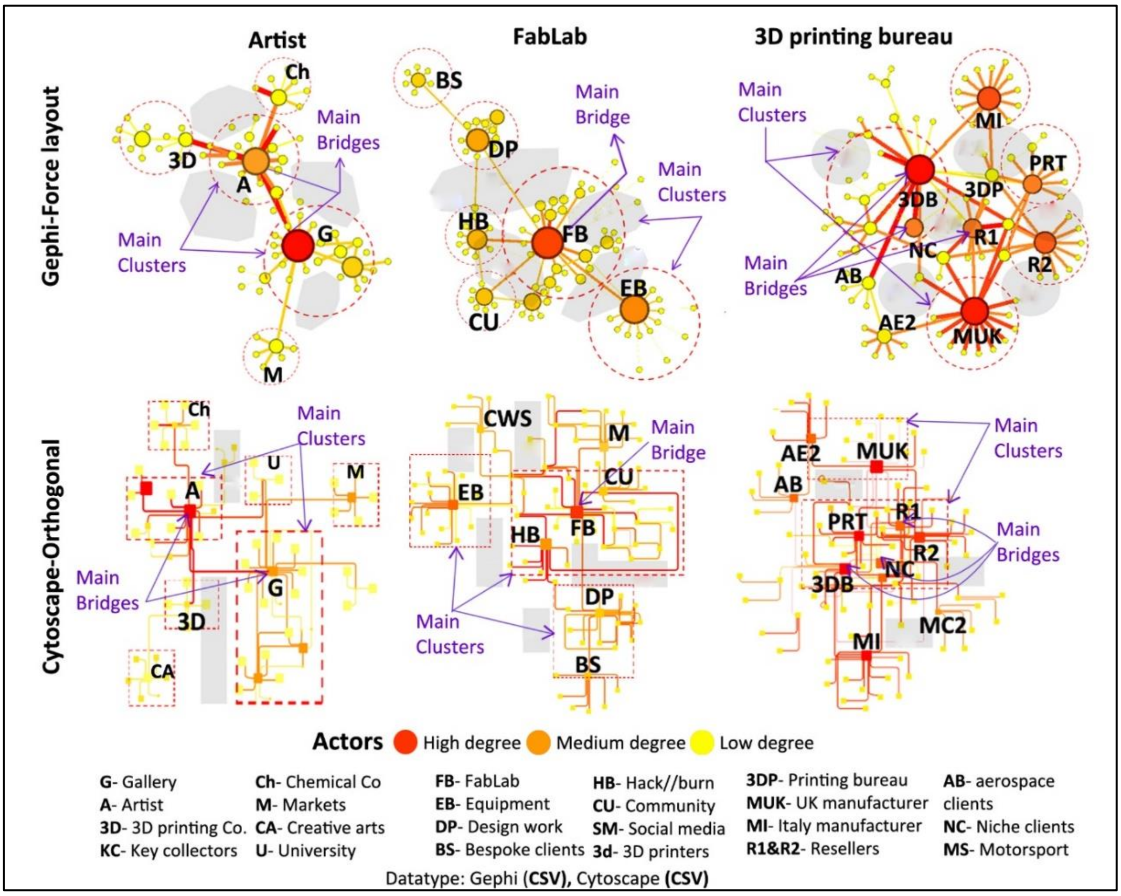


Figure 5.9: Examples of visualisations of clusters and bridges using Gephi, and Cytoscape tools across three ecosystem cases.

5.2.2.3 Exploring ecosystem structural holes

Plotting ecosystem data using OmicsNet 3D and NetworkX Kamada Kawai layouts reveals structural holes consistently across three cases (Figure 5.10). Most visualisation tools generated similar patterns of structural holes (appendix 19). However, the OmicsNet tool has more affordances in revealing holes through 3D interfaces than in other tools. NetworkX also reveals holes more clearly. Although other tools show structural holes, it was challenging to establish consistency and significance, e.g. in Sankeymatic layouts (Figure 5.8).

Analysing structural holes (Figure 5.10), hole-1 separates the gallery and 3D printing firms, and this could be because the gallery is not involved in the manufacturing process done by 3D printing firms. In contrast, hole-2 separates international markets and key collectors, and this could be because collectors seem to be interested in private gallery events instead of international trade fairs. Hole-3 separates the Artist and international markets; this could be because the Artist depends entirely on the gallery for markets.

Finally, hole-4 separates 3D printing equipment manufacturers from the chemical industry, and this could be because they are both focusing on different industries and not directly connected.

Looking at the FabLab case, most of the holes identified are within a geographic space compared to the Artist and 3D printing bureau case. Thus, most holes may be bridged through improving processes within the FabLab space if such bridges can enhance innovation. For example, hole-1 separates equipment booking and community users, and this could mean that most people using the space do not frequently book the machines. Hole-2 separates Universities and FabLab directors, which may mean less exchange of knowledge between the two groups.

In a 3D printing bureau ecosystem, structural holes are observed as follows; hole-1 divides UK manufacturers with foreign manufacturers, probably because they are competing for the same market. Hole-2 separates aerospace and motorsport clients, possibly because they are not aware of each other or not interested in working together. Hole-3 mostly separates manufacturers and equipment resellers, possibly due to competition for the same niche market. These structural holes may inform decision-makers in designing strategies around bridging distant ecosystem actors to promote inflows and outflows of resources, data and information for innovation. Increasing network density by expanding links may lead to increased network effects and productive ecosystems (Giustiniano and D’Alise, 2013).

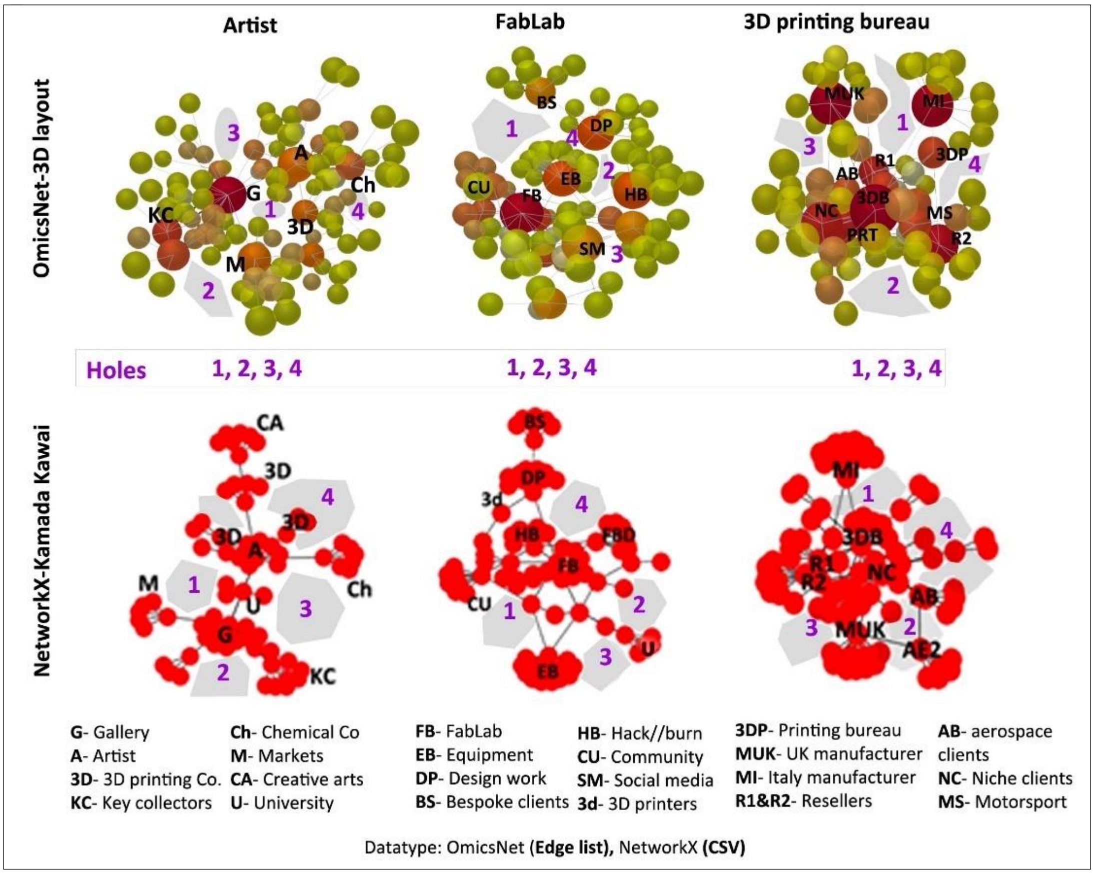


Figure 5.10: Examples of structural holes from OmicsNet and NetworkX across three ecosystem cases.

5.2.2.4 Exploring weak ties

RAWGraphs, R-Chie, and D3 tools characterise ties more vividly (Figure 5.11). However, it was challenging to make sense of these ties through visual network analysis, particularly in R-Chie layouts because of visual cluttering and the lack of mouse hovering features to isolate connections and read labels. The analysis of the artist ecosystem shows weak connections between the Artist and international markets across three tools, i.e. Chord Snip, RAWGraphs and D3 methods. This may be because the Artist does not have contact with the market side of the ecosystem, which is the role of the gallery actor. So, the two communities are intentionally disconnected. Other weak ties can be observed between the gallery and 3D printing firms, key collectors and other galleries. A possible explanation for these weak ties could be because of minimal interactions. As an intervention, the artist might explore connections with key collectors through bridging roles to co-design artefacts with them, thus making use of weak ties.

Regarding the gallery case study, Figure 5.11 shows weak ties between international markets and design work, FabLab staff and some community users, markets and FabLab staff. Tools like Gephi and Chord Snip also show weak ties between FabLab staff and Universities. Weak ties between markets and design work could be because design services at the FabLab are not widely advertised outside the space, or there is no direct connection between the two communities. Weak ties existing between FabLab staff and some community users could be caused by few staff, where users are not getting the maximum support they need. Weak ties between the space and Universities could be caused by a lack of bridges, e.g. innovation activities, between students and FabLab staff.

The 3D printing bureau appears different, and there are many strong ties shown in red and few weak ties in yellow, particularly in RAWGraphs, D3, and Gephi. This might be partly because most actors are connected to their regular customers and isolated from the rest of the ecosystem. Therefore, decision-makers may explore and leverage these ties to gain access to new information.

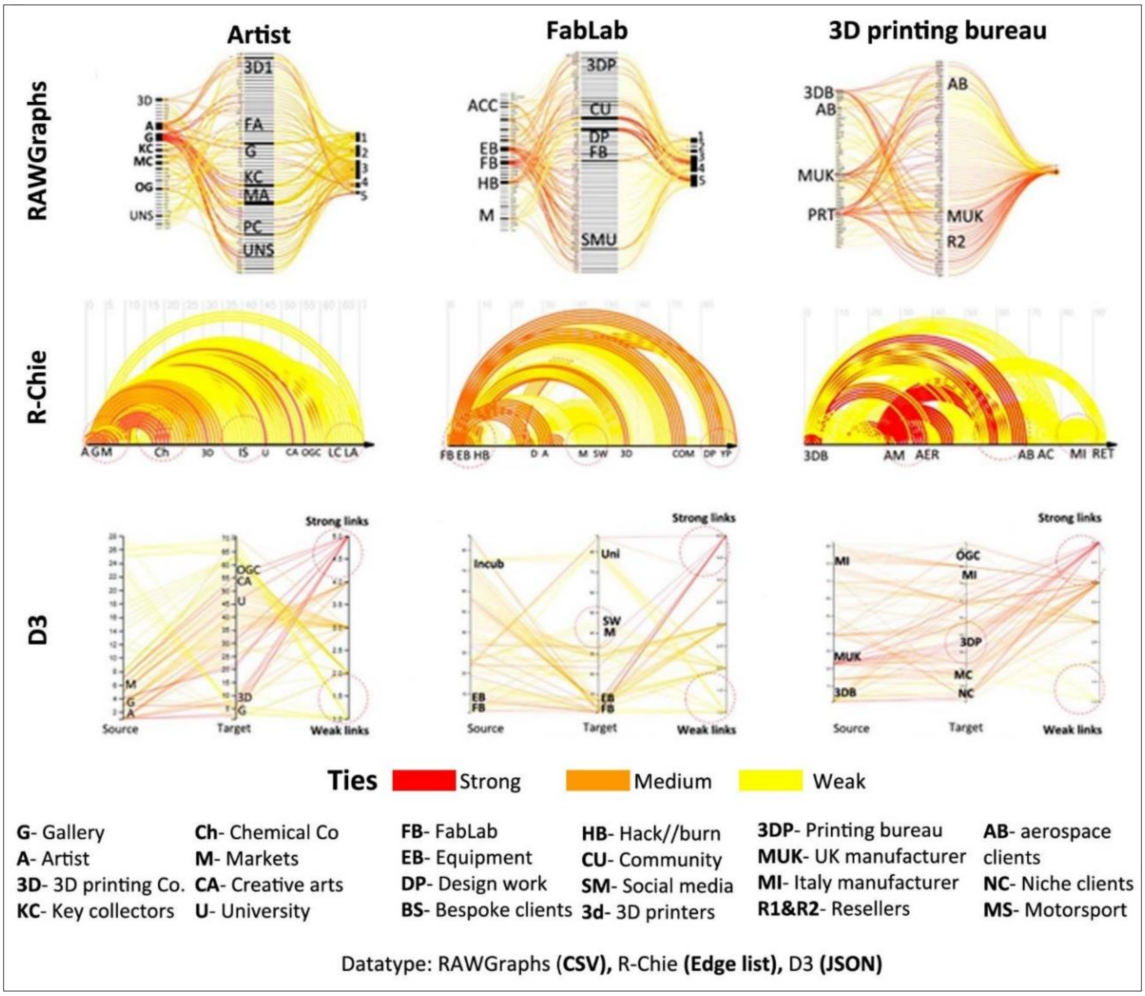


Figure 5.11: Examples of visualisations of weak ties using RAWGraphs, R-Chie and D3 across three ecosystem cases.

5.2.2.5 Exploring ecosystem role structures

Although many tools show the structure of actors in terms of their degree of connections and influence (see appendix 19), the analysis identified SocNetV and Zingsoft (Figure 5.12) and Gephi (Figure 5.9) as the three distinct tools revealing role structures in terms of positions of nodes, demonstrating a degree of influence. For example, both tools show the gallery having a central and high degree position than the Artist, which might mean that it has more influence over the Artist in terms of information flow. Therefore, the gallery may act as a keystone player in the ecosystem, providing stability, resources and health to the artist ecosystem. Under the FabLab case, the staff have a high degree of connection and central position, as shown by the large node in the Zingsoft and Gephi layout. The FabLab and its staff also act as keystones providing health, stability and resources to the community users, incubates and external customers. The artist and FabLab cases resemble keystone-based ecosystems.

Contrarily, the 3D printing bureau case has many dominating players spread across the ecosystem structure, represented by manufacturers, resellers and bureau services, all competing for the same market. Although the 3D printing equipment manufacturers control most value chains, bureaus and resellers also control the clients, thus creating a highly unhealthy milieu. Ecosystem actors may benefit from actively cooperating with well-resourced players (keystones and dominators) in the ecosystem.

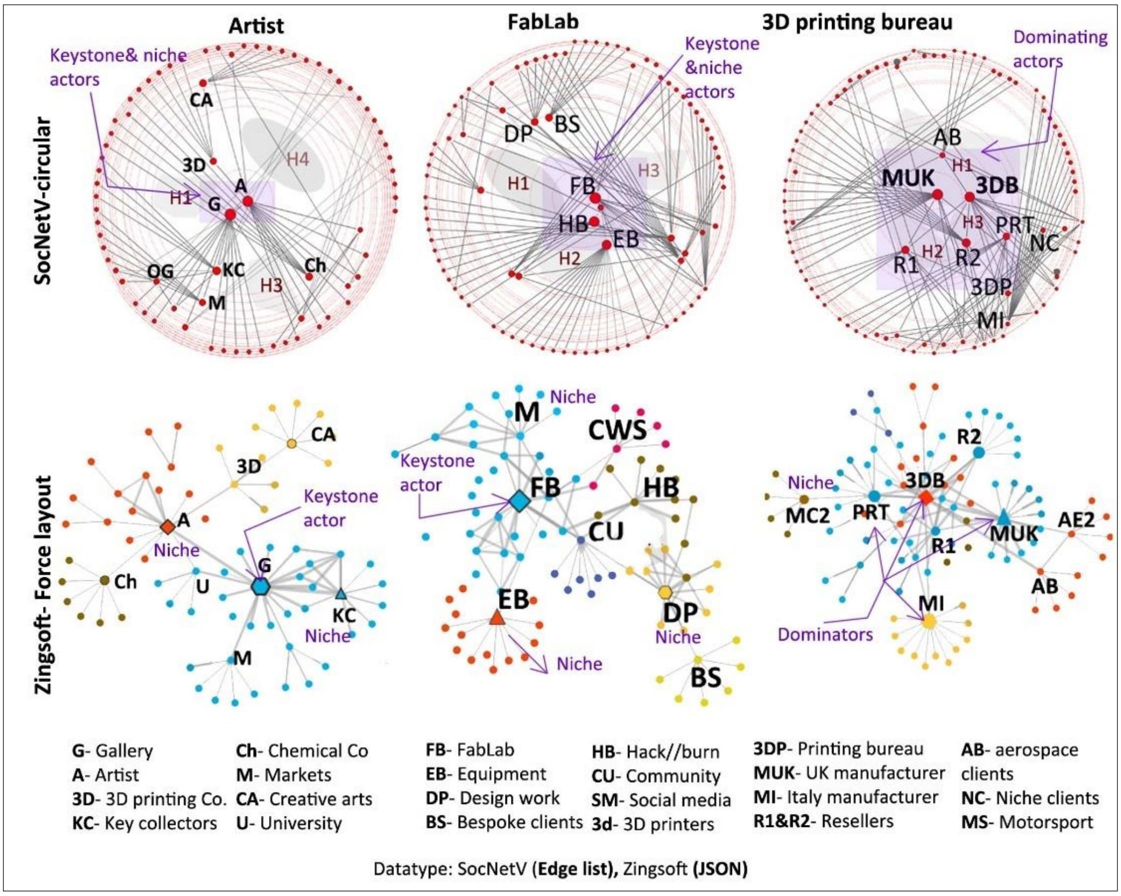


Figure 5.12: Showing examples of visualisations of key roles using SocNetV and Zingsoft across three ecosystem cases.

Highlights of visualisations

The project used 14 open-source visualisation tools with datasets from three ecosystem cases and compared them across ecosystem attributes. The analysis found that all tools used have different benefits and trade-offs.

Characterising ecosystems in terms of clusters and bridges might guide decision-makers in understanding and reconfiguring ecosystem networks. Most tools also revealed node and edge hierarchies. Node hierarchies highlight actors with high and low influence in the ecosystem. This information may be vital in alerting decision-makers on where and how to allocate roles in the ecosystem. The analysis identified weak ties, which may be essential in accessing untapped resources from distant communities. Most tools also revealed structural holes, which are key in showing decision-makers where gaps are in the ecosystem structure and how they may bridge some to promote interactions. The analysis used interactive features (rotating, filtering and zoom) to search for insights about actors and relations. Finally, the tools were useful in characterising ecosystem role structures. Identifying actors relative to others was key to understanding keystones, niches, hubs, and dominators in the ecosystem.

5.3 Chapter conclusions

The chapter presented a summary of the critical factors that constitute the understanding of ecosystems. The chapter also characterised ecosystems using different open-source visualisation tools.

This chapter clearly shows that the FabLab and the artist cases share similar ecosystem characteristics, resembling a keystone-based network. The FabLab ecosystem provides serendipity for actors to form connections, co-innovate, discover new processes and methods. However, the 3D printing bureau ecosystem was an outlier. It was dominated by 3D printing manufacturers and resellers who have high influence density on the entire ecosystem, thus stifling diversity in innovation and access to new markets.

5.3.1 Change of research focus

A FabLab as a makerspace had more potential to create shared value than in other ecosystem cases. This is because a makerspace environment promotes open design and fabrication through co-learning, co-working, co-creation and sharing ideas, thus providing access to the community and local entrepreneurs. This idea is important to stimulate risk-taking behaviours and actions without substantial loss of revenue. Although the thesis initially aimed to explore the topic of additive manufacturing technologies (3D printing) and how these technologies might be augmented to improve SME ecosystems in Botswana, the pilot study insights highlighted the value of makerspaces in shaping local ecosystems.

Insights from the makerspace, such as promoting access to co-working and co-creation with technologies, indicated that the solution to enhance manufacturing ecosystems was not just in importing technologies and what new technologies could produce but in how it could contribute to creating new business models. This provided an opportunity to compare to Botswana manufacturing incubators. Like makerspaces, incubators are designed to stimulate co-learning, co-working, co-creation and sharing ideas. However, based on the author's observation and background as an entrepreneur, many SMEs in Botswana prefered to work in isolation. This indicated that there was a need to create environments to promote collaborations. Therefore, the makerspace idea seemed more relevant to explore and compare with incubators in Botswana, thus refocusing the thesis to explore open design spaces (makerspaces and incubators) as local SMEs' ecosystems.

5.3.2 Tools improvements

This chapter guided the refinement of inquiry questions to enhance the quality of data collection. More probing was needed to explore how ecosystem actors work with stakeholders and what factors hinder ecosystem development. There were several observations made based on the evaluation of the inquiry protocol.

First, based on the feedback from the three cases, the research needed to increase inquiry questions to allow more quality of data to be collected on how directors understood ties with partners. Second, precautions needed to be taken when discussing sensitive issues, e.g. respondents' relationships with key stakeholders. The sensitivity of issues differed across cases. For example, in a FabLab ecosystem, the respondent was less sensitive about the makerspace relationships, whereas the 3D printing bureau ecosystem was different, where the director did not wish to discuss the details of their relationships. Therefore, this challenge required the researcher to be more flexible and open to diverse responses. Since the present thesis aims to enhance the SME ecosystem understanding, it was more relevant to explore makerspaces as local ecosystems.

5.3.3 Limitations

Although there are many properties of open-source tools helpful in making sense of ecosystems, there are limitations that warrant further research. First, colour customization features are limited in most tools, which are crucial in exploring ecosystem data consistently. Second, using 3D dynamic layouts was limited, except in one tool. This is important in inspecting network structures by rotating and zooming layouts. Third, mouse hovering and filtering features were also limited in some tools. These features are vital to get information about ties and nodes quickly. Forth, having a tool that models diverse layouts, i.e. different layout algorithms, is also important to reduce coding.

5.3.4 Chapter contribution

The main contribution of this chapter is an empirical account of how SMEs decision-makers understand and influence their innovation ecosystems. The chapter demonstrates this account by drawing from experiences and reflections of key ecosystem actors. Secondly, the chapter evaluated and reflected on an array of existing open-source visualisation tools that may be used to make sense of ecosystem attributes. This research demonstrated that open-source visualisation tools could be used to gain insights on important ecosystem characteristics where other qualitative methods, e.g. interviews, have limitations.

This chapter contributed key modifications to the research design to enhance data collection and analysis. In the next chapter, the study presents findings from the makerspaces as local ecosystems in the UK.

6 Makerspaces as localised SME ecosystems

In the previous chapter, the thesis discussed findings from three ecosystem settings. This chapter report findings from three makerspace settings in the Northwest of England. The rationale for focusing on makerspaces as local ecosystems is discussed in chapters 4 and 5. This chapter contributes an in-depth analysis of how makerspaces shape local ecosystems.

6.1 Introduction

This chapter analyses makerspaces (also referred to as FabLabs, Techshops, hackerspaces and creative labs) as local ecosystems. This concept emerged from the Massachusetts Institute of Technology course on making almost anything (Abel et al., 2011). The emphasis is on how these open design and fabrication spaces promote co-learning, co-working, co-creation, and sharing ideas (Vuorikari et al., 2019). Most makerspace cultures are defined by the ethos of openness and collective creativity than commercial benefits (Taylor et al., 2016), except those adopting the TechShop approach (Abel et al., 2011). Makerspaces also promote easy access to digital fabrication tools for community users to create solutions and experiment with different business model innovations (Marsh et al., 2018). However, little is known about how makerspaces influence the local ecosystem structure. This study seeks to address the following objective as part of research question 3:

To explore makerspaces as innovation ecosystems in the UK through interactions with experienced makerspace owners and some affiliated makers/SMEs.

To address the above, the study recruited three makerspaces in the Northwest of England, based on the experiences of directors and owners. The cases were investigated through in-person semi-structured interviews and visualisations.

6.1.1 Case selection

In this study, three makerspace cases were selected based on their experience as the oldest makerspaces in the northwest (more than eight years). Also, selected directors from these makerspaces had more experience in working with space users, e.g. SMEs.

- **'Successful' makerspace (Space-A)**
  This case is an independent makerspace, located in the Northwest of England. It was considered for this present research for several reasons. First, because it exhibited characteristics of a 'successful' makerspace model, with less dependence on external grants and loans. Second, it attracted a range of users, i.e. hobbyists, professionals, students and young people. Third, it is self-funded, and the makerspace profit is invested back into the space community. Forth, it develops links between SMEs and knowledge centres, e.g. local Universities and colleges. Therefore, this space seemed to strengthen the innovation capabilities of SMEs in the region. Figure 6.1 shows the inside of the main space.

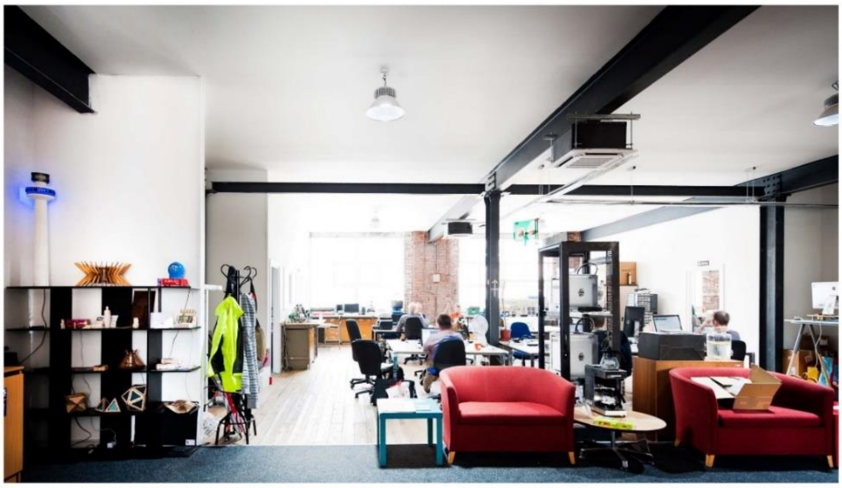


Figure 6.1: Photo showing the main room (Photo by the director)

- **'Failed' makerspace (Space-B)**

  This case is also an independent makerspace located in the Northwest of England. It was considered because the case exhibited some highlights of a failed model of a makerspace, hence crucial and interesting to study. Second, it no longer has a dedicated community space, thus making this an interesting case to explore for insights. Figure 6.2 shows maker activities in the space.

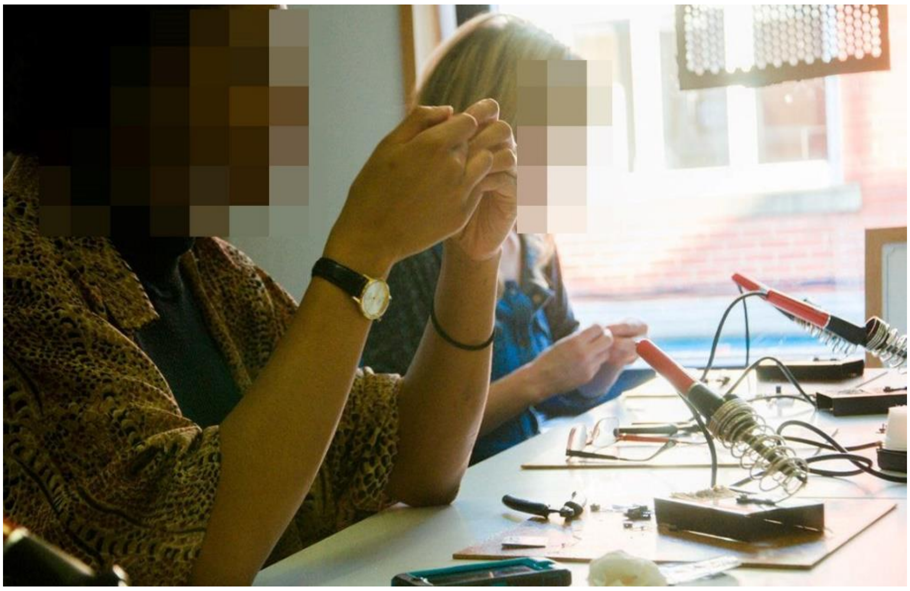


Figure 6.2: Photo showing some activities at the makerspace (Photo by the director)

- **'Emerging' makerspace (Space-C)**

  This is also located in the Northwest of England. This case was selected for several reasons. First, because it is a combination of an incubator, accelerator and the FabLab models located within a bank environment, making this an interesting case to explore. Second, the makerspace is owned and run by the commercial bank, thus presenting a different approach for a makerspace setting. Figure 6.3 shows the inside of a bank makerspace.

Figure 6.3: Photo showing the makerspace (Photo by the director)

The makerspace directors were recruited through contacts from a colleague at Beyond Imagination and contacted by emails. They all agreed to participate in this study. Further details of the three cases can be found in Appendix 8.

6.1.2 Data collection

Semi-structured interviews

Interviews were conducted at the participant's workplaces and followed the interview protocol described in chapter 4 (p.71). Few changes were made to the wording of the interview questions to reduce technical jargon. This was because, in the initial inquiry, some questions appeared more challenging to answer. Figure 6.4 shows how the questions were slightly altered and increased to construct more rich data on the understanding of local ecosystems. The main semi-structured interviews were conducted with makerspace directors and or owners taking an average of 60 minutes (appendix 8), and the researcher also interacted with two SMEs from each case to appreciate their views.

The inquiry moved from general and straightforward questions on the understanding of ecosystems to more specific questions (Figure 6.4). This also covered the background of directors and the makerspaces. All the sessions were audio-recorded with participants permission.

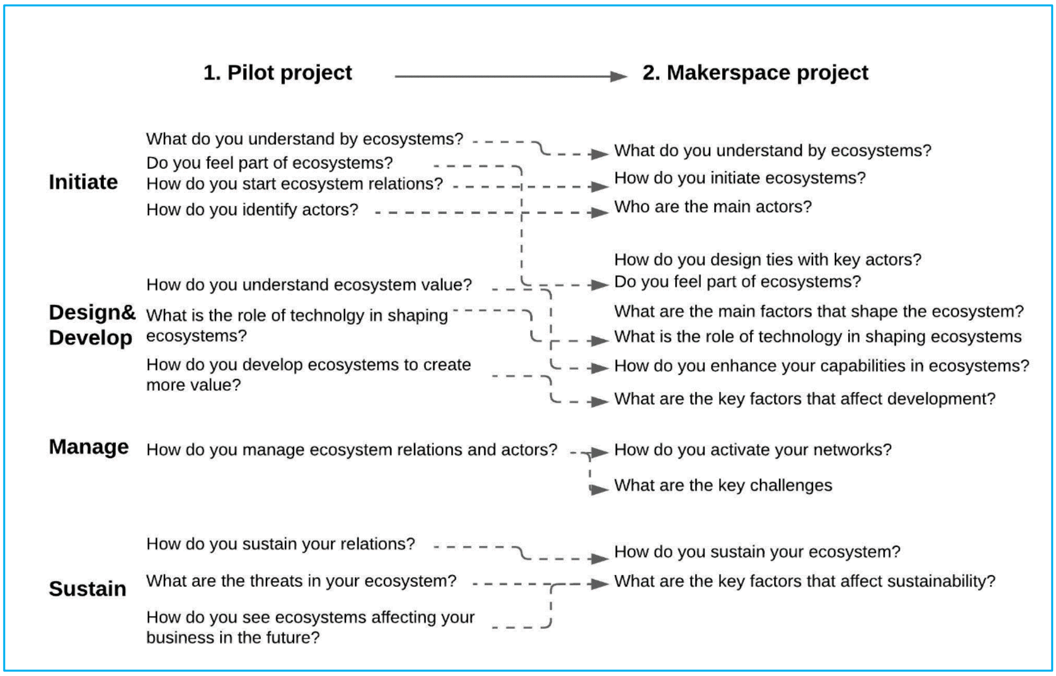


Figure 6.4: Improvements in the interview questions from a pilot study

Visualisations

During in-person interviews, the researcher used the visualisation tool (Figure 6.5) to collect data on ecosystem actors, as described in chapter 4 (p.72). Nevertheless, this was not possible with manufacturing SMEs; most were less willing to share data on their relationships. The information collected from the makerspace directors and website data was deemed enough for the purposes of this analysis. The co-design visualisation data was transformed into edge list datasets for further analysis. The case study datasets can be found online (Nthubu, 2020b).

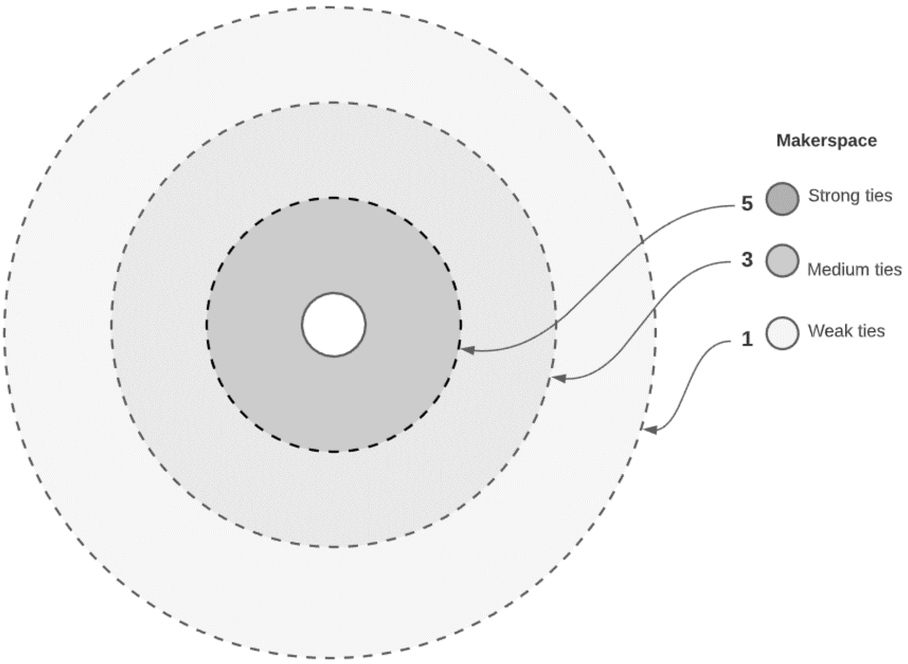


Figure 6.5: Example of the mapping tool used to generate relational data

6.1.3 Data analysis

The second study used the same data analysis procedure discussed in chapter 4 (pp.74-87), i.e. thematic analysis and visual network analysis.

Thematic analysis

The coding was done based on the themes identified in chapter 5 while allowing the opportunity to discover new codes through the open coding process described in chapter 4 (pp.74-82). The aim was to explore how makerspace directors understand local ecosystems. New themes emerged during the coding process to represent a five-stage process of understanding ecosystems instead of the four stages discovered in the pilot study. The themes were interpreted as follows; initiating, designing, reviewing, activating and sustaining ecosystems. This study also involved the second coder, where the two coders discussed their codes and agreed on the final set of codes to make up themes. These new themes emerged from the makerspace ecosystem data as key in understanding local SME ecosystems. Figure 6.6 shows the hierarchical structure of how themes, subthemes and codes were developed and connected in NVivo 12.

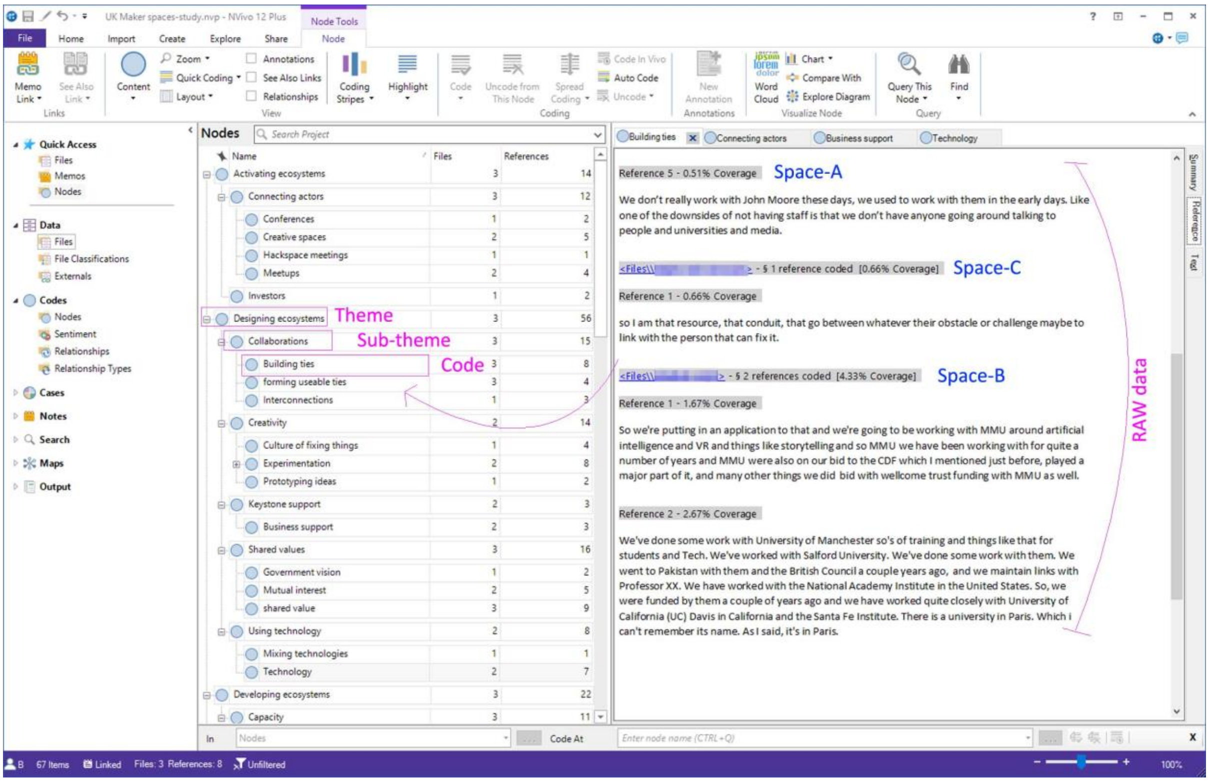


Figure 6.6: The hierarchical structure of themes, subthemes, codes and the reference text/raw data in NVivo 12.

This analysis also used a matrix table to organise main themes, subthemes and questions to show the relationship between concepts. The findings are displayed in the form of a graphical framework, which shows a modification from the pilot study in terms of ecosystems levels (themes) and factors (subthemes), elaborating how ecosystems are understood (this is explained further in the findings section). The rigour of this thematic process followed the same treatment as in the pilot study (chapter 5).

Visual network analysis

The analysis followed the techniques described in chapter 4 (pp.82-87) in terms of visualising data to reveal ecosystem attributes, i.e. nodes hierarchy, clusters, weak ties, bridges, structural holes and role structures, through the use of open-source tools. Unlike in the pilot analysis, where the study used 14 open-source visualisation tools, only three visualisation tools were used in this study. Based on the pilot study analysis, the tools were selected for two main reasons. First, because they were more useable, i.e. less coding required, in characterising ecosystems. Second, the methods were more consistent. Appendix 21 describe how visualisations were produced in details.

The first visualisation method used was the chord layout. Results from this method were used as heuristics to understand the node hierarchy and ties strength. This characterised the importance of actors and their relationships. Second, the force-directed layout revealed clusters, bridges and role structures in the ecosystem structure much better than other tools based on the position and shape of nodes. Finally, the 3D interactive layout revealed the structural holes in the ecosystem better. After selecting the methods, tools and data formats, the researcher formatted the data according to each tool requirements, using the procedure shown in Chapter 5 (p.96) and started the modelling and analysis.

Next, the chapter presents thematic followed by visualisation findings. Then conclude the chapter by outlining its contribution to the thesis.

6.2 Findings and discussions

In the following sections, the chapter presents the main themes that represent their understanding of local ecosystems. Then the chapter reports visualisation findings and chapter conclusions.

6.2.1 Thematic findings

The study summarises the findings by displaying the themes, sub-themes, and interview questions graphically (Figure 6.7). Five main themes came out of this analysis. The first level was about **initiating** ecosystems. Here, participants highlighted information flow and exchange factors, cultivating a culture of openness and trust, identifying key actors and roles in growing local ecosystems.

The second level was about **designing** ecosystems. The focus was on how ecosystem actors could influence the design of new roles and ties to benefit the entire ecosystem. Participants raised key issues around shared value, collaborations, the role of technology, creativity and resource support in growing the local ecosystem.

The third level focused on **reviewing** ecosystems. Here participants described challenges affecting the growth of makerspaces. Two main capabilities came out of the discussions as follows; makerspace capacity and expansion challenges.

The fourth level was to do with the **activation** of ecosystems. The challenges discussed were how the ecosystem resources could be activated to benefit the actors and the community. Participants described factors that could be looked at, e.g. activities to connect actors, attract investors into the ecosystem, and develop regional networks.

The fifth level was on the **sustainability** of makerspace ecosystems. Whereby participants shared challenges that threatened the sustainability of ecosystems and highlighted opportunities that could be leveraged to avert such. They raised the following factors as key; ecosystem health, uncertainties, motivations and ecosystem survival.

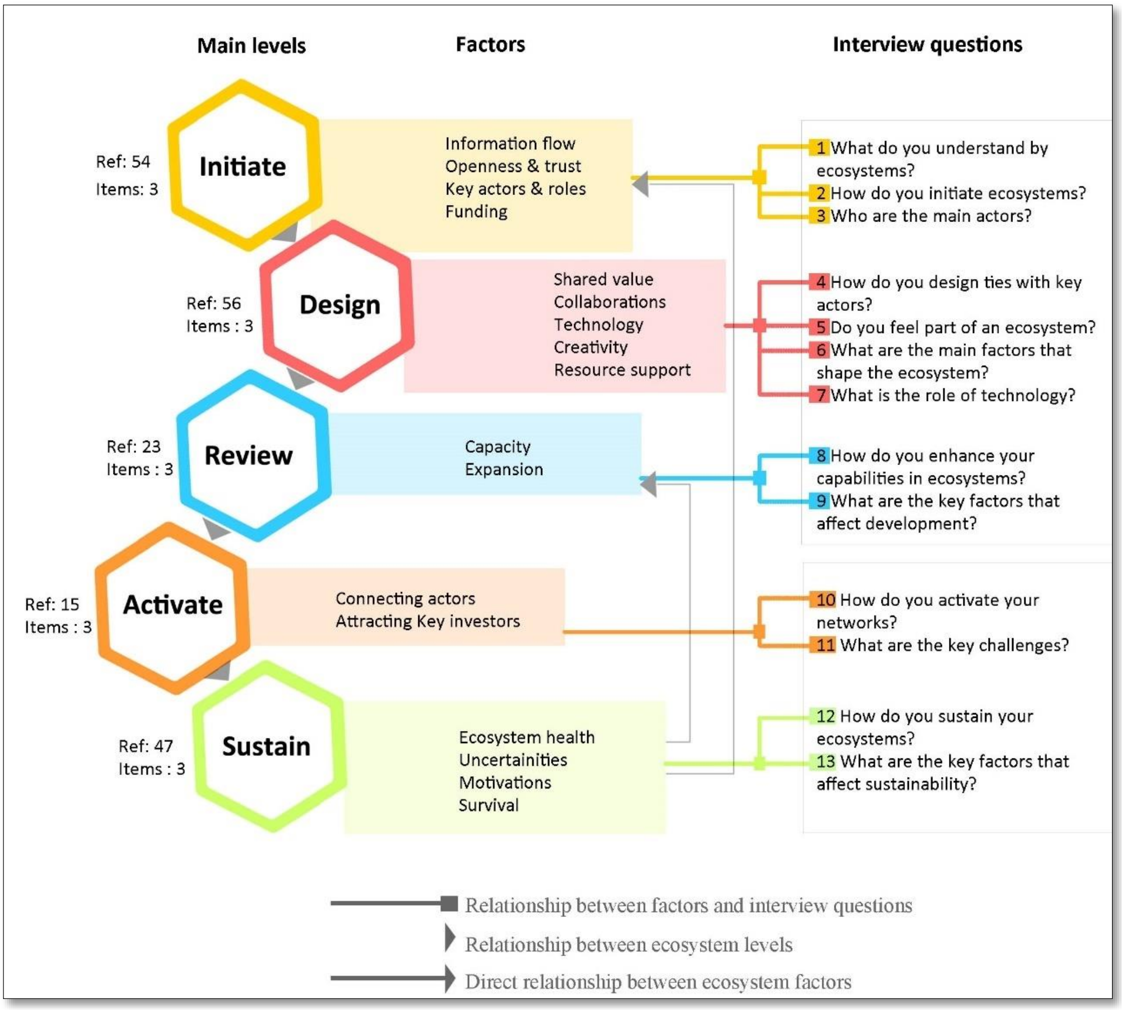


Figure 6.7: Findings from a thematic analysis process showing themes, sub-themes, main interview questions.

6.2.1.1 Initiating makerspace ecosystems

Regarding how makerspaces initiate ecosystems, all directors emphasised the need to understand information flows, how actors cultivate openness and trust, identifying key actors, roles and funding opportunities. Appreciating these factors was highlighted as crucial in initiating productive ecosystems.

Information flows

Information flows entailed the exchange of ideas and knowledge across makers. Interestingly, participants interviewed indicated that organising events around the makerspaces attracted many people, mostly SMEs, students and hobbyists and promoted decentralised making and sharing ideas. One director recalled that their makerspace was created due to a meet-up event of software developers, thus indicating the effectiveness of meetups in initiating local ecosystems:

> *"It was an exciting event [referring to a meet-up event] where we ended up with lots of people balancing and exchanging ideas. I talked about Arduino, and I got to know many people, XX [referring to his co-partner] was there, he already knew a few people through other meet-ups like Geek-up" (Successful makerspace).*

While a 'Successful' makerspace was created following a series of meet-ups by a handful of software developers and internet of things (IoT) enthusiasts, a 'Failed' makerspace was initiated through gaining inspiration from Noise Bridge, one of the early hackerspaces located in San Francisco, and an 'Emerging' makerspace was an initiative of a commercial bank to develop SMEs and a community of makers. Although the three makerspace models differ in design and scope, directors emphasised the need to understand and create an open-source environment for the cross-pollination of ideas across people to initiate knowledge probing behaviours. One director elaborated:

> *"We try and build that culture so that our residents, people that we are incubating are also collaborating as well. How we do that could be different ways, we may organise internal events, have a particular theme, and then our residents may want to speak. It could be that we want to understand what the businesses do quite deep, on a deeper level, so that it might lead to the other businesses who are looking for a web developer, or App developer who specialises in IOS [internet operating system]. I know that one of my residents is a specialist IOS and I can see the connection here for people to collaborate more" (Emerging makerspace).*

As demonstrated in the above quote, an ‘Emerging’ makerspace seems to have an ecosystem orchestrator who promotes dialogue and connections amongst actors. Therefore, makerspaces are places where people are supposed to build a culture for collaboration. These findings corroborate those outlined in previous studies (Sheridan et al., 2014; Marsh et al., 2018). Makerspaces promote sharing and co-creation (Benkler and Nissenbaum, 2006).

Cultivating openness and trust

Concerning openness in makerspaces, directors demonstrated that their spaces are designed to allow actors to collaborate efficiently. However, they both highlighted constraints in promoting open-source practices in makerspaces such as intellectual property and a closed culture. Participants in this study reported that UK makers are less open to sharing ideas than other parts of the developed world, e.g. the USA. One director explained:

> *“I think, sometimes its culture challenges. Us the British are quite reserved, whilst Americans are more open to collaboration, as Brits we are much more closed, I think culturally as a nation, that could be quite a challenge” (Successful makerspace).*

The above quote highlights the challenges of a closed culture in initiating productive ecosystems. Building a safe environment where people can share ideas may potentially promote openness and trust. Amongst the three makerspace ecosystems, a ‘Successful’ makerspace seemed to be doing better in promoting a more open milieu. One director added:

> *“As somebody who has been involved from the start, I have always felt like it’s kind of my space and I am part of it. However, It was nice to be able to see a whole group of new people [referring to community actors] take ownership and feel like it was their space because they helped paint walls and sand the floor down and like run network cables everywhere, like do all this work which makes this space amazing space and then they also feel like it’s kind of their space. Some of it it’s like it is working out the right culture, its lots of little time interventions, a bunch of founders and elders of the community are here all the time, and it’s kind of helps a lot.” (Successful makerspace).*

The above quote implies that initiating makerspace ecosystems starts with building a culture of engaging other people from the community, to create a sense of ownership, where actors can openly co-create ideas, facilitate information flow across diverse people, and promote exchange in a fun and intriguing way. Promoting more social spaces where people can interact on a local and social level was also suggested as key in building a new maker culture in makerspaces. Openness in makerspaces is seen as a tool for survival (Abel et al., 2011).

Identifying key actors and roles

Regarding how makerspace directors identify key actors and roles in initiating productive ecosystems, they highlighted high dependence on peer production events. For example, a 'Successful' makerspace highlighted that open-source hardware components such as Arduino kits, laser cutters and MakerBot 3D printers attracted more users. Users experiment with ideas which they later develop into business innovations. The study observed that the makerspace activities mostly evolved around digital technologies (3D printers, laser cutters, routers, 3D mills), electronic art and in some cases, pottery work. So, having a key actor enthusiastic about finding new connections outside the makerspace is key. One director elaborated:

> *"Mostly, XX [referring to the University contact] was very good at finding ways to make things happen [organising events], finding the right routes and making good use of things so if there is an event, there were many times since we started where there was like an event happening, he would organise for us to attend…"(Successful makerspace).*

Having a contact person (bridge) to connect the makerspace with the University is essential, particularly in activating and co-hosting events, e.g. knowledge exchange and co-creation. Events such as workshops, maker nights and conferences also enabled the makerspace directors to leverage ties with University researchers and other makers affiliated with the University. Another important issue is that most makerspaces developed open events and programs to attract new actors, thus allowing experiments with new digital fabrication tools and business models. Participants reported that free access days could facilitate the identification of new actors and roles, leading to a productive ecosystem. One director added:

> *"If we do a good enough job, that we help you [referring to SMEs affiliated to the makerspace] grow maybe, hopefully, you want to become one of our partners in the future. But, there is no monetary requirement, it's not compulsory, it's just that we can build advocacy between users and XX where you would hope that it would become a natural conversation, have a natural transaction happen" (Emerging makerspace).*

The above statement strengthens the idea that makerspace ecosystems are community-oriented spaces much more concerned with creating shared value for the community actors than primarily focusing on creating economic gains for the investors. All directors emphasised the need to attract community actors, e.g. SMEs, community leaders and others, to initiate the local ecosystem. This finding is in agreement with other studies conducted on makerspaces (Marsh et al., 2018).

Accessing funds

When asked about funding, the participants were unanimous that funders set the direction of the makerspace activities around their goals. Consequently, diverting from makerspace original ethos. They acknowledged the significant role of external funders in developing local ecosystems but acknowledged the challenges of balancing between creating shared value for the community of makers and delivering on funders expectations. This is one of the main challenges of creating shared value highlighted in chapter 3. One director added:

> *"XX [referring to 'Failed' makerspace] kind of started running training programs and because of the funding they got, it was more on training and education, that sought of set the direction, because of the funding they got, but they closed down somehow" (Successful makerspace).*

So, from the above quote, a 'Successful' makerspace highlighted that although they did not receive much funding compared to a 'Failed' makerspace, they managed to remain on course in their plans whereas, a 'Failed' makerspace closed its community space because of the kind of funding they got, which was deviating from their original concept of building the local ecosystem. Although accessing external funding is good, it would be better if aligned with the makerspace visions to create shared value. One director added:

> *"I am kind of against getting funding, you get tied to a corner, and if you can do it without funding, then it's a lot better off"* (Failed makerspace).

Given the above statement, balancing between driving the makerspace ecosystem and accessing funding was crucial in initiating productive local ecosystems. Therefore, a successful makerspace appeared to be better at initiating a productive makerspace, and this was partly made possible through links with enthusiastic community leaders, the local Universities, SMEs and other stakeholders.

-Highlights-

Information flows were demonstrated as key in all makerspaces. Most makerspaces are struggling with understanding and creating an open-source environment. It is suggested that creating events for people to co-create ideas and share experiences could promote knowledge probing behaviours. **Cultivating openness and trust** was identified as essential in promoting ecosystems. Understanding and promoting social activities, e.g. coffee meetings, were suggested to build trust amongst actors. **Identifying key actors and roles** was found to be important in initiating productive ecosystems. Although some spaces have limited funds, they all agreed to attract actors into the spaces they needed to organise open events and design free or discounted programs. However, **Funding** makerspaces seems to be a huge challenge. Most funders often want to control the direction of the spaces. Understanding and attracting more actors and roles from the community, e.g. council leadership, University leaders and students, may drive the makerspace agenda better.

6.2.1.2 Designing makerspace ecosystems

In responding to what and how makerspaces shape local ecosystems, directors highlighted the following: shared value, collaboration, technology, creativity and resource support.

Shared value

As highlighted in chapter 3, ecosystem value creates social and economic benefits for communities and firms. In this chapter, the meaning of value varied according to different makerspace models. For example, an 'Emerging' makerspace created value in business coaching and access to versatile tools; their model was about creating shared value where everyone benefits. In contrast, a 'Successful' makerspace seemed less interested in benefiting economically from the space and reinvesting the proceeds to expand the local ecosystem. Whilst a 'Failed' makerspace was operating as a profit-oriented business but also supported local SMEs. The three makerspaces presented different offerings in terms of value creation. Directors elaborated:

> *"We only survive through freelancing; none of us gets any money from XX [referring to the makerspace]. It is a company that has shares, it could pay dividends, but it all goes back into the space. We don't ever intend to take any money from it" (Successful makerspace).*

> *"We don't maintain a public community side. We decided to close that, we didn't want to be paying money at the landlord's pocket" (Failed makerspace).*

> *"We got a particular shared value growth ambition which is that if we work closely with the community, and then they grow, we will grow also. Some people may say it's a corporate social responsibility; thus, one of ours is very beneficial to the community as well as our business" (Emerging makerspace).*

Leaning towards the economic benefits at the expense of the social can obscure the potential for local ecosystems to attract community users, e.g. SMEs. The above quotes show that makerspaces are diverse in their value creation approach. To maintain the ethos of bringing people together to co-create, some felt that makerspaces must remain consistent in their promise to promote co-creation. These findings agree with Abel et al. (2011), who emphasise the need for businesses emerging from makerspaces to give back to the labs and ecosystem networks that contributed to their work, thus creating a rippling effect across the local ecosystem. These results are consistent with previous surveys on the potential of makerspaces in creating shared value (Taylor et al., 2016).

Collaborations

Having a shared value system amongst makerspaces may lead to collaborations between ecosystem actors. Participants, on the whole, agreed that SMEs could achieve a lot through co-working spaces and access to digital tools. This study found that some makerspaces (Successful & Failed cases) were collaborating with Universities to gain access to advanced digital tools and workshop spaces. For example, one director mentioned that their meetups were moved from the pub to the University workshops to support co-creation with 3D printers, laser cutters and Arduino kits because it was impossible to make things at the pub. Both the makerspace and the Universities recognised the need to collaborate. However, there were challenges in establishing how and in what fashion the actors might engage each other. One director highlighted:

> *"They [Referring to the University] like what we are doing, some of it is that they don't really know how to support us, and we don't really know what sought of support they could give in some ways" (Successful makerspace).*

Collaborating partners needed to agree on a shared value system before engaging each other to clarify what each actor brings to the table. It was suggested that operating without clarity on perceived benefits may not sustain the relationship between collaborators. An 'Emerging' makerspace highlighted the significance of having a network of key actors with a deep sense of their capabilities and roles:

> *"Part of my role [referring to the role of managing the ecosystem] is that I would know someone at the council that I can go to and say I have a business that would like to speak to you…. Then we can say here is Mike's contacts and we can connect dots there, then I might get to introduce Mike, give him some heads-up, and then he goes yeah perfect, introduce me to this business within an hour" (Emerging makerspace).*

An 'Emerging' makerspace seems to be building collaborations between entrepreneurs and the local Government by creating links between them. In this space, the ecosystem manager act as a crucial bridge connecting ecosystem actors. This is important to promote fruitful collaborations in ecosystems, thus enabling actors to gain access to more opportunities for innovation. Similarly, participants reported that other social activities such as maker nights and meet-ups were resourceful in bringing people together to collaborate.

Technologies

When asked about the role of technology in ecosystems, the participants reported a similar set of digital technologies such as 3D printers, laser cutters, CNC milling machines, vinyl cutters, wood routers and Arduino kits. They highlighted the significance of these technologies in supporting co-creation at a relatively low cost. The versatility of the tools attracted SMEs to repurpose digital tools in different ways. One director elaborated:

> *"We are building machines, and we have skills that we adopt from 3D printers, some people don't want 3D printers anymore. People who have had 3d printers for a while at their desks are now going like oh I am making electronics and I want pick and place machine, but they are super expensive, and the 3D printer is a 3-axis machine that I can use to develop a pick and place machine. All I need is a vacuum pick to replace the nozzle…In some places, people don't learn how to fix machines, but here we fix machines and even make new machines ourselves. That's some of the skills that's been lost a bit in the UK" (Successful makerspace).*

Regarding the above quote, one unanticipated finding was that 3D printers are not as popular compared to laser cutters in makerspaces, and SMEs are becoming more interested in repurposing these tools to solve new challenges. Although participants reported that many people are not using 3D printers as initially envisioned, they are still attracted to prototyping ideas before total investment. The director added:

> *"3D printers are good at getting people into the space. But if you want a kit into your makerspace get a laser cutter, like that's the most used kit in a makerspace. 3D printers are nice and easy to use once you have done the design; the design is the tricky part…But also, the laser is quicker, you can do many materials. So, I think that's why the laser cutters are getting more users and a lot more popular than 3D printers in makerspaces" (Successful makerspace).*

Participants agreed on the need to combine both laser cutters and 3D printers because they offer different affordances. They highlighted that these tools provide diversity, thus aiding entrepreneurs to leapfrog in their product development process at a low cost. Consequently, participants felt that mixing up technologies may attract many actors to makerspaces. This finding seems consistent with other researchers who highlighted the importance of makerspaces in providing access to high and low technology equipment to a large community of makers, sometimes freely (Vuorikari et al., 2019).

Creativity

Makerspace directors identified creativity as one of the critical factors that drive the innovation ecosystem. They argued that the informal nature and context of makerspaces provide fertile ground for tinkering and experimentation. It was suggested that most actors who use makerspaces are self-driven and self-directed, thus making it easy to blend with others in collective creativity without the need to worry about business losses. One director elucidated:

> *"So, if you need someone to help you manufacture, let's see if we got one of our corporate clients that would like to get involved. If someone needs a mentor, let's see if we got someone that can mentor you. Looking for funding, who do we have that we know that could be interested in investment about this. So again, we are incubating that business, we might not live there, but we are helping them curate the idea and take it to the next level"* (Emerging makerspaces).

The informal nature of makerspaces comes along as an advantage, where ecosystem actors can leverage the network effects and the diverse roles provided for by the ecosystem. For example, actors have access to experienced mentors, business coaches and funders. These services typically cost a fortune for novice entrepreneurs who are not connected to the makerspace ecosystem. Moreover, one director explained creativity as a culture of fixing things and always looking for better and new ways to solve problems:

> *"These things[referring to tables and chairs] were built by the member of the space, to make the space better, and getting that kind of creative mentality of fixing things and understanding that there isn't somebody to fix things for you, you need to do something about it"* (Successful makerspace).

The above quote implies that collective creativity is a culture of working together to find new ways to solve problems, driven by the actor's self-directedness. Self-directedness is underlined in this context because makerspaces are informal settings shaped by individual makers' actions. These results suggest that for makerspace ecosystems to thrive, creativity needs to be promoted through unrestricted access to invite a wide diversity of people to access digital fabrication tools for tinkering (Cruickshank, 2014). This idea may further hasten collective creativity. However, participants also raised challenges of intellectual property ownership in ideas made in makerspaces.

Resource support

Previously (Chapter 5), the thesis highlighted how the FabLab as a makerspace provided keystone resources to support the tinkering process, most of which are hard to come by, especially by SMEs. When asked about the makerspace resources, one director said:

> *"We don't run an incubation program, I think we provide better support for businesses than they would get on an accelerator program, or business incubator program, or any of this other kind of business support programs. But it doesn't look like that to some people, it is like we are not interested in people who are here for a year, and then we going to kick them out or something, we just have to say they should stay, I mean like they would get in some way better business support that's really useful to get. But a lot of the stuff that seems in the UK at least to be used or delivered as business support isn't actually very useful" (Successful makerspace).*

The director implies that most of the funded incubators and accelerator programs are concerned with running and completing programs, but the real value of providing long term support to businesses is not always realised. Having an open environment for businesses to leverage resources on a long-term basis is suggested as significant.

-Highlights-

Shared value in makerspaces is about maintaining the ethos of co-creation for the benefit of the community. However, the study found that most makerspaces tended to lean towards economic benefits at the expense of promoting a culture of open design and sharing ideas. **Collaborations** promote shared value in the local ecosystem. This study found that some makerspaces are collaborating with knowledge centres with better fabrication tools to promote co-creation. A combination of **Technologies** such as 3D printers, laser cutters and milling machines can attract makers to the space better. The study found that **Creativity** in makerspaces is about collective tinkering by self-directed makers. To hasten collective creativity, more makers need to be recruited to use makerspaces. Finally, the study discussed the issue of **Resource support** in makerspaces. Makerspaces widen access to fabrication tools in communities where they are located, thus creating a keystone advantage for ecosystem actors. To further design productive local ecosystems, long-term access to keystone resources is necessary.

6.2.1.3 Reviewing makerspace ecosystems

Regarding factors that influence the review of makerspace ecosystems, directors highlighted the following key factors; capacity and expansion.

Makerspace capacity

In all cases, capacity implied the extent to which makerspaces handle volumes of actors given their resources and space. It appeared that some makerspaces have the criteria of actors they want to engage. The study also found that these criteria are tied to the type of funding and tools available to makerspaces. One makerspace was leveraging partnerships with Universities, pubs, and other community spaces like public libraries. This was key in increasing the makerspace capacity and shared value. When asked about how they maintain their capacity to deliver shared value, the director elucidated:

> *"So, it's quite granular, and it depends on what the context is and more importantly what the funders need as well, sometimes it goes down to how we convince the funders about the value we create really, which often mean coming up with a picture of what story we need to tell. There is never a proper way of talking to the British council about this as well" (Failed makerspace).*

Implications of deviating from the ethos of a makerspace might lead to a gradual turn into a profit-oriented firm, restrictive and closed to the community of makers. Because makerspaces are faced with huge sustainability challenges, they require the owner's commitment, which is generally funding and time. An example of a disrupted makerspace business model was observed in a 'Failed' makerspace study, where the director reported that they closed the community side of making because they wanted to change their approach to a more profit-oriented model.

Makerspace expansion

Regarding what makerspaces are doing to expand the local ecosystem, all directors reiterated that they mostly use social media platforms, e.g. Twitter and Facebook, to take advantage of a close-knit community of makers to pass the messages through word of mouth. Based on the attitude of creating social benefits for communities and network effects in local ecosystems, it appeared directors depend on a critical mass of both SMEs and hobbyist to expand the makerspace capacity. One director added:

> *"Like yes we need enough people coming to give us cash, that means we can pay the rent, but there are people who come in the evening who aren't running a business, and aren't thinking about running businesses, they also provide useful stuff because some of them fix some machines which helps the businesses that are here to run their businesses. Some of them are just trying out new things, playing around with new bits of technology. The business would be like oh… I like that idea; I can use it for my business" (Successful makerspace).*

The above quote demonstrates that makerspaces are expanded by hobbyists and volunteers who are not entrepreneurs but derive satisfaction in contributing value to the ecosystem in terms of capacity and resourcefulness. Directors also highlighted that a mix of rudimental ideas from these tinkering processes attracts tenacious entrepreneurs to invest, thus expanding the makerspace ecosystem. One director added:

> *"Also, it [referring to the makerspace] gives us the opportunity to work very closely with disruptive companies that allow us or the way they operate get us thinking differently as well to expand the ecosystem" (Emerging makerspace).*

Expanding the makerspace ecosystem is about reaching out to nascent and disruptive SMEs and luring them to the makerspace ecosystem. Participants reported that connecting with new SMEs or exploring new ways of doing things is an essential step in expanding the local ecosystem. Makerspaces must seek unfamiliar places and partners to grow the network. This might potentially lead to creating shared value. These results are in accordance with findings from previous studies (Holm, 2015).

-Highlights-

Makerspace **Capacity** means the ability to handle volumes of makers given available resources. The study found that external funders often limit the capacity of makerspaces by refocusing their mandate. Makerspaces may need to leverage partnerships with like-minded actors, e.g. Universities and local councils. Makerspace **Expansion** entails using social media and close-knit communities to grow a critical mass of makers and tinkerers. Although every makerspace faces financial challenges, expanding these networks may attract more tenacious entrepreneurs to the space.

6.2.1.4 Activating makerspace ecosystems

In addressing the question of how makerspace ecosystems can be activated, all directors highlighted the following factors; connecting actors and attracting investors. The study found that rigorous activities targeted at promoting these two factors may activate a vibrant makerspace ecosystem.

Connecting actors

Who are these makerspace actors that need to be activated? In responding to these questions, participants mentioned community leaders, Universities, hobbyists, entrepreneurs, i.e., nascent and successful entrepreneurs, investors, policymakers, and local authorities. Participants noted that connecting all these actors to the ecosystem was a massive challenge. One director highlighted the need for physical spaces in the city centre to activate people through tinkering and social activities:

> *"They [Manchester City Council]are all moving out of the city centre and about whether they can use some buildings that they have or buy some buildings and allow the creative Industries more grassroots in there, but I think it's kind of a bit too late because large companies have taken up the spaces, that's why we are focusing on Stockport" (Failed makerspace).*

The above quote implies that more art spaces have been exhausted by large monopolies, especially in the city centres where makers could create more impact because of accessibility and visibility. So, makerspaces are drifting away from the city centres because of this challenge, which may limit their efforts to activate a vibrant city ecosystem. Nevertheless, other makerspaces in Manchester and Liverpool reported using avenues such as hosting conferences, hackspace meetings and meet-ups in various places to connect new actors. These platforms were cited as important in getting people to talk about anything in a less structured fashion. Thus, connecting new makers to the local ecosystem.

Attracting investors

While the study highlighted external funding challenges in makerspaces, participants concurred that investors are the most crucial in activating a vibrant local ecosystem. This is because the cost of running makerspaces is exorbitantly high, especially in places like London, Birmingham, Manchester and Liverpool. Some of the studied makerspaces depended heavily on grants, loans and investor capital to remain sustainable. One director elucidated:

> *"So, you see in business, you need money to prop that, to grow that... The investors, the angles of the VC house if there, the appetite isn't there, or it doesn't exist, that needs to exist better. And if people still say it is not there, why are people under the impression that it is not in existence? So, is there a marketing campaign that needs to happen, do more events need to be created, do we need more forums so that people talk about the appetite" (Emerging makerspace).*

From the above quote, it was clear that the ecosystem director recognised the need to build a positive narrative about the opportunities for investment in the city. Thus, promoting local ecosystem events can showcase the city's vibrancy and a critical mass of investable ideas.

-Highlights-

Connecting actors to the makerspace was highlighted as a huge challenge. This is because other industries have taken city spaces. Thus, drifting makerspace activities away from the city centres where they could create more impact. Organizing more events such as conferences targeted at getting people together to make things is key. **Attracting investors** was cited as key in activating makerspace ecosystems. Therefore, directors may need to align with investors who share the same ethos of building local ecosystems.

6.2.1.5 Sustaining makerspace ecosystems

Sustaining local ecosystems was highlighted as a big challenge. When asked about sustainability, directors highlighted the following factors as key; ecosystem health, uncertainties, motivations and survival.

Ecosystem health

The makerspace directors highlighted that having a healthy ecosystem is about makers, and their attitude to make the ecosystem a success. The study found that working closely with businesses and individuals with a different and unique way of thinking was important. In all cases, participants reported that promoting diversity and positive attitudes amongst actors might lead to innovations. Events such as maker nights, hack meetings and maker festivals were cited as key recipes for accelerating ecosystem health. One director elucidated:

> *"You might be interested in 3D printing, you might be interested in anything, making some jewellery or whatever, and there are separate tools which would deliver that in the creative space. But I think it's a FabLab, as a FabLab only that model you can see that nationally it hasn't worked, it needs to be mixed with other making events to activate makers" (Emerging makerspace).*

The majority of participants added that having making activities at the makerspace is not enough to sustain the ecosystem but creating events where diverse groups, i.e. hobbyists, entrepreneurs, investors, schools, community leaders and others, can collaborate is crucial. For example, working with the education department in the city to upskill school children with digital skills was highlighted as key in increasing the critical mass of makers in the city as a long-term strategy. As demonstrated in Patton and Knochel (2017), makerspaces and schools could facilitate meaningful discourses of interdisciplinarity, thus integrating STEM (science, technology, engineering and mathematics) subjects and translating this integration to holistic learning by doing environments. These findings also corroborate those in (Cross, 2017), who highlighted that makerspaces and schools could significantly promote invention and tinkering with low-cost technologies such as microcircuits and 3D printers.

Uncertainties

Although there are huge opportunities to create a healthy makerspace ecosystem as demonstrated above, this is not without uncertainties. One of the troubling factors raised by makerspace directors was the exorbitant costs of renting spaces to maintain the community.

> *"We are still operational ..., it's the community aspect of what we do that's closed. So, maintaining physical space that we don't do now, we closed down the community side of things last year [referring to 2018] …" (Failed makerspace).*

Given the above scenario, the City Councils may need to work with makerspaces to secure physical spaces in the city centre to support the communities of makers. This notion seems to be a challenge for most makerspaces studied here. So, to deliver shared value to both community actors, the local authorities might need to allocate a budget towards sustaining makerspaces.

> *"The makerspace is part of a wider offering of arts, technology space, co-working and things like that. What the British Council call creative Hubs, So I'm not necessarily down that terminology, but that kind of thing, cities, towns, areas, regions, wards, need what used to be called village halls. But they need much more from that. So, there is absolutely a community need for that" (Failed makerspace).*

In the above quote, the director highlighted the significance of makerspaces in developing local communities. One director suggested that makers can collaborate with the City Councils to identify slums and ghetto spaces to regenerate these into makerspaces, eliminating crime spots and slums. The UK Government may need to develop policies to incentivise makerspaces, but this needs to be done carefully to avoid attracting opportunists at the expense of like-minded creators genuinely looking to create shared value for the community.

Motivations

Regarding how extra-rational motivations affect ecosystem sustainability, most participants said that makerspaces are set up by self-motivated individuals. These actors are either hobbyists or a group of makers and funders who are motivated to contribute to the socio-economic conditions of their cities. While a few are motivated by the desire to make a profit out of people's hobbies. In the former type of motivation, directors reported that many people volunteer a considerable amount of time to develop the makerspace, and these are highly altruistic people from the community with specific artisan skills. One director added:

> *"Because we have been doing this for 7 years, so we got a lot of people coming from the community to help out with assembling of stuff and putting things together. Many came to volunteer their time from the community without expecting anything in return" (Successful makerspace).*

Having people volunteer their services contribute towards making the space sustainable. For example, instead of hiring technicians to fix machines, volunteers can do the same free of charge. Another observation made was that in a 'Successful' makerspace, all six directors were renting spaces as freelancers, thus contributing financially to the upkeep of the space. Makerspaces need to increase their openness to the community to attract more altruistic people through open day events to build local ecosystems.

Survival

As discussed earlier in this chapter, the makerspace ecosystem is faced with many uncertainties that may lead to the collapse of the makerspace. Some directors argued that the local government need to sustain local ecosystems by securing physical spaces in strategic areas and offer rent subsidies in the city. This appeared to be the main source of uncertainties. Some makerspaces reported running paid programs and courses to supplement funds generated through co-working spaces and equipment rentals. For example, a 'Failed' makerspace reported offering coding and data analytics courses, which generate much money for survival.

-Highlights-

The research found that diversity in makerspaces could potentially promote a **Healthy** ecosystem. Findings suggest that ecosystem health could be sustained through meetups, workshops and maker festivals. However, the project also highlighted **Uncertainties** in makerspace ecosystems, such as exorbitant costs of rentals to accommodate the community of makers. It was suggested that local authorities need to support makerspaces through subsidies and other favourable policies. Regarding **Motivations**, most makerspaces are owned by self-motivated individuals with high altruistic motives. Getting people to support the makerspace voluntarily may help build shared value in these local ecosystems. To **Survive** the uncertainties surrounding makerspaces, offering courses to supplement the income from co-working spaces and equipment hire is key. As makerspaces mature, some get more interested in profit maximization for survival.

6.2.2 Visualisations

Three open-source visualisation tools explained earlier (see pages 128-129) were used in this study to analyse ecosystem data. Appendix 21 shows how these tools were used to develop visualisations. The chapter reports the findings and implications for decision-making below.

6.2.2.1 'Successful' makerspace (Space-A)

Exploring node hierarchy and weak ties

By plotting the ecosystem data using the chord layout (Figure 6.8), the thesis makes it easy to characterise and reveal hierarchies of nodes and ties. In this visualisation, a 'Successful' makerspace has the highest degree of connection, indicating its significance in the local ecosystem as a physical space. Co-directors are also strongly connected to the makerspace, possibly because they are renting desks and providing support services to the users. Observing the thick red ties in this visualisation, a 'Successful' makerspace is strongly connected to the University, probably because they share collaborative workshop activities, conferences, maker events and co-funding activities. Implications of these strong ties are that the University leadership, researchers, and a 'Successful' makerspace has a shared agenda of building the local ecosystem in the city. This finding is also highlighted on page 136. Nevertheless, there are areas where weak ties are also visible, which could be leveraged to develop the ecosystem, e.g. between the makerspace and STEM programs. Decision-makers may take advantage of digital tools, e.g. Arduino, to introduce exciting technologies and coding skills in young children's curriculum via the makerspaces, to develop the ecosystem at a grassroots level.

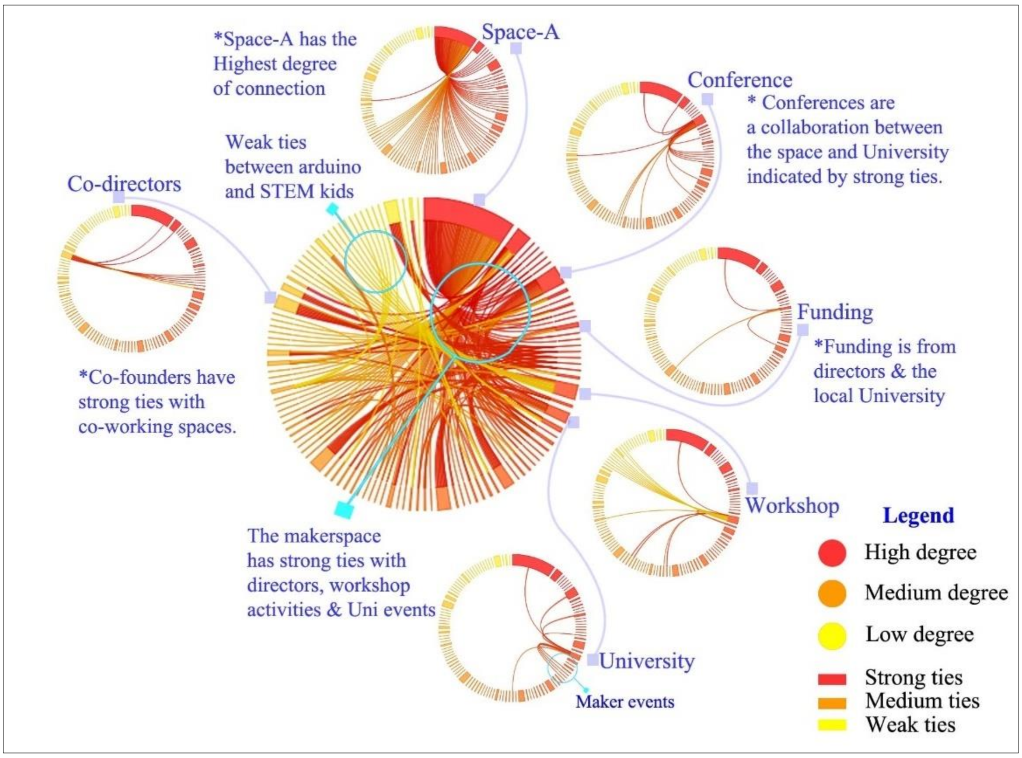


Figure 6.8: Chord layout results showing node hierarchy and weak ties in a 'Successful' makerspace

Exploring clusters, bridges and role structure

The thesis clearly shows clusters, bridges, and role structure by plotting data in a force-directed layout (Figure 6.9). This analysis shows four main clusters. The first one is the physical Space-A, which has a high degree of centrality signalling that it might be a keystone actor. Clusters B and C represents the makerspace co-directors and the University, respectively. Cluster D is the space activities and events extending to other cities. The visualisation implies that there is a close-knit relationship between Clusters A, B and C. This could be so because of strong collaborations between the University and the makerspace. This finding shows that the makerspace is acting as a keystone actor, influencing how the local ecosystem is shaping up. The University seems to resemble a niche actor, delivering events and creative activities to grow the local ecosystem.

Interestingly, the visualisation also reveals weakly connected actors to the ecosystem and bridges to connect isolated clusters. For example, STEM kids could leverage the training program bridge to access 3D printers at the makerspace. The artists also seem to have limited access to activities between the University and the makerspace, and they might increase access through co-working spaces to benefit from the University knowledge spillovers. Inviting some SMEs, i.e. freelancing artists and others in co-working spaces at subsidised fees, may increase their presence in the ecosystem.

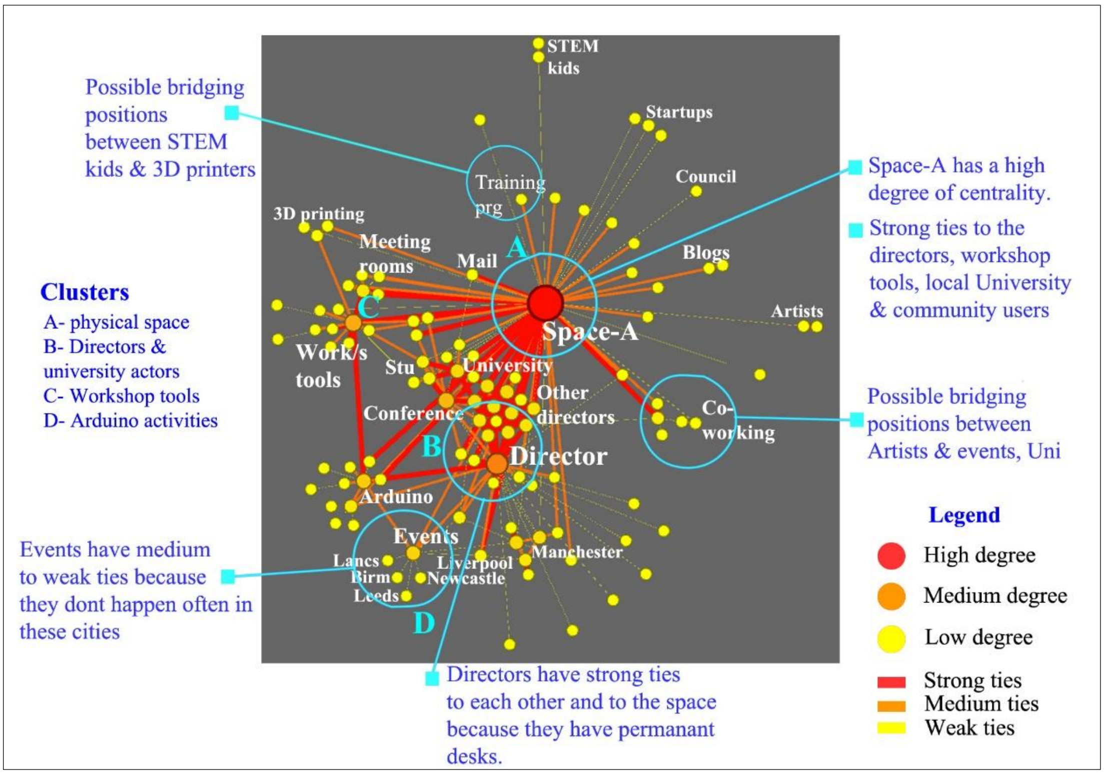


Figure 6.9: Force layout results showing main clusters, bridges and the role structure in a 'Successful' makerspace.

Exploring structural holes

By plotting the ecosystem data using the 3D layout (Figure 6.10), the thesis uses rotating and zoom features to see intricate details of the structure. As shown in layout view (A), H1 separates the co-working desks with Arduino activities, which might mean that most people renting desks are not involved with these activities because they are not aware of the tools or do not have an interest in electronics and coding tools. Therefore, having an appreciation of this gap may help decision-makers take a step forward in closing it by introducing bridges discussed above. Layout view (B) reveals H2, separating workshop activities at the makerspace with maker events conducted outside the workshop, and in other cities. The same can be seen in layout view (C), where H3 separates Manchester activities with camp events in Liverpool—bridging the two holes by facilitating collaborative activities across cities. Layout view (D) reveals

H4, which indicate a case where the artist and other SMEs are not participating in camp events. Decision-makers may decide to extend invitations to these groups of entrepreneurs through leveraging bridges, e.g. co-working spaces. As discussed on page 150, offering subsidised space and equipment rentals fees may help to attract SMEs to the makerspace events.

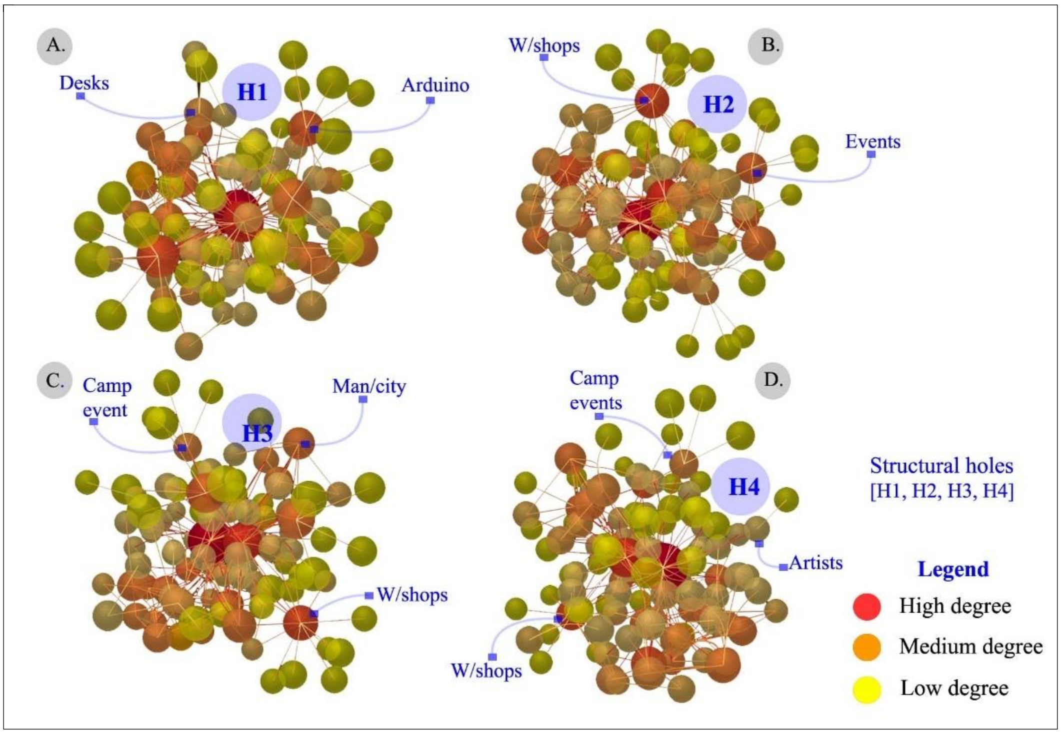


Figure 6.10: OmicsNet 3D layout showing structural holes in a 'Successful' makerspace.

6.2.2.2 'Failed' makerspace (Space-B)

Exploring node hierarchy and weak ties

By plotting the data using a chord layout (Figure 6.11), the thesis makes it possible to identify a range of different hierarchical nodes. For example, Space-B has a high degree of connection, indicating that the makerspace as a physical space may considerably influence the local ecosystem. Interestingly, Space-B has strong ties with consultants, some Universities and local councils, especially in exploring funding opportunities and running programs outside the co-working space. Unlike in a 'Successful' makerspace, the analysis of the visualisation reveals more weak ties indicated by yellow ties between digital skills customers, community users and the makerspace. This could be because the makerspace has limited skills programs and activities in-house. Another reason could be that they are not operating the community space as reported on page 134, thus having fewer people. The implications of these results highlight a different kind of business model compared to a 'Successful' makerspace, where a 'Failed' makerspace seems to present fewer opportunities to create shared value.

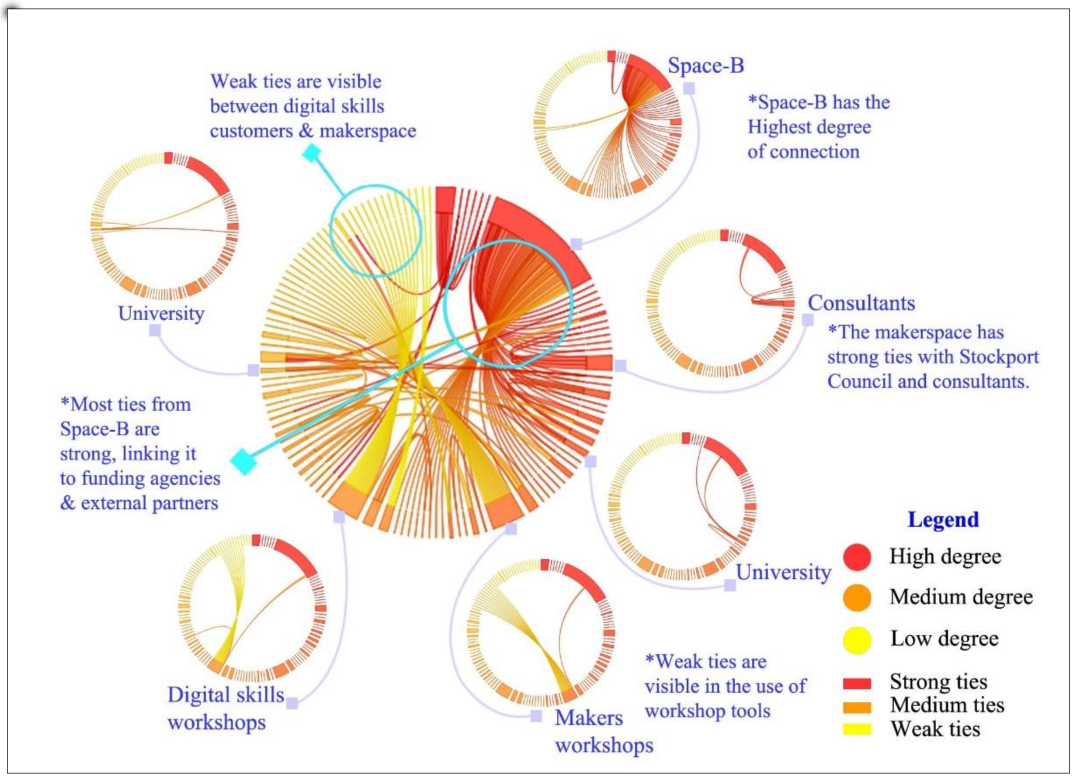


Figure 6.11: Chord layout results showing actors node and tie strength in a 'Failed' makerspace.

Exploring clusters, bridges and role structure

As shown in Figure 6.12, five clusters are revealed in this ecosystem visualisation, where cluster A is the main community; this is primarily the physical space and staff. Clusters B and C are also identified as prominent in the ecosystem, where B and C are the digital skills program and makers workshops. These activities are run by the makerspace and seem to be the core of their business model. Cluster D shows a group of funding bodies connected to the makerspace. Unlike in a 'Successful' makerspace, where directors are co-funding activities, a 'Failed' makerspace seems to be mainly relying on external funding. The analysis of the visualisation also reveals bridges that might be used to promote collaborations. For example, The UK research and innovation fund could be explored to connect STEM kids to digital tools. The University can act as a bridge to provide spaces for workshops, connecting digital makers and local councils. So, these connections may help the local government appreciate makerspace activities and possibly allocate funds towards this endeavour, as suggested on page 147. Although the makerspace has a considerable influence on the local community, it does not seem to create much value for the community of users compared to a 'Successful' makerspace. This could be so because the network resembles a hub landlord-based ecosystem.

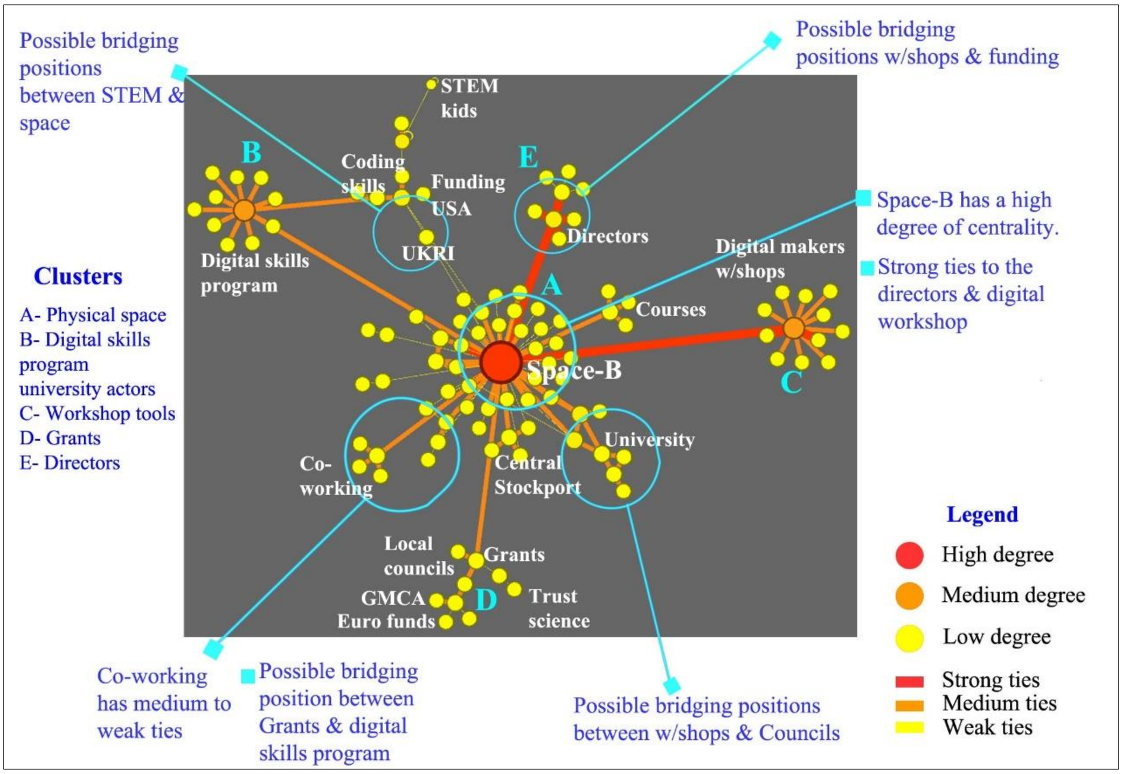


Figure 6.12: Force-directed layout results showing main clusters, bridges and the role structure in a 'Failed' makerspace.

Exploring structural holes

By plotting the data using a 3D layout (Figure 6.13), the thesis demonstrates the usability of these heuristic outputs in aiding the understanding of structural holes. The analysis reveals the layout view (A) with two holes, i.e. H1 and H2. H1 separates makers workshops and digital skills workshops. This may be so because the makerspace is running programs in isolation and mostly outside their physical spaces. Their programs seem to be inclined to digital coding and Arduino than in 3D printers and laser cutters. H2 separates funding and digital skills workshops, and this could be so because makerspace external funders typically prescribe what they want as outputs from the space (p.134). Layout view (B) shows H3 separating some grant agencies with the makerspace; exploring these agencies may increase funding to start the community lab. Layout view (C) reveals H4 separating the digital skills program and the British council. It seems the British council has worked with the makerspace before to develop communities outside the UK. Therefore, leveraging these roles to fund the digital skills program for children may create shared value in the local ecosystems. Finally, H5 in layout view (D) shows a gap between the University students and co-working spaces. This may be because students find it expensive to use co-working spaces or may not be aware of these spaces. Therefore, marketing spaces at discounted fees may encourage them to use co-working spaces. This could lead to the cross-pollination of ideas, hence growing the local ecosystem.

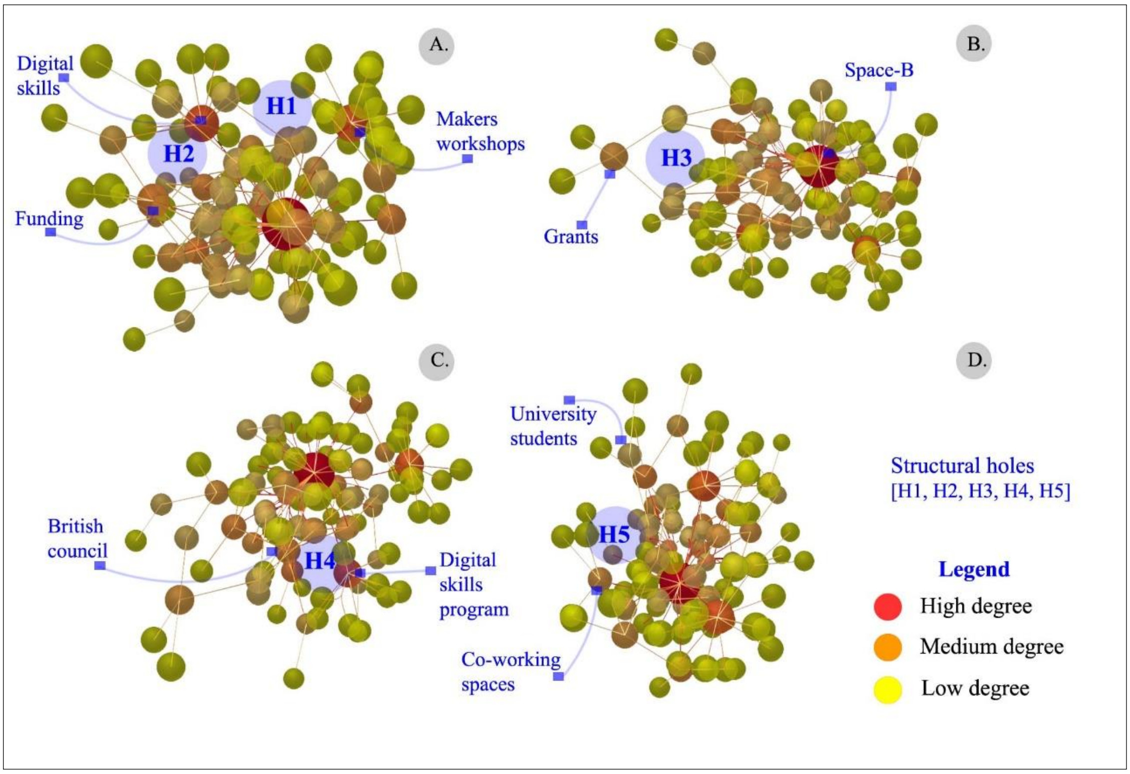


Figure 6.13: OmicsNet 3D layout showing structural holes in a 'Failed' makerspace.

6.2.2.3 'Emerging' makerspace (Space-C)

Exploring node hierarchy and weak ties

By plotting the 'Emerging' makerspace data using a chord layout (Figure 6.14), the thesis clearly shows that it is embedded in a network of 26 other makerspaces across the

UK. Further, the makerspace does not have the highest influence compared to 'Successful' and 'Failed' makerspaces. Strong ties are observed between the makerspace and the FabLab in Manchester, probably because they are managed from the same office. The makerspace and the FabLab seem to be weakly connected to the left side of the visualisation, constituting the industry partners connected to the Bank and 26 other makerspaces across the UK. This is so because all regional makerspaces are operating under different business models. To develop the Manchester local ecosystem, exploring the left side of the visualisation may connect Manchester to the rest of the Bank ecosystem.

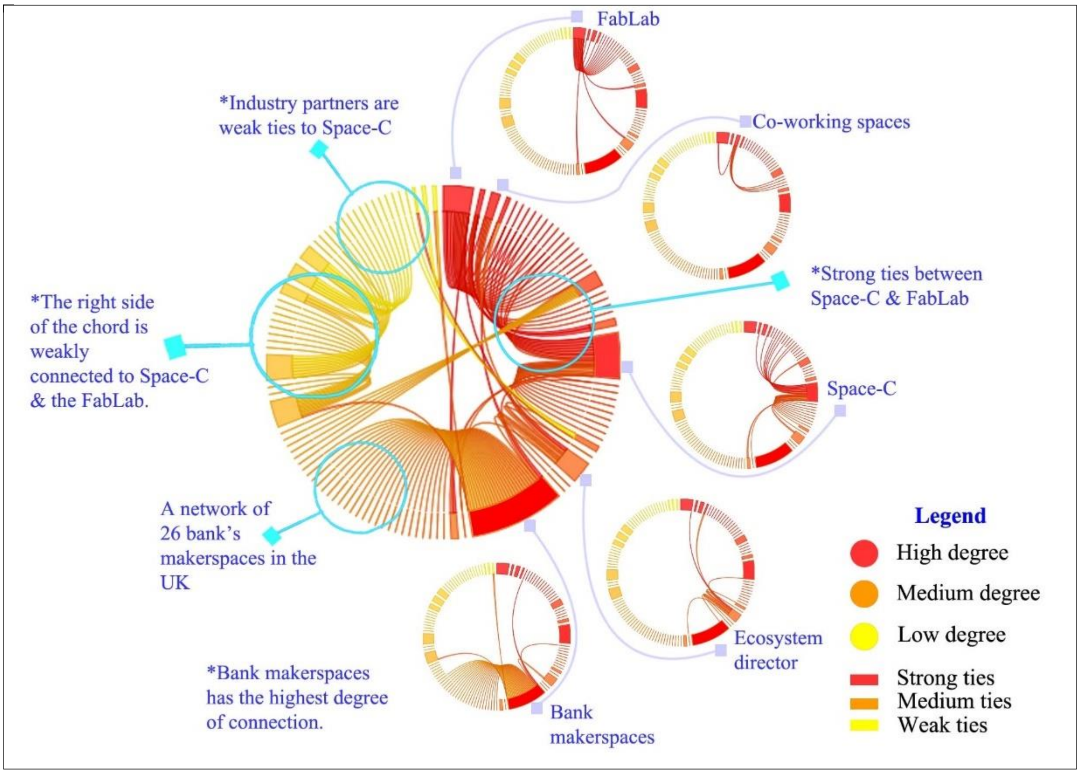


Figure 6.14: Chord layout results showing actors node and tie strength in an 'Emerging' makerspace.

Exploring clusters, bridges and role structure

By plotting the ecosystem data using the force-directed layout (Figure 6.15), the thesis reveals four main clusters clearly, where cluster B appears to be the main community. This is so because it is a network of other makerspaces spread across the UK. Cluster A represents the makerspace, the FabLab, SMEs, Investors and others. Cluster C and D represent technology partners and industries connected to the bank ecosystem. In cluster A, space-C has a high degree of centrality, signalling its high influence. There are bridges present in the ecosystem that might connect isolated clusters, i.e. the UK Government (bridge) may be used to connect technology industries and cluster C through innovation funding. Other makerspaces across the UK may also be used as bridges to connect the 'Emerging' makerspace to other UK cities. The 'Emerging' makerspace appears as a keystone player, providing resources and support to the regional ecosystem in the city of Manchester.

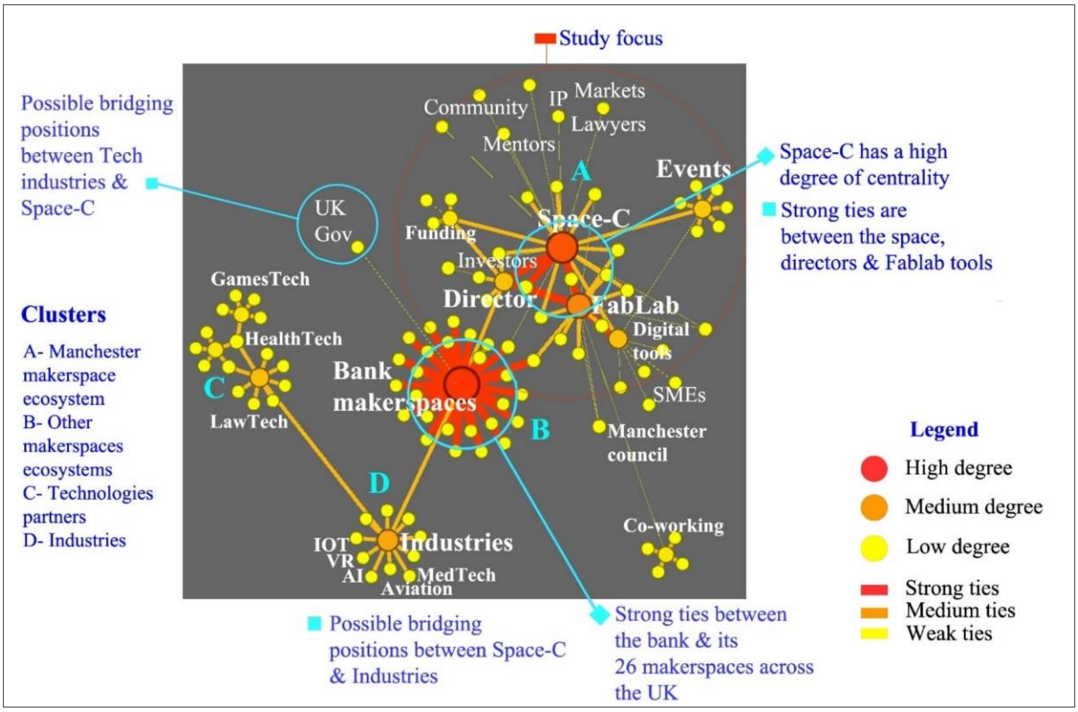


Figure 6.15: Force layout results showing main clusters, bridges and the role structure of the makerspace-C ecosystem.

Exploring structural holes

Regarding structural holes present in the ecosystem, the thesis used the 3D layout to analyse data (Figure 6.16). The analysis of output layout views (A, C) reveals H1. From layout view (A), H1 separates law and games firms with Space-C and the FabLab. Layout view (C) shows another angle of the H1 separating the ecosystem director and health technology partners. These holes may be present because the technology partners are connected to other makerspaces that are not located in Manchester. It would be interesting to leverage these weak ties using other bank makerspaces to create platforms and events to interact and co-innovate. Layout view (B) reveal two sets of holes, H2 and H3. H2 separates Space-C events from the bank industry partners. Connecting the two communities might lead to the discovery of talents by the industries at the maker events. H3 separates co-working spaces at Space-C with digital tools located at the FabLab. This could be so because the two spaces are in distinct locations in Manchester. Layout view (D) also reveals the other side of H2, separating Space-C events and digital tools and makerspaces elsewhere. Creating coffee events between these communities may promote social interactions, which may lead to fruitful collaborations.

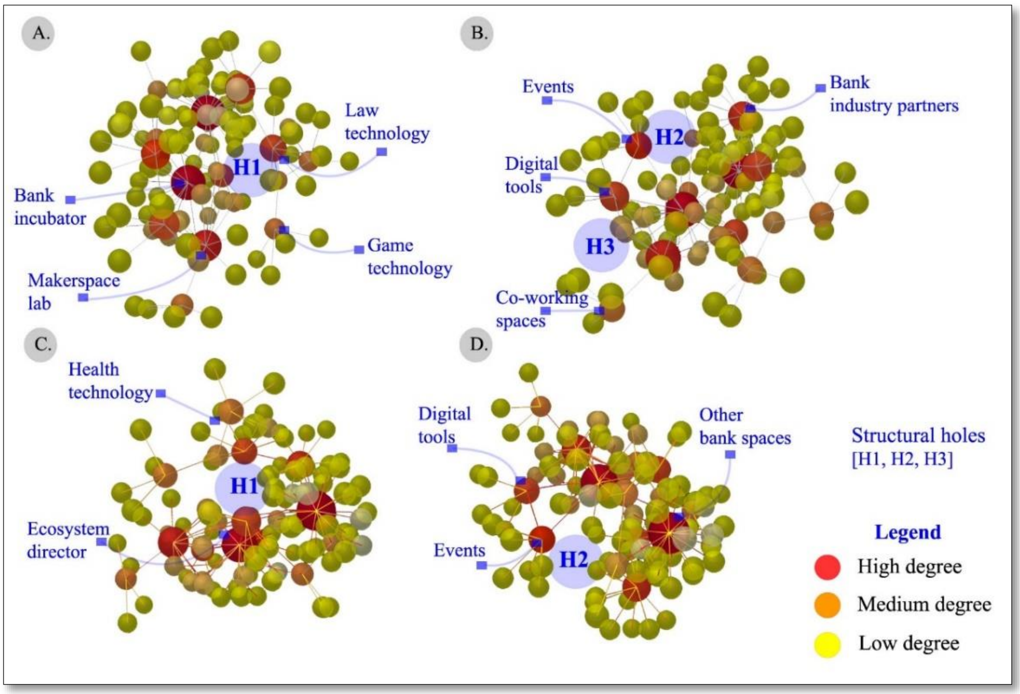


Figure 6.16: OmicsNet 3D layout showing structural holes in an 'Emerging' makerspace.

-Highlights-

- In a 'Successful' makerspace, the study found that the makerspace plays a keystone role because of its strong ties with the local University, co-directors, researchers and students.
- In contrast, a 'Failed' makerspace has strong ties with funders and focusing more on offering programs related to digital skills than engaging community users in tinkering and collaborations.
- An 'Emerging' makerspace has more regional keystone influence over its ecosystem, which is part of a large Bank ecosystem—an 'Emerging' makerspace present important weak ties with key industries.

6.3 Chapter conclusions

To conclude the chapter, interactions with decision-makers revealed a varied understanding of the local ecosystem. Using both thematic and visualisation techniques exposed insights that might support decision-making towards understanding local ecosystems. The study concludes by outlining key themes and insights.

Initiating makerspace ecosystems

By displaying the findings in the form of a framework (Figure 6.17), the thesis shows that the 'Successful' makerspace promotes open design events, e.g. Arduino workshops. This case also promotes trust, uses free maker nights to attract new actors, and recruits community leaders more than in a 'Failed' makerspace. An 'Emerging' makerspace is also promoting openness and trust through organising coffee meetings and meet-ups. However, the analysis found that makerspaces need to promote various interventions more frequently to initiate productive ecosystems (Figure 6.17).

Designing makerspace ecosystems

Amongst the three cases, 'Successful' and 'Emerging' makerspaces promote the ethos of a makerspace ecosystem. In comparison, a 'Failed' makerspace seemingly creates value for itself. All makerspaces use digital tools like 3D printers, laser cutters, Arduino kits, and other conventional tools to provide diversity to users (pp.137-138). In a 'Failed' makerspace the community users do not have much access compared to a 'Successful' and an 'Emerging' makerspaces, although they are also using digital tools to promote collective creativity. Understanding ties and roles and sharing resources can be enhanced through various interventions (Figure 6.17).

Reviewing makerspace ecosystems

By comparing the three cases (Figure 6.17), the thesis shows that a 'Successful' makerspace was the only ecosystem case working closely with local Universities through a memorundum of understanding. The case also reported having many volunteers at their lab. However, all makerspaces are limited in attracting partners from the community, who share the same values of building the local ecosystem. Local councils may provide incentives for enhancing the local ecosystem (Figure 6.17).

Activating makerspace ecosystems

This level is about activating community actors, attracting them to the makerspace activities, and participating in the tinkering and collaborations to develop the community. A 'Successful' and an 'Emerging' makerspaces are more active in organising events, meet-ups and conferences in partnerships with the Universities than in a 'Failed' makerspace. However, a 'Failed' makerspace seems to be aligning with investors better.

Sustaining makerspace ecosystems

The study found that most makerspaces struggle to survive, except for an 'Emerging' makerspace, which is part of the Bank ecosystem. Some of the key findings highlighted include promoting diversity amongst makerspaces through recruiting niche actors. A 'Successful' makerspace reported strong ties with the local Universities to promote diversity. A 'Failed' makerspace seeks partnerships with consultants and local councils to secure funding that can sustain the ecosystem. The study suggests more interventions to sustain the makerspace ecosystem, such as providing incentives to volunteers.

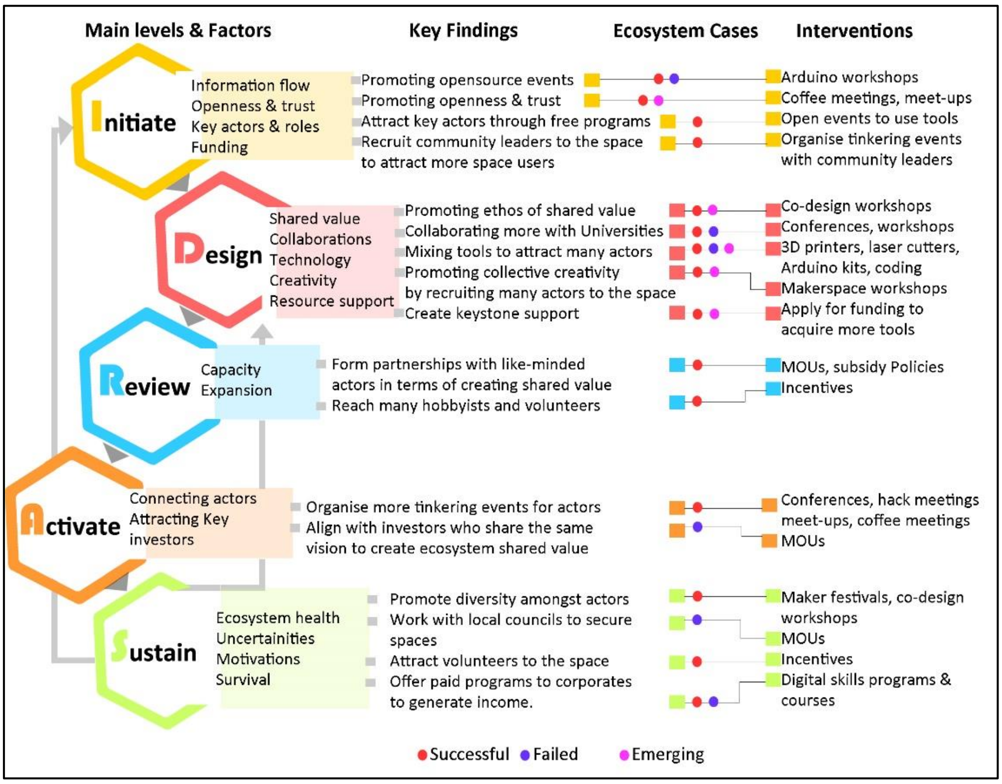


Figure 6.17: Summary of findings and suggested interventions in three makerspace ecosystem case studies

6.3.1 Chapter contribution

Using a combination of thematic and visualisation techniques provided a better understanding of local ecosystem structures. This chapter offered an exploratory and comprehensive picture of three distinct types of makerspaces as examples of local ecosystem structures. The suggested interventions and knowledge might be useful to both policymakers and directors to improve local ecosystems. The next chapter discusses the findings of a similar study about SMEs incubators in Botswana.

7 Incubators as localised SME ecosystems

In the previous chapter, the thesis discussed findings from three UK makerspace ecosystem models. This chapter discusses findings from a similar exploratory study with Botswana manufacturing incubators. The study sheds light on the understanding of local SME ecosystems. The chapter expands on the understanding of the ecosystem design framework discussed in the previous chapter, highlighting interventions to enhance the local ecosystem in Botswana.

7.1 Introduction

The concept of an innovation ecosystem is gaining ground in regional innovation policy. Although ecosystems are construed as a global phenomenon, there are also discussions on how regional ecosystems promote development (Harmaakorpi and Rinkinen, 2020). However, as discussed in chapter 3, ecosystems are often highly self-evolving and difficult to understand and control. This present chapter focuses on building an understanding of local SME ecosystems in Botswana to address this gap. The research question is: How might insights from decision-makers in incubators support the understanding of manufacturing SME ecosystems in Botswana? This study addresses the following objective as part of research question 3 in chapter 1 (p.8):

> *To explore manufacturing SME incubations as innovation ecosystems in Botswana through interactions with manufacturing SMEs and incubator managers.*

The study recruited four manufacturing incubators located in and around Gaborone city in Botswana. A total of 20 participants were recruited from incubators and outside incubation spaces. The selected cases varied considerably in terms of materials used and focus (Figure 7.1). Selecting manufacturing SMEs and incubator managers in their contexts provided the opportunity to explore and construct in-depth knowledge about local SME ecosystems' actions, practices, and behaviours in Botswana.

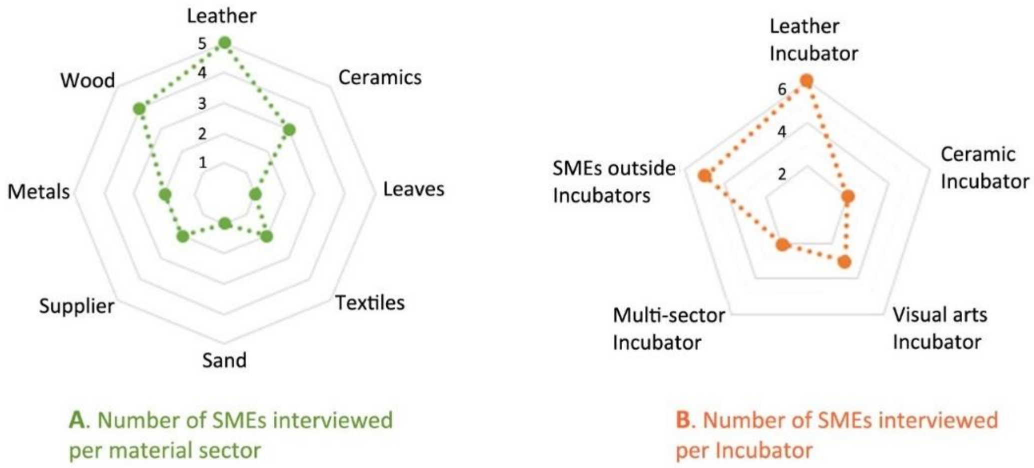


Figure 7.1: Materials and Incubation spaces: A) Number of actors interviewed per material sector, B) Number of actors interviewed per incubator.

The researcher visited participants in their settings to conduct in-person interviews and visualisations. The study presents the case selection rationale below.

7.1.1 Case selection

This case study was the main focus of this present thesis. The case used multiple embedded units, just like in the UK case, to clarify the context and the phenomena of ecosystems across different contexts. The study selected four incubators (13 SMEs and two incubator managers) and five SMEs located outside incubators as units of analysis. The selection of these cases was made based on several reasons. First, the cases are part of Botswana’s priority areas and commitment to promoting manufacturing SMEs towards economic diversification (chapter 2). Second, incubators were treated as innovation ecosystems because the Government uses these spaces to assist SMEs and start-up businesses (BIH, 2020; LEA, 2020). Third, manufacturing SMEs located outside incubators were also selected to compare their understanding of local ecosystems with those located in incubators.

- Leather incubator

  At the time of this study, the leather incubator had 12 manufacturing incubates predominantly manufacturing leather products, e.g. bags, belts, protective wear, leather accessories and upholstery (Figure 7.2). Only six SMEs and one manager participated in this study. This incubator was considered strategic, an initiative to support innovation in the leather industry and fully sponsored by the Government to meet the local leather demands.

Figure 7.2: Examples of leatherwork from the leather incubator (Photo by the author)

- Multisector incubator

  Like the leather incubator, the government fully fund the multisector incubator to support multi sectors ranging from manufacturing furniture to food products. This case presented a unique opportunity to study different sectors located at the centre, unlike in the leather incubator where SMEs use similar materials and mostly manufacture the same products. There were six incubates in this setting, and only two participated in this study. Samples of their work are shown in Figure 7.3.

Figure 7.3: Examples of plastic and wood laser engraving from the multi-sector incubator (Photo by the author).

- Ceramic incubator

  This incubator represents a failed project which used to be funded by the Government but now independent. Most manufacturing SMEs which used to be incubated in this setting are no longer operational. This was an interesting case to explore given its peculiarity and varied model from Government-funded incubators. At the time of this project, three manufacturing SMEs were associated with this space, and all of them participated in this study. Examples of work from these SMEs are shown in Figure 7.4

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Figure 7.4: Examples of ceramic work from a ceramic incubator (Photo by the author).

- Visual arts incubator

  The Government and other non-governmental organisations partly fund this incubator to promote visual arts in the country. This was a representative case because it was the only existing visual arts incubator in the country at the time of this study, thus making it unique and exciting to investigate. Only two SMEs and the manager participated in this study. Examples of work from this incubator are shown in Figure 7.5.

Figure 7.5: Examples of products from the visual arts incubator (Photo by the author).

- SMEs located outside incubators

  Five manufacturing SMEs located outside incubators were also selected for this study. These SMEs were important in this study to explore how they understand their ecosystems. SMEs were selected from the automotive industry, leather suppliers, upholstery, ceramics and metal products manufacturing deemed important in this study. Figure 7.6 shows an upholstery SME operating in the open space.

Figure 7.6: Example of work from an SME operating in the open space (Photo by the author).

7.1.2 Data collection

Since the research was exploring incubators as local ecosystems, the thesis adopted the same instruments, e.g. interview questions and a visualisation tool used in the previous chapters 5 and 6.

Semi-structured interviews

Interviews were conducted at the participant's workplaces and followed the interview protocol described in chapter 4. A year before conducting interviews, the researcher travelled to Botswana to engage manufacturing SMEs in incubators through informal group discussions. Discussions were centred around how disruptive technologies (3D printing) might augment manufacturing processes in Botswana. These interactions exposed researchers to the thesis goal. The initial step was necessary to build trust, confidence, and interest in manufacturing SMEs and incubator managers. Prior interactions also build familiarity with the research context and how the study might best construct knowledge in those settings. After a year of establishing relationships, participants were recruited into the research through emails and phone calls.

In total, 17 SMEs and two incubator managers agreed to participate in this research, and the data construction took place at their workplaces. This was important for the researcher to have a first-hand experience of what participants do in their natural settings. The interview was conducted based on questions provided in appendix 4. These interviews lasted between 30 to 60 minutes. All interviews were conducted in English language, but participants also occasionally nuanced their conversations with ‘Setswana’ language (i.e. Botswana national language). Further, interviews were recorded with permission from the participants and transcribed into text (translated and written in English).

Visualisations

This study used the visualisation tool (appendix 5) to collect data alongside semi-structured interviews on ecosystem actors. The visualisation tool helped remind participants about their connections in terms of importance. The co-designed visualisation data were later transformed into tables of datasets for further analysis in each case, following the procedure in appendix 21. Unlike in some UK cases, it was possible to use the visualisation tool with all participants in Botswana to map their contacts and key roles. The datasets can be found online (Nthubu, 2020a).

7.1.3 Data analysis

This study also used the same data analysis procedure discussed in chapter 4 (pp.74-87), i.e. thematic analysis and visual network analysis.

Thematic analysis

Firstly, the interview audio data was transcribed verbatim to capture the originality of data from participants. After the verification of transcripts by the participants through emails, the researcher pre-coded each transcript, i.e. reading the scripts one by one and line by line noting interesting ideas about ecosystem understanding. The transcripts and researcher’s notes were loaded into NVivo 12 software for coding. The coding was done based on the themes identified in the UK study and pre-coding process while allowing new codes to emerge. The analysis aimed to explore how manufacturing SMEs and incubator managers understand the local ecosystem. During the NVivo 12 coding process, transcripts were read to identify ideas against the main themes; this allowed interpreting results in terms of initiating, designing, reviewing, activating, and sustaining ecosystems.

To analyse the raw data, the researcher read each script and created codes to represent ideas related to the five themes or new interesting ideas about local ecosystems in Botswana (Figure 7.7). The coding process involved cutting and dropping raw data into the codes under each theme. This was done for all scripts before clustering codes into sub-themes. Based on the similarity of ideas in codes, clustering was done to group codes into sub-themes and to group ideas into manageable levels. Some codes were moved to other themes. Clustering codes was an iterative process of re-reading transcripts, changing code labels and moving codes to fit categories under each theme. The second coder was involved in this coding process to generate codes separately, then the two coders discussed their codes and agreed on the final codes used in the reporting of the findings.

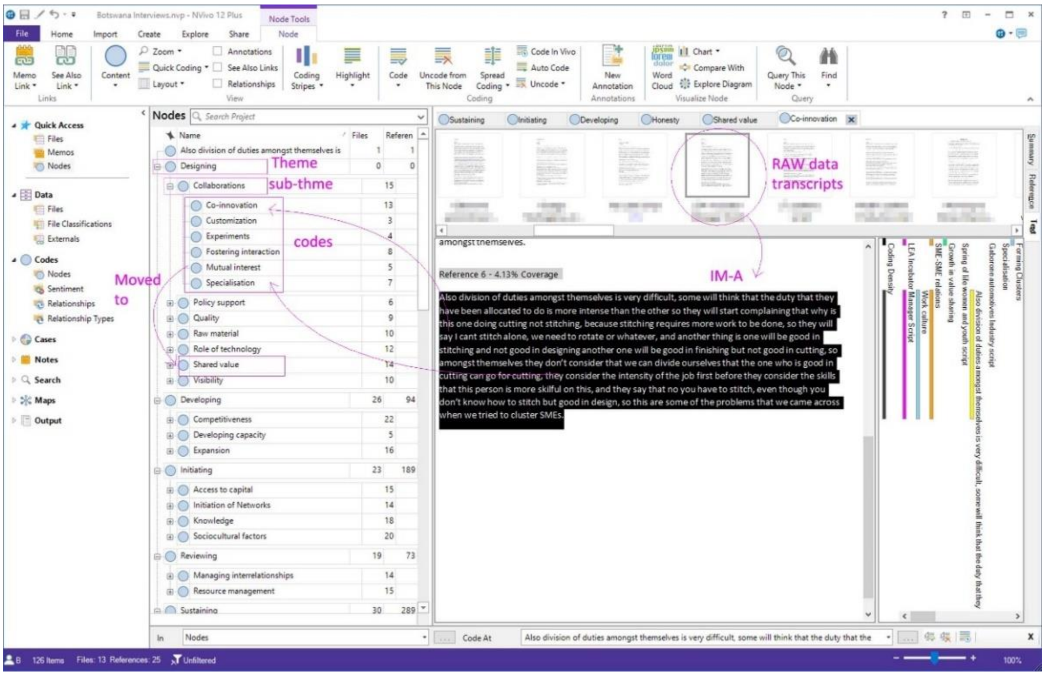


Figure 7.7: Screenshots of the thematic analysis process showing how raw data was transformed into themes.

This study also used a matrix table to organise main themes, subthemes and questions to demonstrate the relationship between concepts. There were slight differences in the dynamic factors between the UK and Botswana. For example, factors such as competition, investors, evolving ecosystem relations, and policies were among the key dynamic factors identified as sub-themes. The rigour of this thematic process followed the same treatment as in the UK based case studies. Conclusions were drawn from the thematic findings and reported in findings section.

Visual network analysis

Regarding visual analysis, the study used three open-source tools, i.e. Gephi, Google chord snip and OmicsNet, to explore data following the procedure in appendix 21 and ecosystem network theories in chapter 4 (pp.82-87). Appendix 21 also describe how visualisations were produced in details. The study also suggested interventions mainly based on insights identified in analysing ecosystem attributes. At the end of this analysis, a 'Jigsaw' ecosystem design framework is proposed. These results are elaborated fully in the next sections.

7.2 Findings and discussions

This section discusses the findings from the thematic and visualisation analysis to give a nuanced and in-depth understanding of the local SME ecosystem.

7.2.1 Thematic findings

The graphical representation of findings shows the first column displaying core themes, the second column showing sub-themes and the last column highlighting interview questions that guided conversations with ecosystem actors (Figure 7.8). Five core themes came out of this analysis. The study modelled the themes in the form of the jigsaw pieces to better understand the complexity of local ecosystems. The first piece was **initiating** innovation ecosystems. Here, the participants described the challenges associated with starting productive ecosystems. They highlighted factors such as enabling trust, identifying key contacts, identifying knowledge sources and accessing capital.

The second piece was the **design** of innovation ecosystems. Discussions were around the challenges of how and where to begin in making sense of the local ecosystem. Participants highlighted factors such as establishing shared value, forming collaborations, using technologies, policy support and indigenous materials as key.

The third piece was around the **review** of innovation ecosystems. Here participants discussed the challenges of assessing the ever-changing relationships with stakeholders.

Specifically, they highlighted factors influencing the review and development of dynamic capabilities in resource capacity, competitiveness and expansion.

The fourth piece focused on how ecosystems might be **activated**. Participants described how they wish to activate their connections with stakeholders. Here, they described factors such as educating ecosystem actors, investment partners and seeking the Government's involvement at local levels.

The last piece was around the **sustainability** of the ecosystem. Whereby discussions centred around the following factors; health, evolvement, motivations and survival. Participants discussed the challenges of cultivating these dynamic factors. In the following sub-sections, the chapter reports findings on each piece of the ecosystem jigsaw.

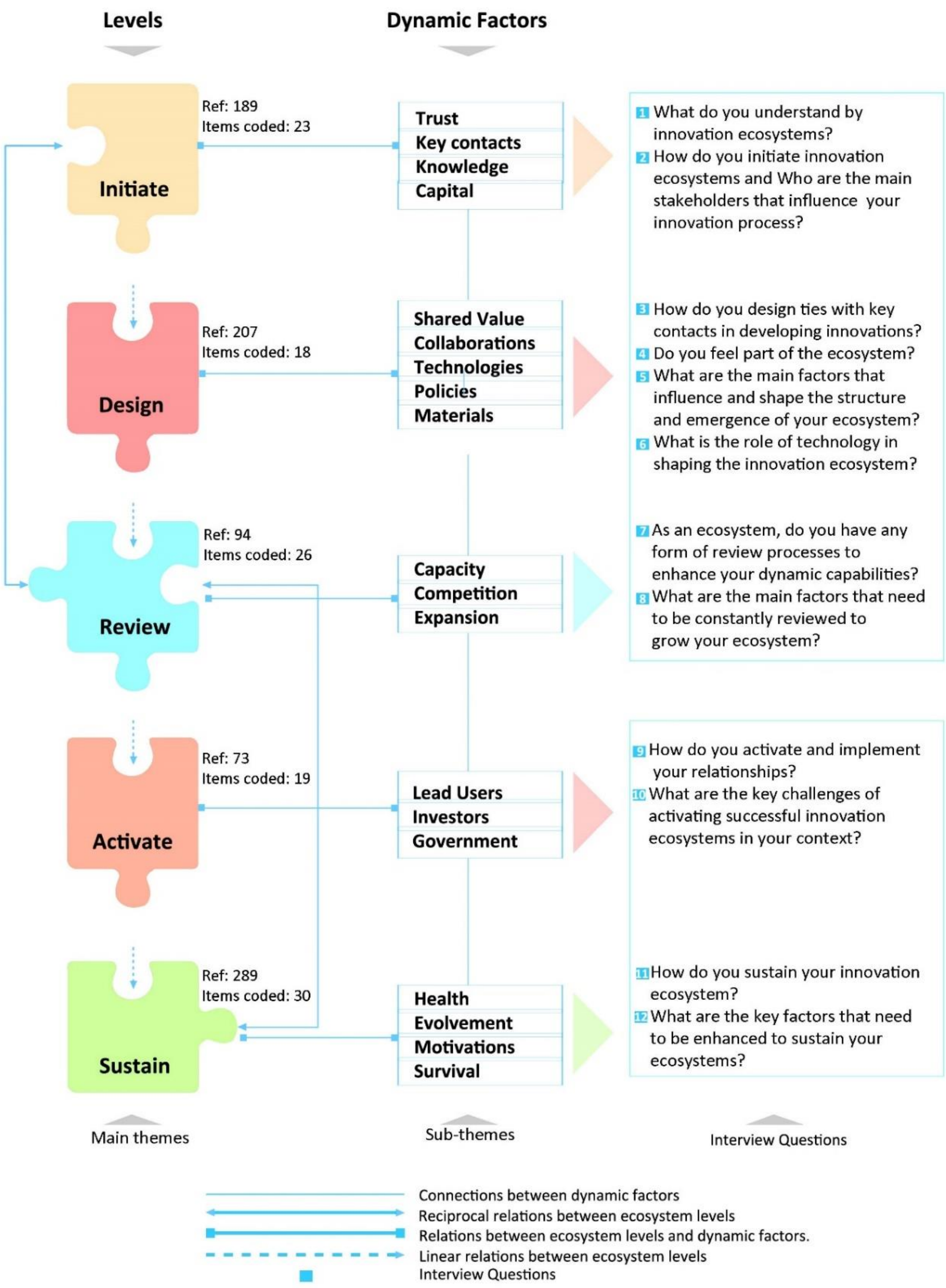


Figure 7.8: Findings from a thematic analysis process showing themes, sub-themes, main interview questions and their relationships.

7.2.1.1 Initiating ecosystems

When analysing the initiation of local ecosystems, four determining factors came out of this theme; Enabling trust, identifying key contacts, identifying knowledge sources, and accessing capital.

Enabling trust

Most participants highlighted building trust as the main determining factor in initiating local ecosystems. Lack of trust was directly linked to the reluctance of SMEs to engage in incubation activities. Overall, the findings indicated no governing mechanisms to influence partner alignment, coordinate innovation activities, and build trust. Most participants were reluctant to work with other stakeholders because of perceived risks associated with opportunistic behaviours, i.e. acting greedily and unfairly in value extraction. Some participants feared increased risks of losing business to competitors. Others described the local ecosystem as volatile and uncertain, highlighting legal contracts, formal guidelines, and alliance agreements as unusable in their context. Thus, suggesting trust as a possible mechanism for local ecosystem governance:

> *"It is difficult really because we as Batswana lack trust. We do not trust each other with exchanging ideas and goods. We are always looking for opportunities to get more or even to negotiate ridiculous fees just to avoid growing someone's business" (SME-K).*

The majority of participants agreed with the above quote and suggested using trust as an alliance mechanism to initiate ecosystems in incubation spaces. These observations support previous studies on the significance of trust (Das and Teng, 1998; Manzini, 2015) and its perceived benefits in developing trust-based governance mechanisms that may horizontally support ecosystem initiation. Furthermore, these highlights also corroborate Cobben and Roijakkers (2019), where different kinds of trust instruments were tested, such as letters of intent and gentlemen agreements to remedy the ecosystem governance challenges. One SME demonstrated the benefits of using trust through social controls, e.g. gentlemen agreements:

> *"You know those are like lifestyle things [referring to trust and friendship ties], for instance, like for now if I need someone to do something for me in Cape Town, you know I would just call, I will give you this money when I have it, can*

you do this for me now and then he does it for me, or go and attend the meeting on my behalf or whatever the circumstance is, or attend the exhibition if I am not there, so those are the type of gentlemen agreements we have" (SME-A).

The above quote supports instruments such as gentlemen agreements as effective in promoting trust. Enabling trust reduces transaction costs associated with other mechanisms like legal contracts. Building trust between key stakeholders may help avoid communication problems (Coupe and Cruickshank, 2017).

Identifying key contacts

Identifying key contacts to grow incubators was seen as a challenge. Although the incubators provided keystone support, they lacked niche roles to develop innovative ideas and complimentary services, e.g. reliable supply chains, R&D funding, venture capital, investors and grants to initiate local ecosystems. Throughout this study, most ecosystem actors seemed unfamiliar with their position and other actors in the ecosystem. Incubators were criticised for lacking a straightforward approach to attract key actors. Identifying a set of actors and aligning roles to work efficiently was highlighted as a huge challenge for both SMEs and incubator managers:

"Concerning how we work with others, they [referring to incubators] tried in the past to encourage that we meet and collaborate on a project. They tried with XX tender, and that was it, we were in conflicts as SMEs over some people coming late for work, others feeling that they are putting more effort, and at the time SMEs wanted to be paid equally. In the end, we were separated, and SMEs were isolated on their own. We believe they [referring to the incubators] should have trained us on how to work together, how to resolve conflicts and other small issues" (SME-I).

The above quote highlights the lack of alignment, coordination of interests and expectations about ecosystem roles as a huge challenge. Although the incubators secured the business and assembled manufacturing SMEs to collaborate on it, the initiation process failed because of a lack of alignment of interests in value creation and capture modalities. Consequently, to support the initiation of productive ecosystems, identifying key contacts and mapping their roles is critical. Moreover, mutual agreement amongst ecosystem actors regarding their expected roles is also important. This finding broadly supports the work of other scholars (Adner, 2017b; Walrave et al., 2018), who linked ecosystem roles with value creation and appropriation.

Identifying knowledge sources

Knowledge and skills acquisition are crucial factors in enabling ecosystem actors to identify opportunities and mobilise resources to expand the local ecosystem. Universities, technical colleges and training institutes are critical roles that ecosystem actors might explore to help them initiate local ecosystems. However, the study found that incubators were isolated from knowledge centres:

> *"We do organise workshops here in the incubator as an intervention to the challenges that our clients face such as customer service skills, marketing, bookkeeping, but as you know, it is never enough to keep up with the challenges clients face daily, we do not have any partnerships with universities"(IM-A).*

Regarding the relationships with knowledge centres, most ecosystem actors highlighted a gap between these centres. Even though previous work highlighted the positive correlation between Universities and industries (Mercan and Göktaş, 2011), most SMEs typically use platforms such as workshops and trade fairs to search for new knowledge. Nevertheless, it appeared to be improbable for SMEs to identify new knowledge during workshop interactions. Consequently, the gap between SMEs and Universities seemingly leads to a discontinuous innovation process in the local ecosystem. Notably, local ecosystems lack "*new blood*", which could be supplemented by a stream of young talented people from the Universities.

Universities are vital inputs into building productive entrepreneurial ecosystems (Feld, 2012). Typically, institutions of high learning are always keen to connect with the industry to create placement opportunities and industry labs for their students and staff. It can, therefore, be assumed that exploring linkages with knowledge centres might potentially initiate knowledge spillovers leading to productive local SME ecosystems. These results further support the long-standing concept of the Triple Helix Model, where it is suggested that innovation comes from the hybridisation of Universities, industry and the Government (Tamtik, 2018).

Accessing capital

Access to capital was highlighted as a major hurdle confronting most SMEs in and outside incubators. From the national level of the innovation ecosystem, it was reported that the Government put in huge money through different schemes, grants and subsidies to support SMEs (see chapter 2). Although these capital assets help to get SMEs started, few mechanisms were put in place to regulate the efficacy of capital at the initial stages of SME development. Most SMEs outside the incubators were the most affected by capital imprudence:

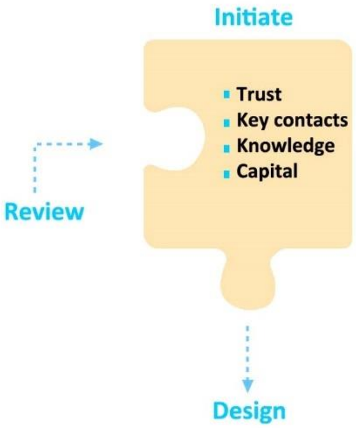
> *"Gender affairs department funded us with a total of BWP 250,000[approx. 25,000 USD], and we had a challenge in running the business because we did not know how to go about it. After being funded by Gender affairs department, we were funded by CEDA, and we got another loan from the bank to support the business. The bank decided to give us four years grazing period before we can start paying back the loan. We currently have a problem with stock." (SME-L).*

The above quote suggests that even though SMEs were provided with capital to develop the business, they could not identify and recruit key ecosystem actors such as logistics partners and local suppliers to initiate the ecosystems around their business model. The study also found that SMEs outside the incubators were disconnected from incubates. An example was observed at the leather incubator, where companies enjoyed access to materials and rent subsidies, and the local leather suppliers were cut out from the ecosystem. This finding was unexpected and suggested that local suppliers were gravely affected by direct competition from incubators:

> *"It is difficult to manage our customers[referring to leather manufacturing SMEs] because they are housed in the XX incubator, and XX incubator is our main competitor, so they buy material and keep it in their warehouses, and sell it to the SMEs in their incubator, so how do we compete with that?" (SME-K).*

Therefore, there was a need to maintain a balance between incubates and SMEs outside incubators to initiate a productive local SME ecosystem. One way of maintaining a balance was for the incubators to delegate raw materials to the local suppliers and extend the subsidies to them. With the latter approach, the incubators would then act as feeders instead of competitors in the local SME ecosystem.

-Highlights-



Establishing trust is a crucial factor between ecosystem actors, which needs to be nurtured through instruments such as gentlemen agreements. Most ecosystem actors in incubators operate in silos despite having geographic proximity to others due to a lack of trust. **Identifying key contacts** need to be coupled with mutual agreement amongst ecosystem actors regarding their expected roles, contributions and value exchange. **Knowledge sources** are key to capacitate ecosystem actors with skills to initiate local SME ecosystems. The study found a disconnect between incubators and local institutions. **Access to capital** needs to be coupled with mechanisms to regulate the efficacy of capital in the initial stage of the ecosystem. Incubation subsidies need to be extended to SMEs outside incubators. If the four factors are initiated, the next piece, i.e. design, can be easily explored.

7.2.1.2 Designing ecosystems

In responding to how ecosystem actors in incubators influence the local ecosystem structure, SMEs and incubator managers highlighted several factors; establishing shared value, forming collaborations, using digital technologies, policy supports and using indigenous materials.

Establishing shared value

In terms of establishing shared value, incubators reported that they aim to support SMEs in creating a competitive advantage. However, few SMEs did not immediately see the value in ecosystems. Consequently, this behaviour acted as a barrier to recognise the benefits of local SME ecosystems. Most participants reported that their uncoordinated actions and practices led to conflicts and, ultimately, the weakening of communities in which they are embedded. They also reported that they lacked the collective-impact approach, with no explicit agenda towards building the local ecosystem. Collective impact is the actor's commitment towards a common goal to solve a particular problem through a structured collaborative approach (Porter and Kramer, 2011). SME-I noted:

> *"So, we currently do not have the capacity, but there is a lot of us [referring to leather SMEs]. We are all small, but there is a lot of us if we all came together and became an ecosystem and decided ok, this is the product that we are all going to work together on, and showed capacity and then petition the Government to say, please do not allow anyone to bring the belts into the country, we will make all the belts, anyone wants a belt, we are here" (SME-I).*

The above quote implies that actors located in the same incubators did not have a common goal. This finding was unexpected because incubates were geographically located in the same space. However, the incubator managers highlighted how difficult it is to define a shared value proposition. Defining and establishing a common goal is significant to clarify who needs to do what in the local ecosystem in explicit terms. Most SMEs failed to share resources, i.e. physical equipment, workspaces, business customers and parts of the supply chain, to develop benefits for the ecosystem actors and the community, contrary to what is suggested in previous studies as a way of creating shared value (Manzini, 2015; Dedehayir et al., 2017).

Forming collaborations

When addressing collaborations, participants mentioned that they failed to form productive clusters because of their attitudes, actions and practices. Although the study highlighted the possibility of using a collective-impact approach, operationalising this proved to be an arduous task amongst actors at the leather and ceramic incubators. So, when analysing failed cluster projects, most participants highlighted a lack of commitment to delivering on their designated roles:

> *"Our partners were supposed to firstly help us with capacity building and then help us with looking for international markets or external markets for our products, and they met none of those objectives, and that is why I feel that this relationship is just a waste of time" (SME-O).*

The above quote suggested that ecosystem actors lacked the commitment to execute their roles which eventually led to inadequacies within the local ecosystem. The inabilities to obtain key inputs associated with employee's capabilities was problematic.

Lack of aggression and commitment also led to less interest in forming collaborations, and without collaborations, it was challenging to design productive ecosystems. In most incubators, there were fewer collaborations with knowledge sources, i.e. Universities, colleges, R&D centres which may be attributed to limited innovations. Therefore, leveraging the generation and diffusion of knowledge was vital, as alluded to on page 173. These results are consistent with other research findings highlighting that firms could no longer develop innovations independently but need to collaborate with knowledge centres (Valkokari, 2015; Siikonen et al., 2011).

Using technologies

When tackling the question of how technology shapes the local ecosystem, ecosystem actors had mixed reactions. Most ceramic and visual arts incubators were more protective of their conventional manufacturing processes and maintained that there was more value in craft processes and products. Those from the leather incubator, multi-sector and those located outside incubators were more open to exploring new technologies such as laser cutters and 3D printers. Ecosystem actors in support of new technologies highlighted that conventional manufacturing processes were contributing to low-quality products, thus affecting their competitive advantage against imports:

> *"So, 3D printing comes in as a tool to prototype a product before fully investing. There are about five products in the line that are not touched yet because of the lack of our 3D printers, ... We also make our tools [referring to tools used in their weaving processes], which should be 3D printed, because now we are welding them…what we should be doing is we should be 3D printing the tools before we make the final one you know because 3D printing is good for prototyping"(SME-A).*

> *"I would try and preserve our indigenous low technology type of production, but we fuse in here and there to match in with the new technology, but we will not face out our production processes and say the technology has arrived no…" (SME-D).*

> *"Even as far as 3D printing of plastic components as we were discussing yesterday, if we take all the plastics and melt them down and use printers, we*

can print new corks and gears, it could be cheaper, and it clears off our landfills currently filled with lots of the plastic waste that is not degradable" (SME-E).

Looking at the first quote from the leather incubator, SME-A emphasises the need to use 3D printing technologies in prototyping tools to support weaving processes. Therefore, in SME-A's context, identifying 3D printing bureaus or partnering with the Universities in prototyping tools might lead to more value creation. In contrast, SME-D from the ceramic incubator highlights the need for the ecosystem to leverage conventional processes while exploiting new technologies. Most ceramic SMEs emphasised a competitive advantage in handcrafted products and the availability of a specific tourism market for such products and processes. The researcher also validated this claim during the site visit, where tourists engaged in hand-making ceramic products, which they then took away as souvenirs. In contrast, as a firm located outside the incubator, SME-E noted that 3D printers might be useful in their ecosystem regarding re-manufacturing replacement parts and recycling plastic waste.

Given the three quotes, the study posited that while digital manufacturing technologies undoubtedly could support the local ecosystems, this seemed to resonate well with the leather incubator, multi-sector and standalone SMEs. Whereas in the ceramic and visual arts incubators, participants reported that these technologies threatened the already existing competitive advantage. Contrary to expectations, the ceramic ecosystem provides more value to tourists through leveraging human-machine and material interactions than what precision-based digital technologies could offer at the moment. This finding corroborates previous studies (Devendorf et al., 2016), which highlighted de-emphasis on precision and promoted uncoordinated experiences emerging from hand-material interactions as valuable.

Policy support

To address the question of policies, the study focused on both SMEs in and outside incubators. The policy situation in Botswana has often focused on putting much money in start-ups without enacting mechanisms to regulate the efficacy of capital, as elucidated on page 175. Most SMEs highlighted a high rate of start-up failures, although the Government is providing a significant number of grants (chapter 2). Incubators are faced with a mammoth policy design task to turn the situation around. The main question was on why SMEs continue to fail with so much financial support from the

Government? Most SMEs and incubator managers attributed the failure to the lack of robust policies to build and promote competitiveness. They ascribed most failures to inefficient regulations around the curtailment of powerful foreign-owned businesses. In order to support the design of local SME ecosystems, an appreciation of the local SME innovation ecosystem factors was emphasised to develop new policy requirements:

> *"This import substitution of leather goods is a bit difficult for us[referring to local manufacturing SMEs] to compete with, and the Government need to introduce a policy that can regulate the import of leather goods because most of the leather goods around are from either China, India or neighbouring countries" (IM-A).*

> *"The Government should try and regulate retail stores to buy a certain percentage from us, from manufacturing SMEs, as it is now they [referring to foreign-owned retail stores] have succeeded in taking us out of business completely because they are not buying even a single percentage from us. All the retail stores are buying from outside the country" (SME-N).*

From the above quotes, it appeared that large and established ecosystems, i.e. foreign-owned retail ecosystems, were dominating the local SME ecosystem, thus competing directly with manufacturing SMEs located in and outside incubators. The lack of regulatory policies to address these dominating behaviours was noted as a big challenge. To design ecosystem friendly policies, incubator managers emphasised that policymakers and SMEs need to dialogue and develop favourable guidelines to reduce the importation of leather and ceramic products. Most ecosystem actors blamed the Government for excluding them from the design of policies. They highlighted problems with limited coordination between relevant Government departments, particularly on the existing policy instruments. Participants suggested incentives such as subsidies and tax rebates to motivate and promote linkages between large retail ecosystems and SMEs, relax immigration laws, allow SMEs to recruit foreign partners, relax tax compliance fees and introduce employees sharing policies within local SME ecosystems.

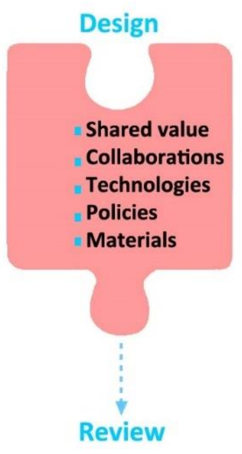
Indigenous materials

In responding to how indigenous materials might support local SME ecosystems, SMEs reported a huge opportunity in the untapped leather industry to expand the local ecosystem. The key challenge with leather processing was identified as a lack of skilled personnel and lack of Government buy-in to invest in the raw material processing industry:

> *"The other challenge is that it is very difficult to process our leather locally even though we are producing the largest leather materials in Africa through Botswana Meat Commission" (SME-K).*

Concerning the leather and ceramic incubators, participants agreed that the challenge with exploring local materials (leather and ceramics) was exacerbated by the Government's reluctance to invest money towards these industries. Another condition that emerged from the study that inhibited value creation in indigenous materials was the huge importation of ceramic materials. Participants suggested that the Government's leather and ceramic processing input could usher a more nuanced local SME ecosystem, leading to more robust connections with local communities.

-Highlights-



Establishing shared value is the collective vision that keeps ecosystem actors on board, working towards economic and social benefits. Ecosystem actors lacked this because of their isolated actions. **Forming collaborations** is gravely affected by a lack of commitment and trust. To remedy the situation, forming relations with knowledge centres may benefit ecosystem actors in terms of knowledge diffusion and capacity. **Using digital manufacturing technologies** resonate well with other incubators, whereas in the ceramic and visual arts incubators, it could destroy the already existing competitive advantage, particularly in the tourism industry where interaction with materials is preferred. **Policy support** to reduce imports and introduce incentives to promote linkages between SMEs and large firms is vital. Promoting **Indigenous materials,** i.e. leather, ceramic industries, and Government buy-in, could lead to a more nuanced local SME ecosystem. If the five factors identified here are addressed, the next level, i.e. Review, can be explored.

7.2.1.3 Reviewing ecosystems

Reviewing development factors can enhance the local ecosystem. Most SMEs highlighted three main factors as follows; capacity, competition and expansion.

Capacity

Capacity is explained as the highest output level the ecosystem can maintain in generating shared value given available resources (Xu et al., 2018). This assumed a constant level of the desired output, which was found improbable to maintain given the dynamism of an SME ecosystem in this study. Consistency in reviewing inefficiencies in terms of ecosystem resources was highlighted as necessary. In retrospect, most ecosystem actors related poor performance of local ecosystems to an acute lack of skilled labour, lack of financial capital to invest in manpower development, lack of access to new technologies and lack of data use. Similarly, incubator managers reiterated SME's incapacities and poor etiquette to execute market-leading ecosystems. The incubator managers claimed to be offering training on some of the skills needed to monitor ecosystem dynamics. However, a vast majority of SMEs held a view that the interventions were not suited to their needs:

> *"But we believe we still lack in terms of sales and marketing to grow the business ecosystem. ... The way our company operate is that currently, it is clear that we are putting much money into the business, but it is not making a profit. We are pumping in a lot of money, and we do not see the profits coming out of it" (SME-N).*

One way of addressing capacity challenges was to identify key actors in the ecosystem who can provide niche services in the value creation process (p.173). The study also found that manufacturing SMEs might benefit from connecting with firms from other domains, e.g. sales and marketing fields, promotions and accounting. It would be intriguing to consider key actors as innovative partners rather than just a list of inputs adding to the total contacts of SMEs. Increasing capacity by allowing more specialised actors into the incubator would allow ecosystem actors to focus on their core innovation roles. Therefore, reviewing the ecosystem also implies inter alia looking back at the initiation and forward-looking at the activation levels to ensure alignment of roles amongst ecosystem actors. For example, exploring University roles might increase SME innovation capacity. This finding is consistent with that of (Link and Sarala, 2019), who found that entrepreneurs are potent co-creators of shared value from University knowledge.

Competition

Aside from reviewing the ecosystem capacity, most participants described competitiveness as key in the local ecosystem. For ecosystem actors to thrive, they need to be able to compete effectively with large retail ecosystems. Participants highlighted competition problems such as the unregulated influx of cheap imports, constraints associated with unregulated retail prices, local market penetration bottlenecks, overdue payments by the Government and lack of export opportunities. When assessing the ecosystem landscape regarding cheap imports, most participants emphasized that the local market was attracted to low prices than quality, thus favouring cheap imports over handcrafted products from the local SME ecosystem:

> *“Normally, pieces such as this [pointing at a wooden sculpture in his office] do not often sell fast because they are pricy, so people often love them but fail to spend huge cash on them. So normally we survive through small crafts that are less expensive, which can be afforded by most people here. Big pieces like this take a while to sell” (SME-F).*

Regarding the above quote, most ecosystem actors were aware of the bottlenecks in their ecosystem but lacked the propensity and capabilities that might increase competitiveness. How can they attract the local market towards pricy crafts? Most ecosystem actors seemed less interested in exploring ways to attract the bottom of the pyramid market. The study observed that lack of collaborations amongst SMEs led to a lack of competitiveness, especially in incubators, as discussed on page 178. Interestingly, ecosystem actors chose to compete amongst themselves for a smaller market than to collaborate in bigger markets. Other scholars reported that if actors compete in a healthy ecosystem, they both thrive, but they will all be hurt if the ecosystem is unhealthy (Iansiti and Levien, 2004). This observation is in accord with the analysis of the findings at the incubators, where actors are hurting due to internal competition.

Most participants unequivocally demonstrated that the Government was the problem hampering the development of local ecosystems, primarily through delays in payments due to hierarchical decision-making processes and culture. A fundamental difference between SMEs and the Government process was that SME ecosystems operated in a flat, networked structure, whereas the Government of Botswana operated in a top-down hierarchical world. One SMEs adds:

> *"The Government is our main problem when it comes to payments. They sometimes take more than two months to pay us, can you imagine, after spending all your money delivering on the project and… then you have to wait on some people[referring to managers who are responsible for signing off payments] who are lazy to do their job. It is frustrating sometimes, and that is how we lose business to others. They cut our cash flow" (SME-B).*

The above findings were unexpected and suggested that the Government as a critical feeder in the local SME ecosystem negatively affected the SMEs competitiveness. It is interesting to note that this view was held by most participants in and outside the incubators, indicating that it was a genuine concern that harmed competitiveness. The implications are that if the culture of overdue payments was spread amongst the Government departments, it was difficult for SMEs to grow the local ecosystems. Therefore, the Government may need to take decisive actions on procurement and make it '*friendly'* to local SMEs.

Most SMEs alleged price-fixing by large retailers as one of their key strategies dominating the local markets. The Government may need to intervene in law enforcement and incentivise incumbent retail players to support and possibly form ties with local SME ecosystems. In the end, the more SME ecosystems grow in density and diversity, the more innovation happens, and incumbent ecosystems could benefit directly from the explosion of these nascent local ecosystems. This finding supports evidence from previous observations (Schoemaker et al., 2018).

Expansion

Besides building competitiveness and capacity, expansion was also seen as an impetus to grow the local SME ecosystem. What can SMEs do to expand their ecosystems beyond the status quo? Reviewing existing and failed ecosystem projects such as cluster initiatives in incubators seemed to hold the clue to the question. Most incubators appeared reluctant to review failed attempts in ecosystems and in exploring new ways of doing things.

The study also found that most SMEs in incubators were risk-averse and engaged less in experimental work. They seemed to lack attributes such as risk-taking affinity and aggression associated with tenacious entrepreneurs, thus limiting their propensity to succeed as local ecosystems. This was rather an unexpected finding because, unlike SMEs located outside incubators who often operate under tight budgets, incubates are exposed to subsidies and free tools as part of the incubator interventions, thus giving them 'soft budget constraints' to allow experimentation and risk-taking, as explained in (Fransman, 2018).

However, most SMEs highlighted the problems and risks of engaging in co-creation during cluster projects. Some of the problems were explained in previous sections, such as conflicts on roles, reporting late for work and not delivering on tasks during collaborations. Most participants reported failure and risk-taking as a problem rather than as a learning opportunity. Experimentation with new ecosystem configurations seemed non-existent amongst incubates. The incubator manager added:

> *"So, we[incubator] intervened to purchase the machinery for the clients [SMEs] so that they can use the leather machinery at any given time without any charge. So, this is one of the interventions, it is one of the benefits of being part of the incubator, but we do not see SMEs doing collaborative work because of these machines or spaces" (IM-A).*

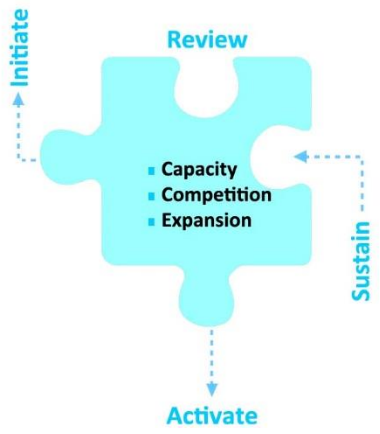
Regarding the above quote, although the incubators provided shared resources like equipment to promote co-creation and collaboration, most ecosystem actors were not interested in collaborations. This is partly because of a lack of trust, as alluded to on page 172. When responding to expanding markets and developing new opportunities, most participants highlighted expositions and trade shows as the main avenues for seeking new markets. Difficulties in expanding beyond the city were attributed to a lack of resources. For instance, most ceramic firms were largely dependent on the tourism market, predominantly located in the northern part of the country, approximately 600 kilometres from the capital city, making it difficult to reach by road. An implication of this was that most markets were limited to the city, where the tourist markets are scarce.

However, one ceramic SME demonstrated efforts towards reviewing markets outside the city and identifying bridges (key contacts to connect them) to reach new opportunities:

> *"We are currently looking for spaces to sell our products, and there was a lady[referring to a potential key actor] who wanted to display our products in the Town of Kasane[600 kilometres north of the capital city, Gaborone]. We are still awaiting funding to move towards those spaces. We believe that after independence[a holiday] we will be finishing up the deal to go there" (SME-J).*

The above effort represents an example of seeking expansion towards new markets. Therefore, reviewing markets and identifying key actors, i.e. tenacious entrepreneurs, large firms, financers, and the Government and local communities to play bridging roles, are needed to expand local ecosystems. The key issue here is that ecosystem actors need to experiment with others and fail, learn from their mistakes and keep working. Previous literature also suggested that failed experiments and projects might fruitfully contribute to the expansion of the ecosystem (Raven and Verbong, 2004).

-Highlights-



Capacity is when the ecosystem maintains the highest outputs with given resources. Reviewing ecosystem resource capacity and locating key roles to augment capacity is critical. **Competition** problems were cited as; cheap imports, price-fixing by dominating retailers, the Government inefficiencies in procurement, inaccessible export markets. To remedy the situation, the Government need to improve procurement services, regulate retail prices, introduce incentives to encourage retailers and SMEs interconnections. **Expansion** is the key to reach new markets. The study found that most nascent SME ecosystems did not continually review their ecosystem dynamics to develop and expand beyond the capital city, whereas their innovation opportunities were found in some parts of the country. Reviewing the ecosystem is connected to initiating and activating it; this needs to be done iteratively to ensure efficiency before activating it, which is the next piece of the Jigsaw.

7.2.1.4 Activating ecosystems

Regarding the activation of the local ecosystem, most participants had little understanding of the deliberate steps they could take. A practical understanding of ecosystem dynamics and a structure was fundamental in fomenting action amongst ecosystem actors. The following key factors came out of this analysis; educating ecosystem users, identifying investment partners, and lobbying for the local Government's active involvement in ecosystems.

Educating ecosystem users

Who are these users? Incubates and partners were identified as users because they face current SMEs ecosystem needs that will be general to other players in the future (Von Hippel, 1986). Since the study established that manufacturing SMEs exist in nascent forms and are embedded in local systems, there was an acute lack of knowledge about these ecosystem mechanisms. The study found that it was necessary to educate the ecosystem actors as a starting point. Although most incubators offered business coaching, mentoring and monitoring, these kinds of interventions were found to be firm centric as opposed to ecosystemic:

> *"I once helped two corporate clients, but I think we lack in that side of the market [referring to following up on customers]. We helped IT stores with design and manufacture of laptop bags. We also designed and manufactured some once-off merchandise products for clients" (SME-I).*

Given the above quote, ecosystem lead users were less informed about activating the dormant connections they have with firms and SMEs outside incubators. Given the above scenario, it is crucial to promote collaborations between these entities beyond just one-off transactions. Few ways of activating connections might be to engage both SMEs in and outside incubators and other interested entities like investors, Universities and corporates through co-design workshops and open events. Investors may also need to be educated about local ecosystems; to have a clearer picture of what value they might contribute to the local SME ecosystem.

Investment partners

For any nascent SME ecosystem to thrive, investment partners need to be involved. From these case studies, it was demonstrated that a substantial portion of start-up capital was from the Government. Most participants highlighted challenges associated with access to financiers to provide seed capital and strategic direction. Therefore, identifying and activating connections with angels or seed investors, tenacious entrepreneurs, commercial banks, and other financial firms who can provide money and business knowledge in exchange for convertible debt or ownership equity was important:

> *"We believe if the Government can give us the business [referring to the Government, giving them more powers to run their SMEs autonomously], we will be free to look for investors. We are still under the Government. They gave us the money to set up the business and to buy machinery as you can see here [pointing at the machines in the workshop], so if we go [referring to before the end of the two years incubation period], we cannot take their stuff, the machines belong to the Government" (SME-N).*

Again, from the above quote, participants blamed the Government for the lack of investor's engagement. Participants reported that the Government of Botswana was prohibiting them from looking for investors. Contrarily, the incubator manager reported that SMEs were not prohibited from recruiting investors from outside the incubators. In this case, it was apparent that ecosystem actors needed investors to provide seed capital and guidance. In all cases, the managers reported that they need proper incentives and rewards mechanisms to motivate SMEs within their settings to become more comfortable exchanging data and technologies with external stakeholders. Otherwise, the internal employees might also pose as a formidable resistance against new investors and other partners. Introducing mentors, education programs, investors, employees incentives may accelerate the activation of the local SME ecosystem.

Government involvement

This thesis demonstrated that Government plays a pivotal role in building local SME ecosystems through start-up funding. However, according to most ecosystem actors, this was not enough. In a mature ecosystem, cities take the lead in supporting SMEs to activate the entrepreneurial ecosystem (Hwang and Horowitt, 2012; Feld, 2012). So, when participants responded to how the City Councils might actively assist them to grow, they highlighted that local councils could take deliberate actions to buy from them instead of importing everything from outside. Botswana is a small country with a little over two million people and approximately 232,000 people in the capital city. Given the small populated city, SMEs reported difficulty in finding markets within the city. Therefore, getting the local Government to support SMEs was important to activate a vibrant city ecosystem:

> *"I leant that while pursuing the XX council recently when you talk to them on the phone, there is nothing much that they say to you, but when you go there personally, they often take you seriously and engage" (SME-G).*

From the above statement, local councils are willing to engage in the SME ecosystem. Although they still prefer the face to face kind of encounters, which could be related to the issue of trust. Therefore, most SMEs expressed the intent to connect with local councils through knowledge exchange workshops and voluntary community work in the city to develop trust-based relations.

-Highlights-

Educating ecosystem **lead users** is crucial because the study found that most SME ecosystem partners engage in one-off transactions because they lack the understanding of social capital. Therefore, engaging in open dialogue might promote knowledge about the value of networks. **Investment partners** are vital in activating productive SME ecosystems. Getting investors to commit financially requires flexibility from SMEs to offer ownership equity. Furthermore, SME ecosystems need to develop incentives for SMEs and employees to openly share resources with external players. **Government involvement** at the central level plays a pivotal role in SME ecosystems in terms of start-up capital. It was suggested that more could be done through the local Government by deliberately buying from SMEs. If these three factors are tackled, the next piece of the Jigsaw would be to sustain local ecosystems.

7.2.1.5 Sustaining ecosystems

When analysing SME ecosystem sustainability, ecosystem actors raised many factors: ecosystem health, evolvement, motivations, and survival.

Ecosystem Health

Regarding ecosystem health, most participants described unhealthy relationships as the actor's inabilities to deliver on roles. Incubator managers reported that managing and ensuring interdependencies was more complicated than dealing with individual SMEs. They highlighted the difficulty in aligning SME behaviours towards a shared value proposition, citing different agendas, lack of trust, lack of openness, and lack of commitment to delivering on their mandate as a collective:

> *"They do not commit, they will rather bring excuses that I will do this at a later stage, and some remain to complain and as a result that affects productivity" (IM-A).*

> *"I know artists always complain. At the end of the day, they should also consider what and where they are; no one can get this opportunity anywhere." (IM-B).*

Regarding the above quotes, incubator managers highlighted that most SMEs lacked the commitment to deliver on their roles. This was further elaborated earlier on page 177. Incubator managers also raised vital issues around work attitudes, highlighting a laisser-faire kind of attitude, leading to a lack of urgency when delivering collaborative projects. Furthermore, the culture of over-reliance on Government support was also ascribed to the perpetual SME's "dependency syndrome". Most participants highlighted uncertainties surrounding their supply chain, which was primarily linked to South Africa regarding raw materials and machinery repairs. Participants described these linkages as unreliable because of the incessant strike interruptions. These unpredictable events lead to misaligned business choices and negative ecosystem performance (Li and Garnsey, 2014).

In order to transition to a more sustainable local ecosystem, actors may need to recruit niche actors, such as leather manufacturers, ceramic material producers, community farmers and local suppliers. The key issue is that the local SME ecosystem needs to leverage new interactions to promote cross-pollination of ideas, leading to a healthier (productive) ecosystem.

Ecosystem Evolvement

Evolvement in this thesis means the ability of ecosystems to change form into new complex structures, thus raising questions of how to adapt to new changes. The ability of local ecosystems to evolve is directly linked to ecosystem health:

> *"This year is our last year in the incubator, and we tried to write letters and explain our difficulty in business and asking for an extension. We are supposed to vacate this office in August, but we told them that we are still having serious problems with running the business" (SME-N).*

In the above quote, the ecosystem actors anticipated that the changes in their existing relations might negatively impact their functions outside the incubator. This kind of evolving relations may be challenging to deal with outside the comfort of the incubator. Nevertheless, engaging with multiple actors from inside incubators is critical to prepare the ecosystem actors for emerging disruptions. These results are consistent with other researchers who elaborated that socio-technical experiments could build an environment for ecosystem health (Talmar et al., 2018; Rong et al., 2018). To prepare for the post-incubation period, actors may need to pursue connections with new stakeholders within and outside the incubators.

Ecosystem Motivation

In addressing how SMEs use extra-rational motivations to sustain their ecosystems, they mostly described their interest in economic benefits and were less interested in extra-rational motivations, e.g. altruism and social networking. These findings were not a surprise. Given the financial struggles of SMEs, their perception of value was anchored on the propensity to make more profit than anything else. Notwithstanding, few of them expressed the passion and desire to connect with others to innovate:

> *"Let us say right now I am doing this[referring to his work], and I stopped what I was doing, so I can just think if I had already done this, I could be making money, but I do it with all my heart, I do not charge anything" (SME-H).*

Although not immediately profitable to most SME ecosystem actors, the study found that the spirit of altruism may better contribute to forming sustainable relationships with external actors. This idea might translate into economic and social benefits. For example, few participants also reported engaging in community projects as volunteers to develop relationships with community leaders in the ceramic ecosystems. Although such relationships do not immediately translate into economic benefits, they largely contribute to social capital:

> *"One of the independence holidays I volunteered to decorate the Kgotla area to give back to the community, in XX which is under my constituency and also increase exposure for my products" (SME-C).*

Looking at the above statement, ecosystem actors may volunteer services to local councils to build trust. So, engaging in voluntary community works may create formidable relationships between ecosystem actors. Altruism, networking and volunteerism were important extra-rational motivations identified in this study that ecosystem actors could leverage to sustain relations with the community, Local Government and other stakeholders. Other researchers also point to these motivations to sustain local ecosystems (Presenza et al., 2019).

Ecosystem Survival

Given the above three factors identified as crucial in ecosystem sustainability, survival was highlighted as the main instinct of every entrepreneur, particularly those in incubators, because they have a limited timeframe to grow into viable businesses. Survival was reported as the ability of SMEs to continue to exist in local ecosystems in the face of adversity from external shocks. Most SMEs highlighted many dangers associated with their continued existence, such as dominating retailers, cheap imports, lack of policy support and limited export potential. Most of these dangers were associated with the third piece of the framework, i.e. review of ecosystems. If the ecosystem lacks capacity, competitiveness and expansion, it is improbable that it would survive in the face of uncertainties. Indications of unhealthy ties were identified amongst actors in incubators, mainly from their interactions in cluster projects. Failure to review their differences and pursue new roles to address these deficiencies led to disconnections between actors. To survive ecosystem disruptions, connecting with incumbent retail ecosystems, local Government and other SMEs in and outside incubation spaces and finding niche actors such as private investors, successful entrepreneurs, Universities is vital.

-Highlights-

The **Health** of SMEs ecosystems was highly uncertain because of a lack of niche actors in the ecosystem. Ecosystems need to recruit new actors to promote cross-pollination of ideas. **Evolvement** is the ability of the ecosystems to change from simple to complex structures. Most SMEs highlighted these complex changes as a potential problem for their survival. Incubates need to forge new relations within and outside the incubator to broaden their capacity. In terms of extra-rational **Motivations**, most SMEs highlighted that they are highly motivated by the propensity to make more profit, which is good but could be made more sustainable by leveraging altruism, social networks and volunteerism. Regarding the **survival** of ecosystems, SMEs may forge relationships with incumbent retail ecosystems, local Government, venture capitalists and others.

7.2.2 Visualisations

In this section, results of the analysis are presented based on chord, force-directed and 3D layouts methods described in this thesis (chapter 5).

7.2.2.1 Leather Incubator

Exploring node and tie hierarchies

By plotting data from five SMEs and the incubator manager using the chord layout (Figure 7.9), the thesis reveals node hierarchies and ties in a simple way. SME-A has the highest degree of connection from the graph, indicating extensive contacts beyond the incubation space. Surprisingly, SME-A is not connected to other SMEs in terms of resource exchange, although they are in the same space. IM-A has strong connections with all SMEs, thus acting as a keystone actor in this environment. Although the incubator provides keystone services to SMEs, all SMEs appear isolated, some with large networks connecting international actors. These observations corroborate those found in thematic findings. Therefore, a closer connection of SMEs might open opportunities for collaborations, thus enhancing the local ecosystems.

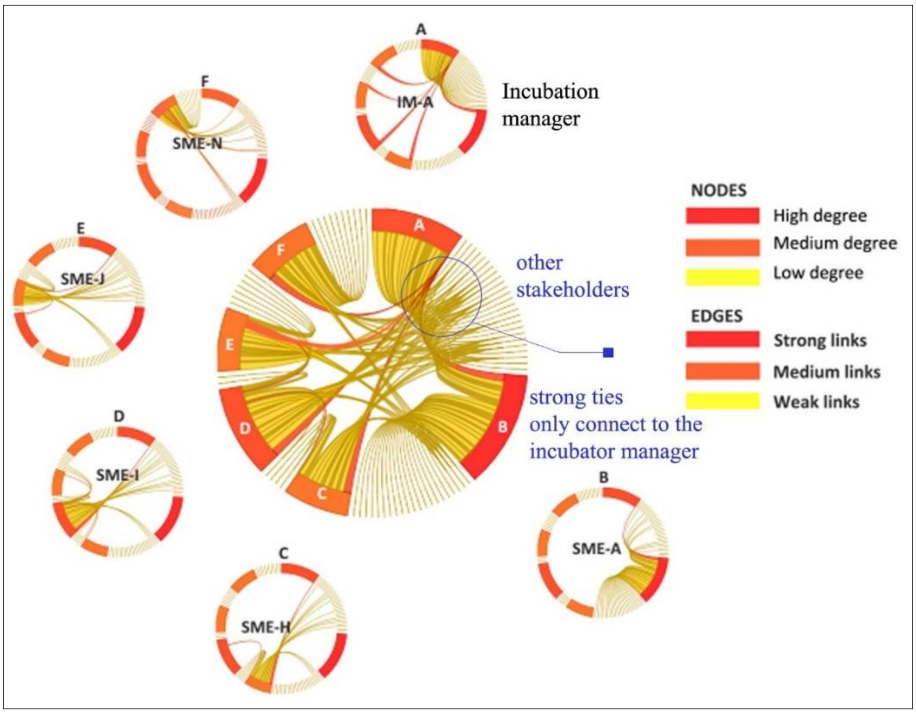


Figure 7.9: Chord layout results showing the leather incubator SME ecosystem node and tie hierarchies.

Exploring clusters, bridges and role structure

By plotting the ecosystem data using the force-directed layout (Figure 7.10), the thesis reveals three main clusters, where cluster A represent SME-A network and B represent a group of SMEs. Although these SMEs are disconnected, they all seem to be weakly connected to Botswana Investment and Trade Centre (BITC). So, BITC acts as a bridge between these isolated SMEs. The incubation manager is depicted as having a high degree of centrality, and all SMEs strongly connected to this role. This implies that the manager has a considerable influence on this local ecosystem. These results are not surprising because the incubator provides keystone services to all SMEs. The visualization also reveals bridging positions such as banks, councils, Government departments and networking workshops where decision-makers may explore new roles and contacts. All the bridges currently have little influence on the ecosystem. Exploring bridges might help SMEs open avenues for funding, lobby for Government schemes and subsidies, and promote exchange programs for innovation activities. Exploring weak ties shown in yellow links through bridging positions may lead to new talent and information discoveries (Berg-Ridenour, 2016; Granovetter, 1973). The role structure resembles a keystone-based ecosystem since all SMEs depend on the incubator for support.

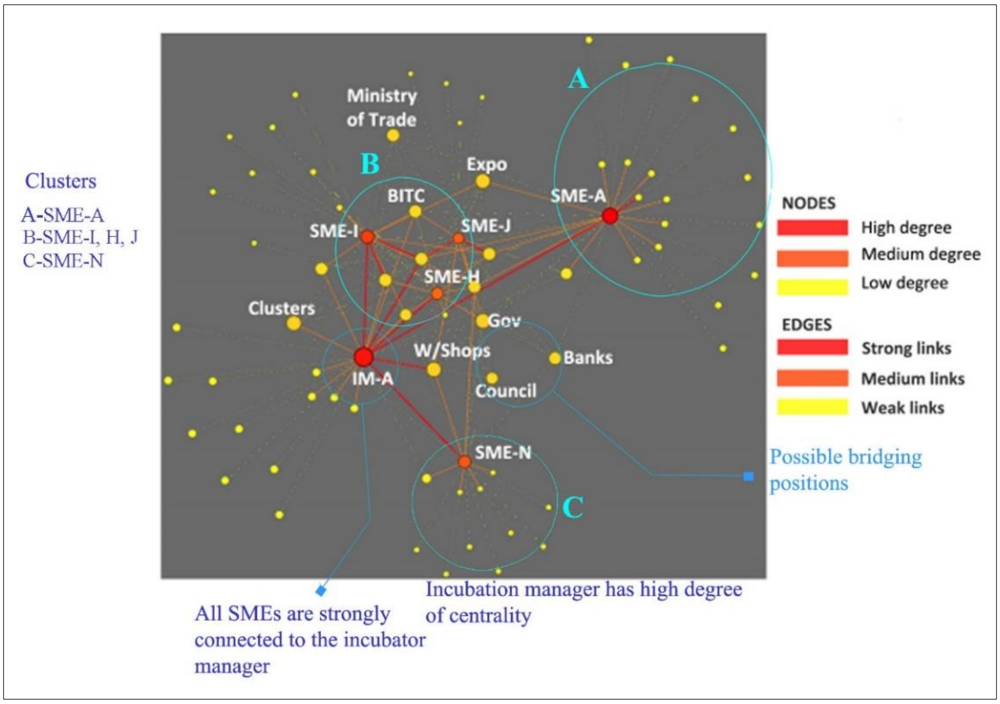


Figure 7.10: Force-directed layout results for the leather incubator SME ecosystem clusters, bridges and role structure.

Exploring structural holes

Using the 3D layout to model ecosystem data reveals hole-1 (Figure 7.11), which separates SME-H from A and J. These holes mean that they are not interacting and sharing resources although SMEs are in the exact location. The same can be said for structural hole-2, and 3. Isolations could be attributed to different age ranges amongst SME owners; for example, SME-N is a group of older women compared to other youthful SMEs, which may explain fewer interactions between the two groups. Some SME owners are not working full-time at the space, which could also be ascribed to these isolations. To promote interactions amongst SMEs, decision-makers may consider bridging holes by exploring key roles discussed on page 178. Decision-makers may also consider using networking activities to create a link between SMEs and key stakeholders, i.e. banks, local councils and central Government.

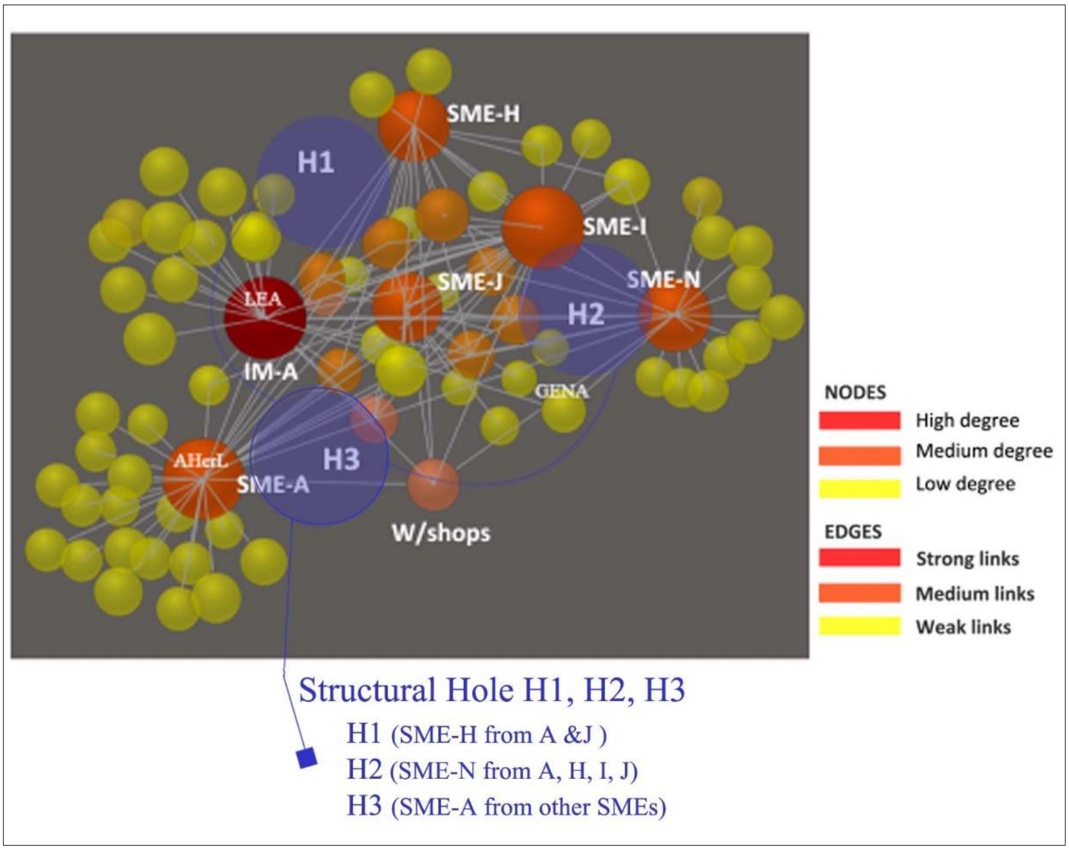


Figure 7.11: OmicsNet 3D layout results depicting the leather incubator SME ecosystem structural holes

7.2.2.2 Ceramic Incubator

Exploring node and tie hierarchies

Using the chord layout to plot datasets from the ceramic SMEs, the thesis reveals SME-O as the most connected actor with a higher degree than other SMEs (Figure 7.12). Unlike in the leather incubator, here, most connections are weak (highlighted in yellow). The incubator manager's role is non-existent because there is no active staff available to support the space. SME-O is a community interest company compared to the other two ceramic SMEs, possibly explaining its high degree of connection with the community actors. Notably, the three SMEs are disconnected from each other, probably because they are competitors. Although on page 185, SMEs reported that they depend heavily on the tourism market, it appears they have weak ties with the tourism agency who could be helping them to market their products. Decision-makers may explore ties with the tourism agency, expositions and exhibitions to expand their market and link with tourism communities outside the city. This may also increase their influence in shaping the local SME ecosystem.

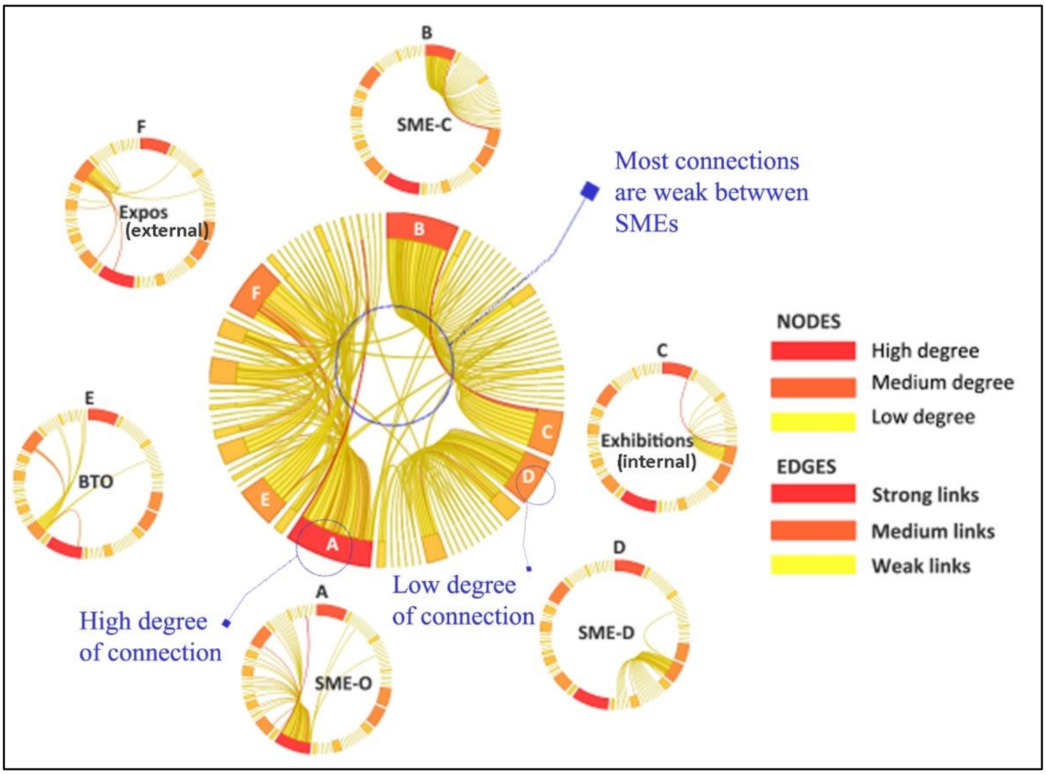


Figure 7.12: Chord layout results depicting three ceramic SME ecosystem node and tie hierarchies.

Exploring clusters, bridges and role structure

Plotting the datasets using a force-directed layout reveals three main clusters (Figure 7.13), where A is a dense cluster revealing SME-O as strongly connected to the local councils and community leaders. Cluster B is isolated from the tourism players and community leadership. Cluster C works closely with the government. SME-O has a high degree of centrality compared to the other two SMEs. Although the three SMEs are disconnected, there are potential bridging positions that decision-makers in both entities may consider pursuing to promote interactions and collaborations. Examples are the tourism agency and expositions. From these results, it seems SME-O is dominating the ceramic ecosystem.

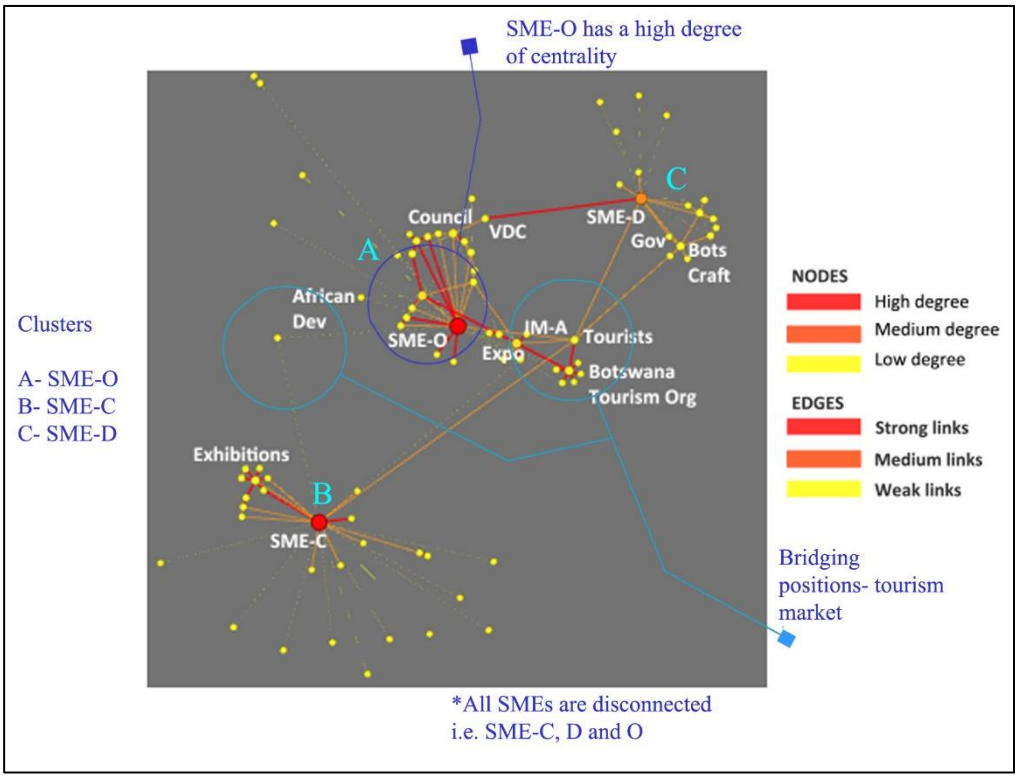


Figure 7.13: Force-directed layout results depicting three ceramic incubator SME ecosystem clusters, bridges and role structure.

Exploring structural holes

Using a 3D layout makes it possible to analyse and reveal structural holes much clearer (Figure 7.14). The analysis results show that hole-1 separates SME-C from SME-O, Universities, and the tourism organization. Consequently, SMEs cannot benefit from Universities through knowledge spillovers and from the tourism organization through leveraging their platform for accessing new markets. The University and the tourism organization roles exhibited limited influence in this space. Hole-2 separates SME-C and D from interacting and exchanging essential innovation resources, possibly due to their competing interests. Hole-3 also separates SME-D from leveraging University resources, i.e. talent, R&D knowledge and equipment, local councils and village development committees. So, seeing these structural holes may help decision-makers build bridges to close the holes through collaborations with Universities, village committees, local councils, and expositions.

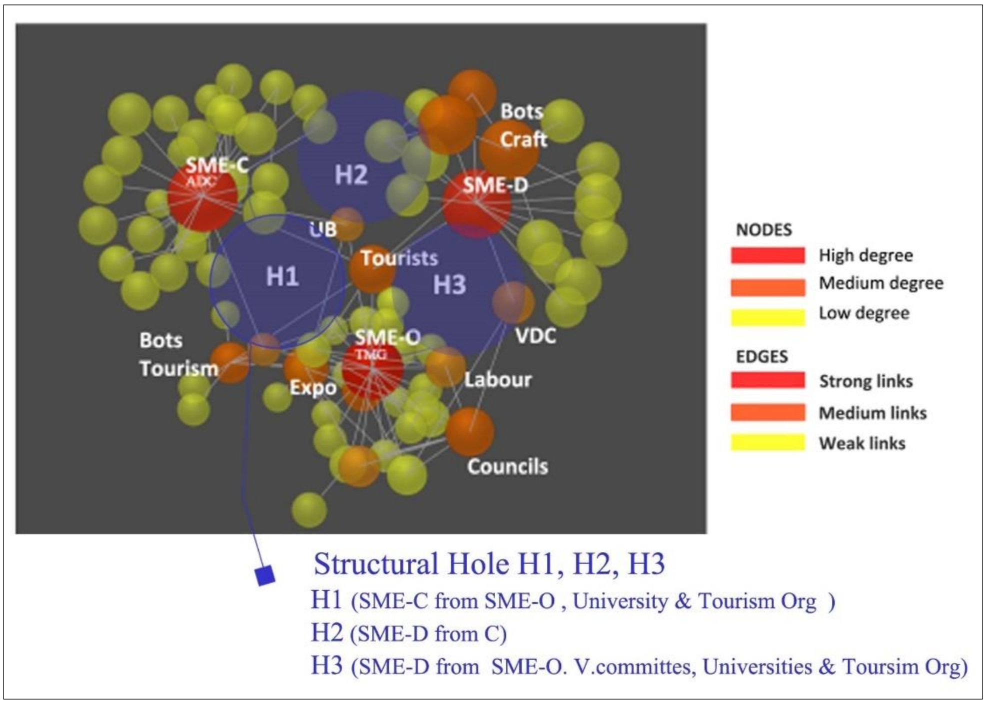


Figure 7.14: OmicsNet 3D layout results depicting three ceramic incubators SME ecosystem structural holes.

7.2.2.3 Multi-sector Incubator

Exploring node and tie hierarchies

Under the multi-sector incubator, two SMEs were investigated. By plotting SME data using a chord layout (Figure 7.15), the thesis clearly shows SME-G as the most connected compared to SME-B. Both SMEs are strongly linked to the incubator manager, although they are weakly linked to each other. The strong link to the incubator is due to the subsidies available there regarding rent and machinery. However, a closer look at the ecosystem shows that SMEs are weakly linked to critical roles like banks, government ministries, exhibitions and trade shows. Only one strong link is revealed between SME-B and workshops. These are workshops organized by the incubator.

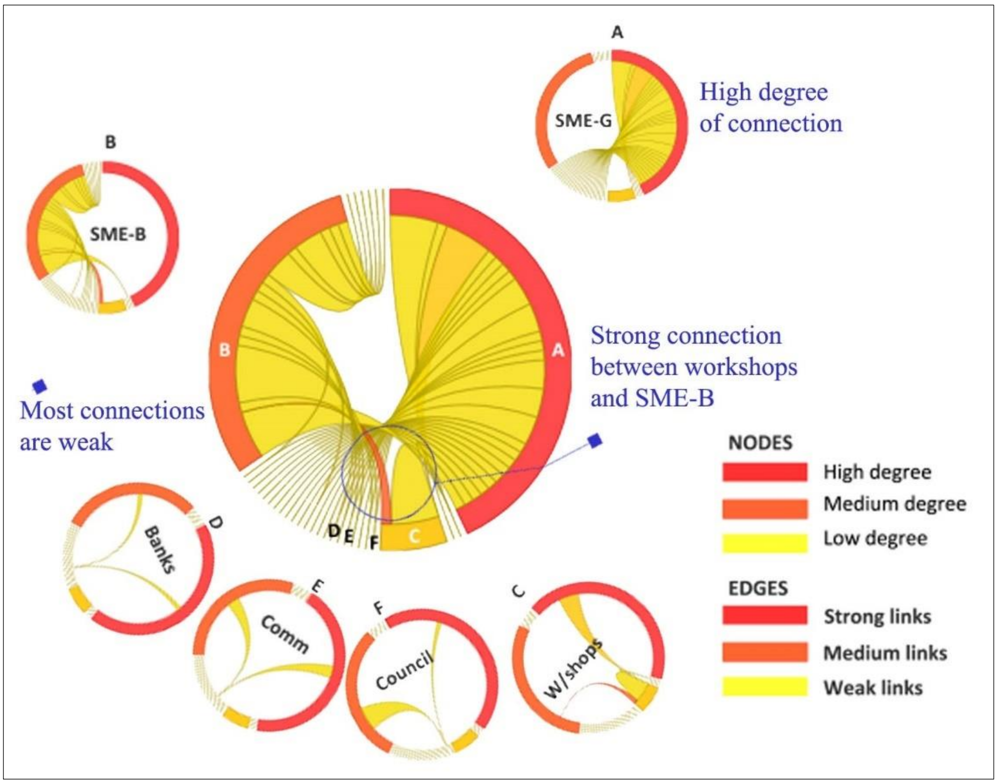


Figure 7.15: Chord layout results depicting two multisector incubators SMEs ecosystem in terms of node degree of connection and tie size.

Exploring clusters, bridges and role structure

By plotting data using the force-directed layout (Figure 7.16), the thesis demonstrates how the two SMEs are structured in this ecosystem. Two clusters, i.e. A and B, are visible, associated with two separate SME networks. There are also bridges visible which can be leveraged by actors in these SME networks to expand the ecosystem. For example, commercial banks have limited influence on the ecosystem, and this could be a bridge to support SMEs innovation ecosystems. The SMEs might also activate other tenacious entrepreneurs, angel investors and knowledge sources to build robust ecosystems. There is no role structure formed clearly in this ecosystem structure because of limited data, so both SMEs are connected to similar actors but not directly connected.

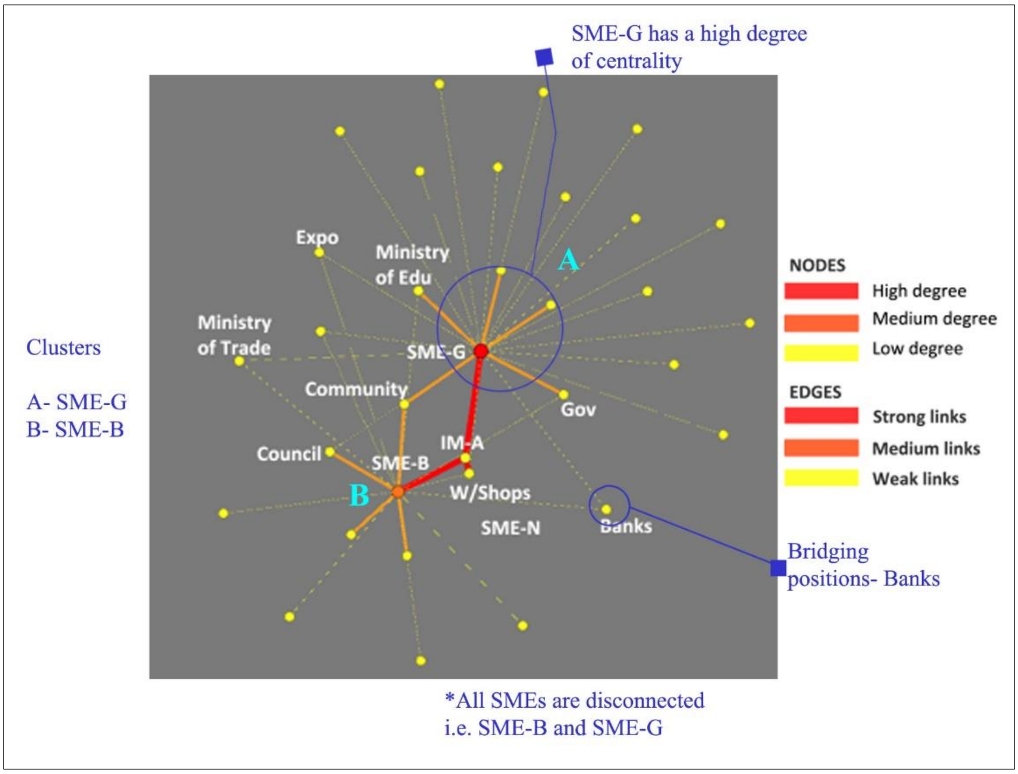


Figure 7.16: Force-directed layout results depicting two multisector incubator SME ecosystem clusters, bridges and role structure

Exploring structural holes

Using the 3D layout makes it possible to see structural holes, which may be of significant value to decision making (Figure 7.17). The results show that H1 separates SME-B from G, community actors and the Trade Ministry from the incubator manager, local councils from the incubator workshops. H2 separates the Ministry of Education and Banks from the Incubator workshops. These holes may exist intentionally because of SMEs competing interests. Decision-makers may address these holes by initiating new contacts with key actors at forums such as expositions and exhibitions based on mutual interests or approach local councils and ministries to develop new relationships. Design workshops may be used to bring these actors together to discuss ecosystem structures and value creation. Compared to the leather incubator, here, the incubator manager has limited influence in the SME ecosystem.

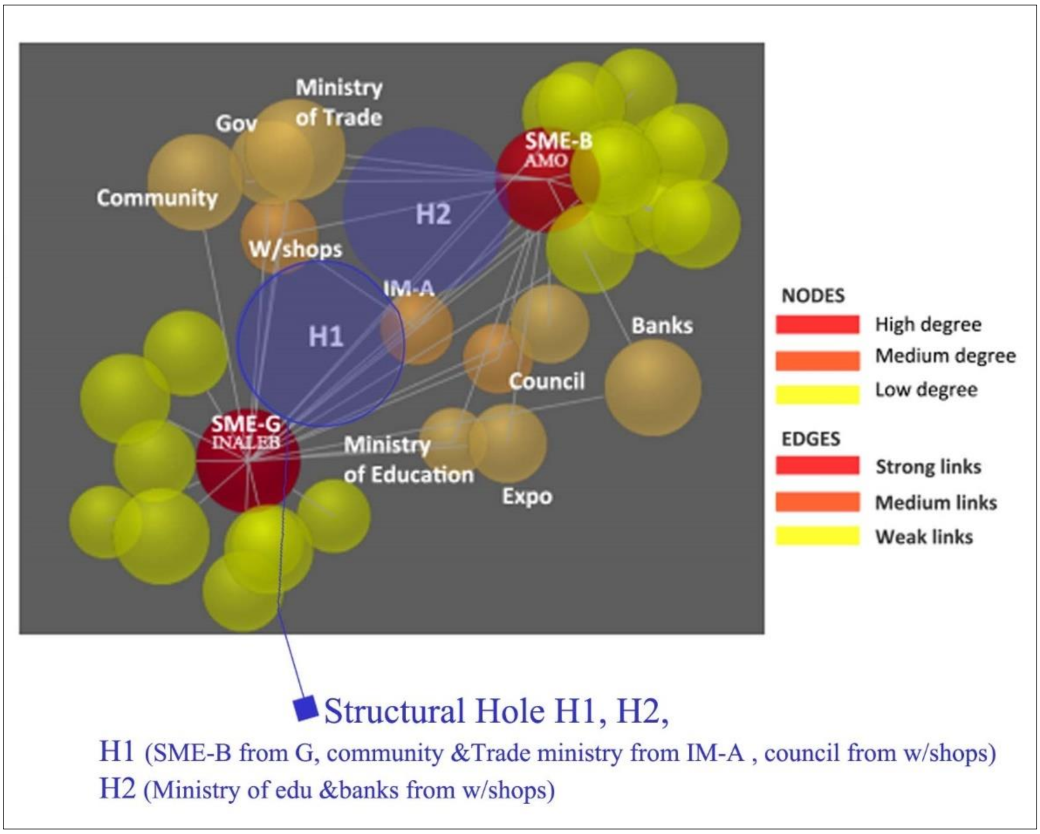


Figure 7.17: OmicsNet 3D layout results depicting two multisector incubators SMEs ecosystem in terms of structural holes

7.2.2.4 Visual Art Incubator

Exploring node and tie hierarchies

Three key actors were engaged at this incubator. The thesis used a chord layout to analyse node and tie hierarchies (Figure 7.18). The results show that SME-Q has a high degree of connection compared to SME-F and IM-B. It seems SME-Q is located near the restaurant, where there is proximity to many customers, thus explaining its high degree of connection compared to SME-F. The two SMEs are disconnected because they are doing completely different things, one is in sculpture manufacturing, and another is in textile design. However, both SMEs are strongly connected to the incubator manager, which acts as a keystone actor. Weak ties can be seen between SMEs and Government departments, incubator workshops and Botswana Investment and Trade Centre (BITC). Identifying weak ties might help decision-makers explore new roles to increase influence in shaping the local SME ecosystem.

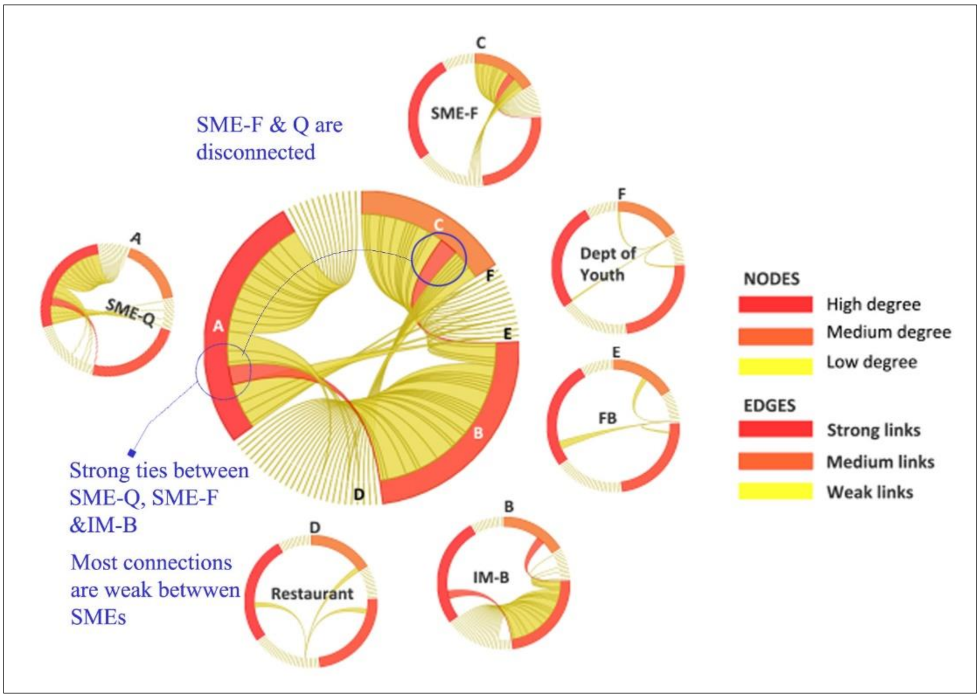


Figure 7.18: Chord layout results depicting three visual arts incubator SME ecosystem nodes and tie hierarchies.

Exploring clusters, bridges and role structure

The thesis identifies three main clusters in this ecosystem by plotting the data using a force-directed layout (Figure 7.19). Cluster A shows the incubator staff, forming a bridge between clusters B and C. Clusters B and C are weakly connected. The analysis also shows IM-B having a higher degree of centrality than the other actors in the ecosystem. The incubator manager acts as a keystone actor, providing subsidized office and workshop spaces for SMEs. So, like in the leather incubator case, here, the incubator role is considerably more influential. Although SMEs are disconnected, bridges are identified that decision-makers can leverage in expanding the ecosystem, i.e. trade shows, expositions, restaurants, BITC and Government departments are identified as potential roles that can add value to the SME ecosystem.

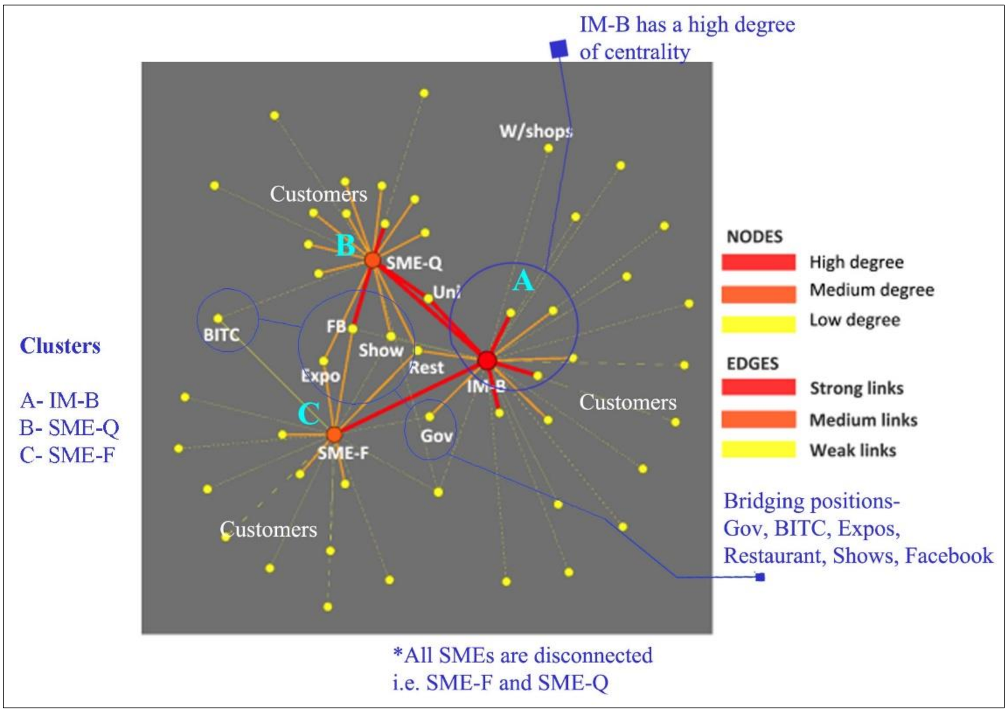


Figure 7.19: Force-directed layout results depicting three visual arts incubator SME ecosystem clusters, bridges and role structure.

Exploring structural holes

By plotting the ecosystem data from two SMEs and the incubation manager using the 3D layout (Figure 7.20), the thesis shows three structural holes which separate the ecosystem into three communities. Hole-1 separates IM-B and SME-F clusters. This could mean that the SME is not engaging the incubator manager in their innovation activities. Hole-2 separates the two SMEs from interacting, possibly because they do not trust each other with the business exchange. Hole-3 also reveals that SME-F is isolated from the University activities, suggesting that their interests are not aligned. This kind of knowledge might be useful for decision making. The geographic proximity to the University might allow SMEs to collaborate with researchers and students.

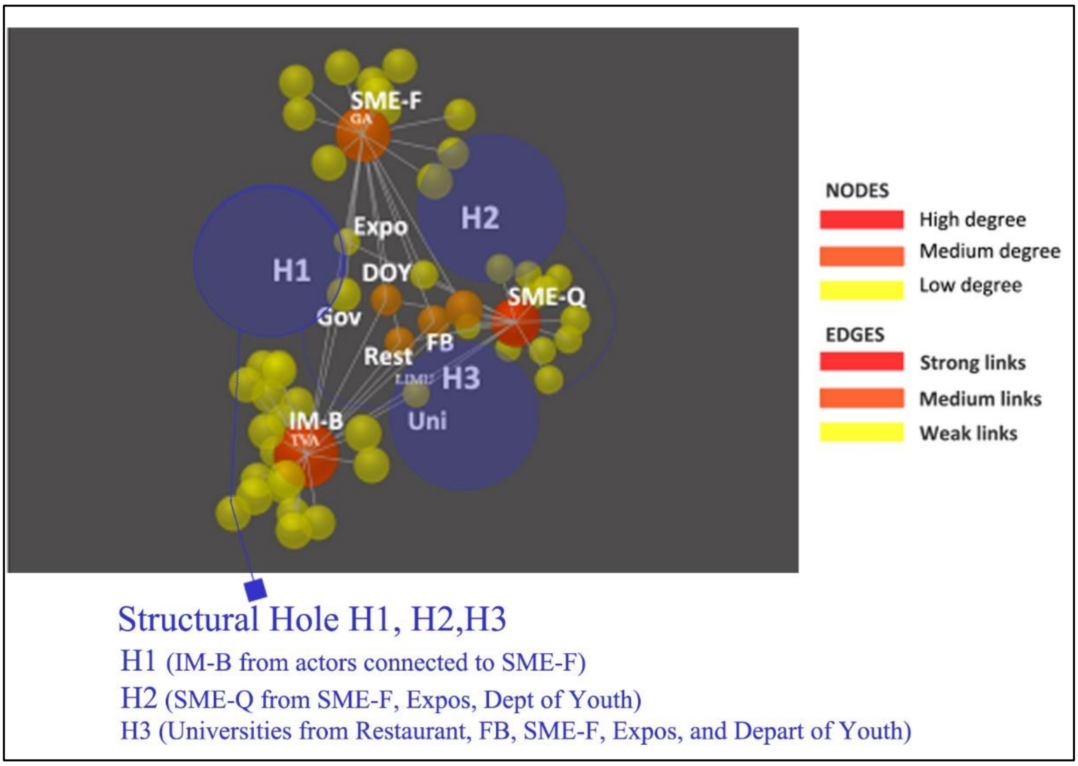


Figure 7.20: OmicsNet 3D layout results depicting three visual arts incubator SME ecosystem structural holes.

7.2.2.5 SMEs Outside Incubators

Exploring node and tie hierarchies

The thesis explored possible connections by plotting the ecosystem data from five standalone SMEs using the chord layout (Figure 7.12). The analysis of the results shows SME-L with a high degree of connection amongst SMEs, and SME-K having the lowest degree of connection. This is because the SME-L network extends to other countries, i.e. China and South Africa, while others are limited within Gaborone. Although these are independent SMEs in their own spaces, the visualization results show that SME-P and SME-M share a community of actors because they are geographically located in the same district. Aside from that, all SMEs are disconnected from each other.

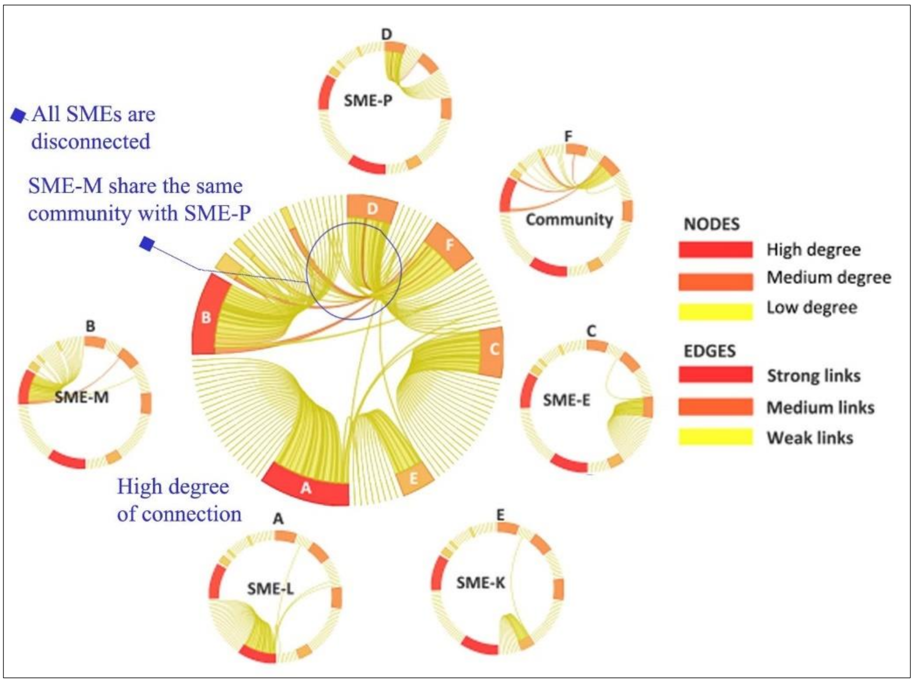


Figure 7.21: Chord layout results depicting five isolated SMEs ecosystem nodes and tie hierarchies.

Exploring clusters, bridges and role structure

The thesis clearly shows that the five SMEs are disconnected by plotting data using the force-directed layout (Figure 7.22). However, the visualisation also identifies SME-L as a potential keystone or hub with a high connection with other SMEs. So, leveraging these connections may benefit other SMEs in terms of ecosystem expansion and competitiveness. The Government and Local Enterprise Authority (LEA) actors are positioned at the strategic points in the ecosystem structure to act as bridges and keystones to support independent SMEs.

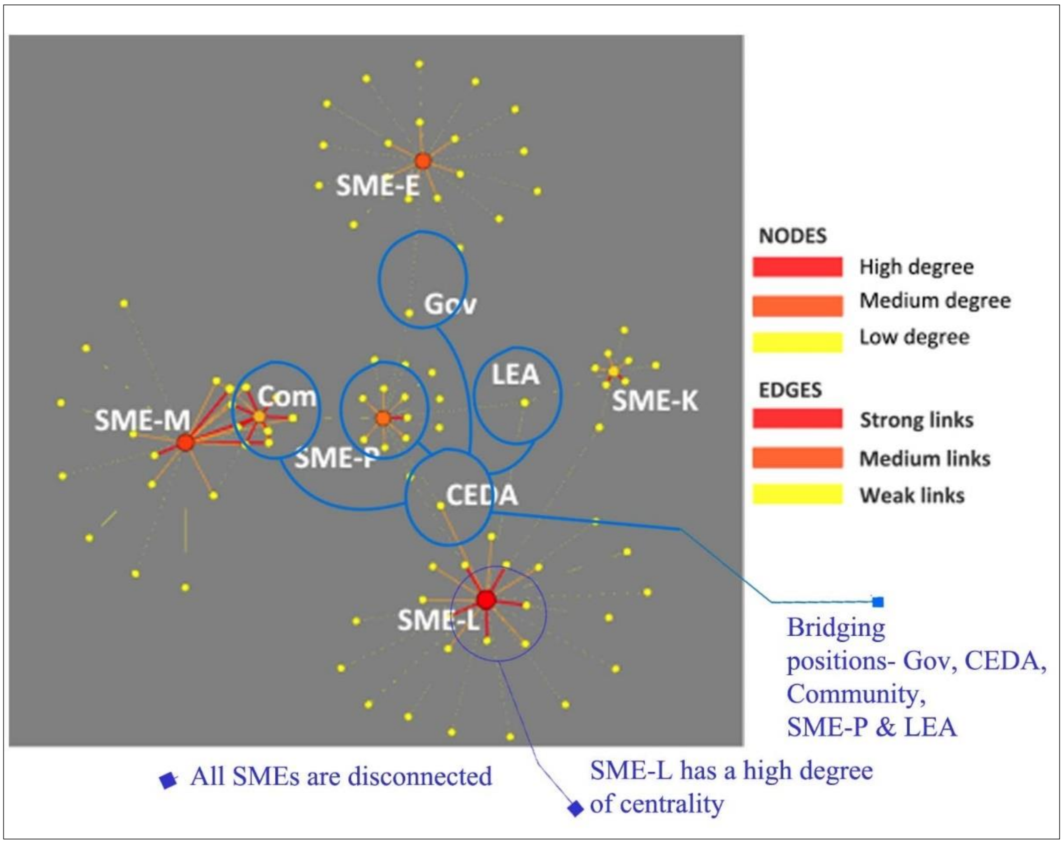


Figure 7.22: Force-directed layout results depicting five autonomous SMEs ecosystem clusters, bridges and role structure.

Exploring structural holes

Using the combined visualisation, a 3D layout reveals several holes in the network (Figure 7.23). Since SMEs are not located in the same space, structural holes show that all SMEs are standalone, albeit weakly connected to key actors such as local councils, community leaders, financial organizations, Local Enterprise Authority (LEA), Citizen Entrepreneurship Development Agency (CEDA) and Government departments. So, introducing strong links and activating bridges between some of these actors may effectively connect SMEs to collaborate. This may also increase SME innovation capabilities.

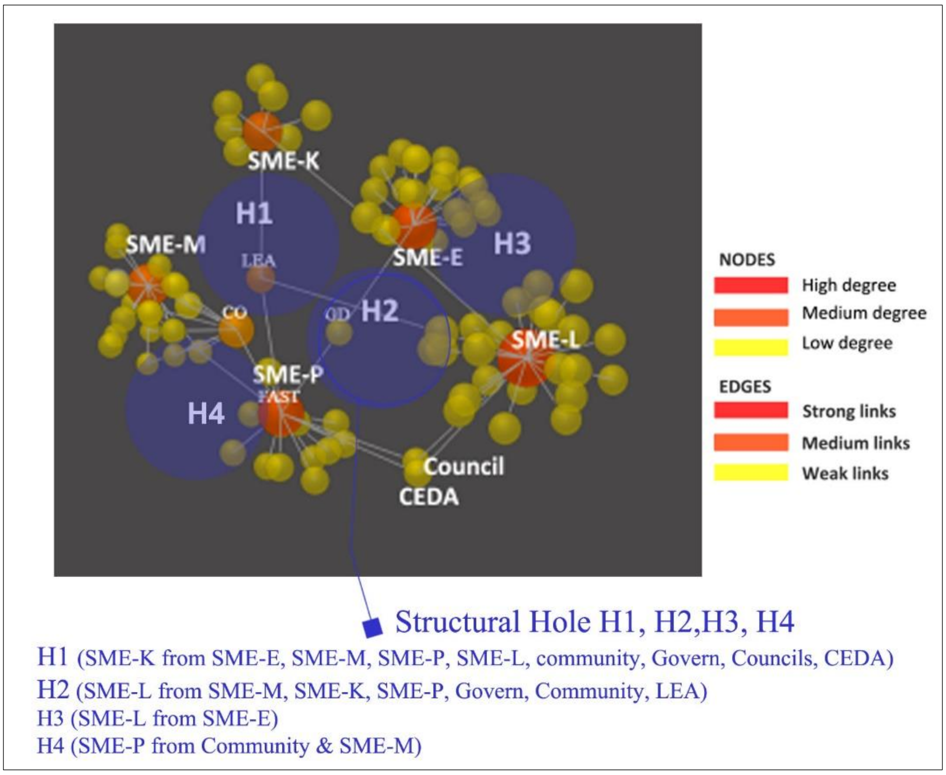


Figure 7.23: OmicsNet 3D layout results depicting five autonomous SMEs ecosystems in terms of structural holes.

-Highlights-

- In all spaces, SMEs are weakly connected. Although weak ties are great in leveraging new data, a combination of strong and weak ties is better. This can be addressed by promoting interactions amongst SMEs.

- In the leather and visual arts spaces, the incubator managers roles have more influence than SME roles. Whereas in the multi-sector and ceramic spaces, they have limited influence on the ecosystem.

- Banks, Government departments, local councils, investors, successful entrepreneurs all have limited influence in all SME ecosystems. Again, these roles can be leveraged more to increase their influence on the local SME ecosystem.

- Concerning SMEs outside incubators, they are all disconnected from Government subsidies available at the incubators. Extending subsidies to external SMEs is critical in developing local ecosystems.

7.3 Chapter conclusions

This chapter focused on incubation spaces as local ecosystems. By combining findings from chapters 5 and 6, and this present chapter, the thesis synthesises a framework for understanding local SME ecosystems called the 'Jigsaw' framework (Figure 7.24). This framework consists of five 'Jigsaw' pieces of understanding local ecosystems, i.e. Initiate, Design, Review, Activate and Sustain.

Overall, the thematic and visualisation findings indicate that a range of factors limited the growth of local SME ecosystems. First, considering the initiation of local ecosystems, the thesis concludes that ecosystem actors need to explore key contacts and establish trust before engaging in meaningful resource exchange. Establishing relationships with knowledge centres and identifying funders and investors is also vital in initiating productive ecosystems. Promoting policies on subsidies and tax rebates to stimulate the local ecosystem is important.

Second, regarding the design of ecosystems, ecosystem actors might establish a shared value based on their collective capabilities. This could be supported by forming collaborations with Universities and other entities to stimulate entrepreneurship in the city. University partnerships may attract faculties and students to participate in incubator and accelerator programs. It was elaborated in this chapter that the links with local communities in terms of indigenous material and promotion of conventional technologies need to be developed. Focusing on these areas through Government support may accelerate the understanding of local ecosystems.

Third, when looking at the review, diagnosing factors influencing the development of local ecosystems is a challenge, particularly looking at the capacity, competition and expansion. This implies keeping a wider lens on how these factors change by continuously studying the ecosystem structure. The Government departments in Botswana are identified as a bottleneck in procurement processes, low market penetration and lack of export. These are policy problems that may be addressed through co-design of policies as part of the review of local ecosystem structures.

Fourth, regarding activating ecosystems, many innovations took place in isolations despite proximities in incubators. This is a huge challenge. Most SMEs do not know how and where to activate important roles and actors in the local ecosystem. This may include getting investors and entrepreneurs to commit financially to the ecosystem and engaging Local Councils to contribute to ecosystem activities.

Finally, sustaining SME ecosystems is a challenge. This is because of a lack of niche actors, i.e. social innovators, in the local ecosystem. Ecosystem actors need to recruit new actors to promote cross-pollination of ideas, improve innovation and broaden the ecosystem capacity. To increase productivity and survival, building trust and commitment is re-emphasized. SMEs might need relationships with large retail ecosystems, Local Government, venture capitalists and Universities to sustain local ecosystems.

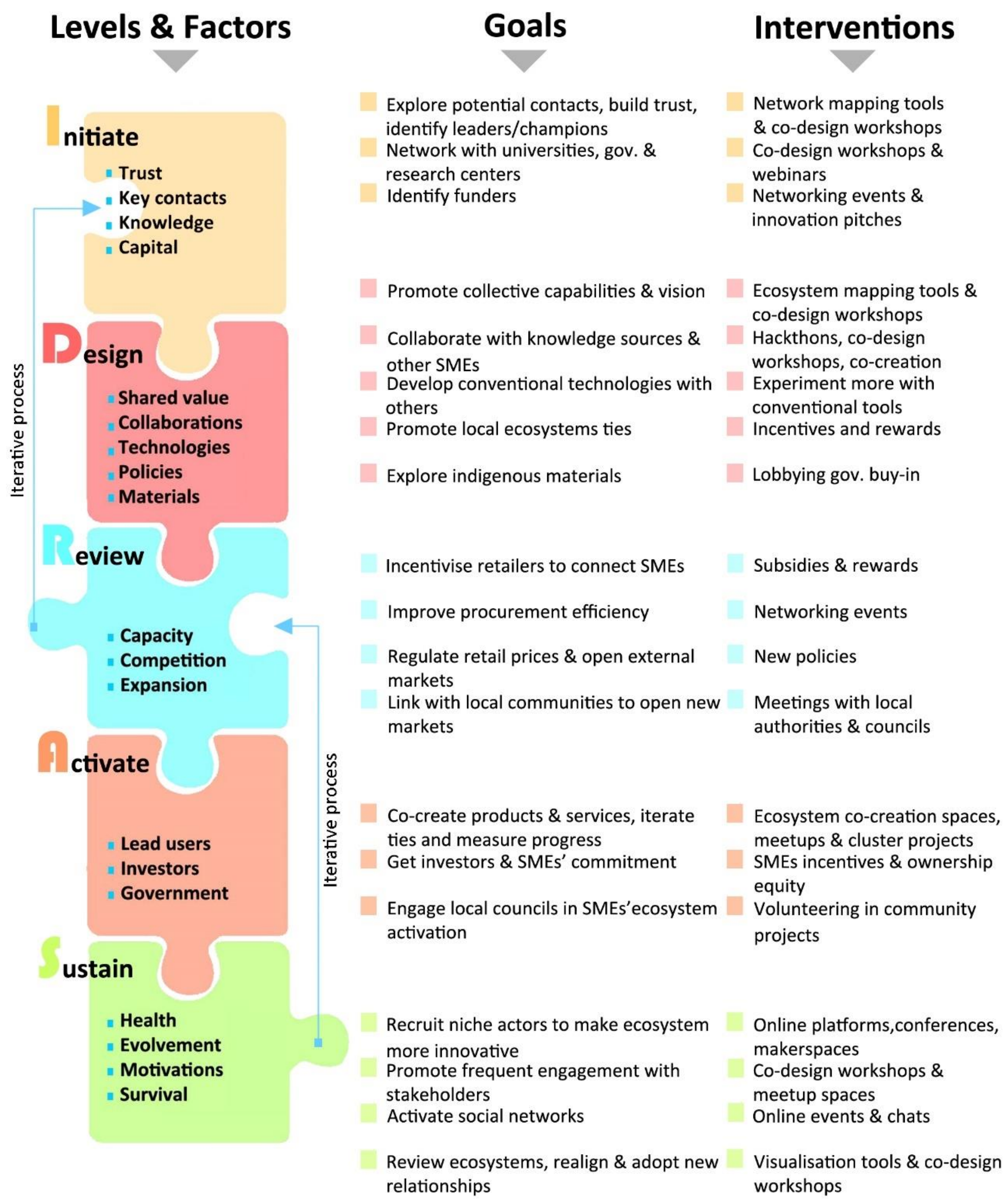


Figure 7.24: Jigsaw ecosystem design framework

7.3.1 Chapter contribution

The contribution of this chapter is in proposing the Jigsaw framework for enhancing the understanding of local SME ecosystems. The study contributes a novel co-designed framework where there is a lack of a structure that helps SMEs and stakeholders. Critical factors influencing the structure of local ecosystems have been identified to guide ecosystem actors and decision-makers in understanding local SME ecosystems. Practically, this could have implications for SMEs strategies because aligning interests and goals while operating different business models can be challenging. The framework may also inform innovation policymakers in Government departments dealing directly with entrepreneurship development, e.g. Local Enterprise Authority (LEA) and Botswana Innovation Hub (BIH). Local SME ecosystem actors may leverage some of the interventions suggested in the framework to enhance their understanding of the local ecosystem.

In the next chapter, this thesis presents findings from a series of in-person co-design workshops to evaluate the Jigsaw framework proposed in this chapter.

8 Co-designing the understanding of localised SME ecosystems

In the previous chapter, the study proposed the Jigsaw ecosystem design framework to help local ecosystem actors understand their ecosystem. This chapter presents findings from three in-person workshops where the framework was evaluated. The findings show that the framework is useful in visualising, understanding and activating local ecosystems amongst ecosystem actors.

8.1 Introduction

This evaluation study involved three in-person co-design workshops held in Botswana. The workshops aimed at testing the Jigsaw framework developed from synthesising findings from the exploratory studies in the previous chapters. This chapter addressed the following objective:

> *To evaluate how ecosystem design and visualisation approaches support and enhance the understanding of local SME ecosystem structures in Botswana.*

To achieve the objective, the evaluation addresses the following;

- To introduce ecosystem actors to the concept of innovation ecosystems through discussions and visualisation techniques.

- To engage ecosystem actors in understanding ecosystems by identifying where actors are located, how they are connected and how they define ecosystem shared value.
- To engage participants in groups to explore future ecosystems and determine how to activate and sustain new ecosystem structures.

8.1.1 Workshops plan

The study adopted a co-design approach (Sanders and Stappers, 2008) to decipher complex ecosystem knowledge by using visualisation outputs as heuristics for learning. The role of the researcher was to design a co-creation space where different non-expert designers could visualise their local innovation ecosystems and explore future ecosystem potentialities.

Three workshops were conducted with 100 participants from various African organisations (SMEs, policymakers, entrepreneurs and higher education institutions). The first workshop was with 15 entrepreneurs (leather manufacturing incubates) from the Local Enterprise Authority (LEA), a government organisation tasked with promoting sustainable SME development across the country. This incubator was involved in the exploratory case study reported in chapter 7. The researcher recruited these participants during the exploratory interviews a year before the workshop was conducted. Therefore, the researcher and participants had an established rapport before the workshop.

The second workshop had 65 participants from Lancaster University's Recirculate project, which involved a wide range of seven countries (Nigeria, Mozambique, Uganda, Kenya, Malawi, Zambia, Botswana). Participants were recruited through a collaboration between the Recirculate project (from Lancaster Environment Centre) and Beyond Imagination project (Lancaster Institute for the Contemporary Arts). As a result, the study had access to stakeholders from various levels of innovation ecosystems across Africa. The Jigsaw framework was tested on a separate set of ecosystem actors than in the first workshop to determine the tool's usability at various levels of the ecosystem structure.

The final workshop was with 20 entrepreneurs from the Botswana Innovation Hub (BIH), a government organisation promoting entrepreneurship ecosystem development amongst SMEs. Participants were recruited through a visit to the centre a year before the workshop was conducted. The hub contributed to the recruitment of participants by putting up an advert for SMEs to volunteer their time.

All the workshops were divided into three parts, as follows:

First part

- This part was intended to support participants in putting together pieces of information about their significant past and present positions in the innovation ecosystem. During the first and second workshops, participants were asked to split into their respective manufacturing SMEs, most of which had between one or two participants. They were then invited to graphically represent themselves by drawing their position and image in the ecosystem and narrate the visual story to the rest of the group in 60 seconds. This was a fun and enjoyable way to begin the workshops and introduced the use of the visualisation techniques in deciphering complex innovation ecosystem attributes that were hard to find without visualisations, e.g. strong and weak ties, the position of actors.

  After laying the groundwork in this part, participants were introduced to the concept of innovation ecosystems and the significance of creating shared value (both economic and social benefits). The facilitator collected feedback by taking notes on how participants defined ecosystems and their thoughts on ecosystem shared value. Furthermore, the researcher took photos of participants visualisations for further analysis. An example of the type of visualisations produced during this part is shown in Appendix 14. Participants were advised to use the visualisations as building blocks during the second part. During the second workshop, the visualisation was not done for the first part because of time constraints. Figure 8.1 shows the Botswana Innovation Hub participants during the first part presentation.

Figure 8.1: Photo showing SMEs attending the presentation on the concept of innovation ecosystems during the third workshop at Botswana Innovation Hub.

Second part

- In the second part, participants were introduced to the main innovation ecosystem design tool discussed in chapter 4. They were then asked to discuss what they valued most in their respective ecosystems. Then they made a list of significant criteria for ecosystems and agreed on five criteria to fill in the tool spaces. The criteria formed part of the participant's perceived innovation ecosystem value. Furthermore, participants also made a list of important contacts in their ecosystem networks. They were then asked to use the design tool to map contacts against the innovation ecosystem criteria. Appendix 13 describes this process thoroughly. Figure 8.2 depicts a moment during part 2 of the first workshop. The design tool prompted participants to make decisions and priorities with stakeholders based on the strength of ties. They were also asked to connect contact with a single line to complete the graph. Joining nodes with lines made it less challenging to identify ties between actors in the visualisation output. At the end of the part, each participant presented their visualisation output. They also shared a brief evaluation of the output and probable future impact on the ecosystem. Finally, they were asked to share their thoughts on the usability of the tool, i.e. whether it was easy to use or difficult before moving to the third part. The second part was similarly applied to all three workshops.

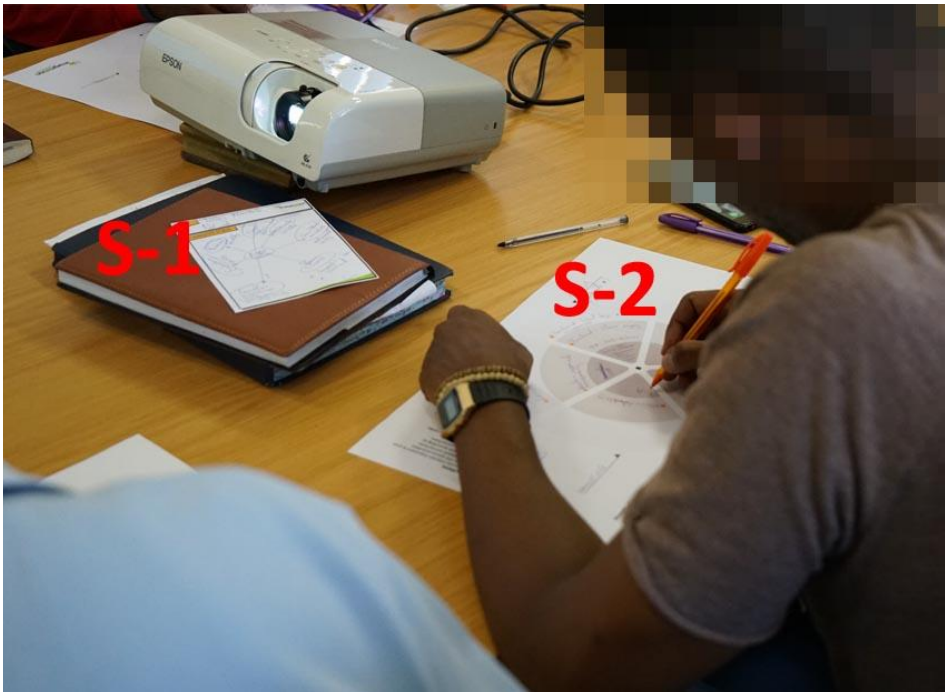


Figure 8.2: Photo showing the participant from SME-O mapping his ecosystem structure during the second part of the first workshop. Item (S-1) is the output from the first part.

Third part

- During the third part, participants were divided into groups (Appendix 11). They followed the same procedure described in part 2, i.e. selecting five criteria that are common to their group and discussing a list of key contacts from each group member. They also used the second part visualisation outputs as design prompts in this section. Participants were then asked to use the design tool to map their contacts. Unlike in the second part, participants used assorted colours to represent their individual SMEs in a group visualisation. They joined the nodes and then discussed emerging graphs. Figure 8.3 depicts a moment of part 3 in the first workshop, where SME directors from different ecosystems were working on mapping a new image of the combined ecosystem. At the end of this section, groups presented their visualisation outputs.

During the workshop parts, participants engaged, designed, shared and communicated insights about the understanding of ecosystems and how they could activate and sustain these to grow their local innovation ecosystems.

Figure 8.3: Photo showing participants mapping images of ecosystems in groups at the leather incubator.

8.1.2 Data collection and analysis

The study collected data in audio recordings, researcher's observation notes, visualisation maps and feedback reviews. Firstly, the audio data was captured during the presentations of visualisations which were then transcribed. The transcripts, facilitator notes and feedback reviews were subjected to a coding process using NVivo 12 and followed the coding protocol described in chapter 4 (pp.74-82). Codes and themes were discussed to evaluate how participants used the framework.

Aside from the thematic analysis, participants engaged throughout the three parts in a visual analysis process of the workshop outputs. As part of the co-design process, participants analysed their visualisations in groups through dialogue and presentations. The design tool was instrumental in this co-design process as it helped participants to understand existing local ecosystems and how these ecosystems might be enhanced in the future. A summary of the findings from visualisation outputs can be found in

Appendix 11. Participants also reflected on the tool's functionality regarding its useability (see results in appendix 12). Next, the chapter report findings from three co-design workshops.

8.2 Findings and discussions

8.2.1 Co-designing with manufacturing SMEs at the leather manufacturing incubator

This workshop reached 15 participants from 10 SMEs located at the leather incubator in Gaborone. Participants were all familiar with the purpose and objectives of the study. The characteristics of participants are shown in Table 2 below.

Table 2: Participants characteristics in the first workshop

Groups	**SMEs pseudo names**	**Characteristics**
A	HM, WP, HL	Upholstery and Leather manufacturing. Handweaving of a variety of bags using local materials.
B	LTL, TF, XX, MT	Leather products care and maintenance, furniture manufacturing, shoe and bag manufacturing.
C	MF, ITR, TSL	Furniture manufacturing, Leather shoes and bag manufacturing, upholstery work, remanufacturing of car interiors, sofas and bags.

During the first part of the workshop, six categories came out of the visualisation data as follows; funding partners, marketing partners, participants roles, key roles, supply partners and few connections. Visualisations revealed connections with supply partners as the most common theme amongst visualisation outputs, thus indicating high influence in the ecosystem. Second, some participants visualised their role at the centre of the map and recognised other influential roles in the ecosystem, particularly those they share strong ties with, by positioning them close to the centre. However, most participants portrayed themselves as having fewer connections in the ecosystem, representing this with fewer ties.

There were structural similarities in the way participants visualised themselves across most visualisation outputs, and this could be attributed to the use of one oval table, where participants set next to each other, as shown in Figure 8.4. This may have resulted in copying other participant's visualisations. However, the main objective of the section was met. The workshop introduced participants to the concept of ecosystems and empowered them to think creatively about their ecosystem knowledge, and how visualisations and discussions can help them become creative in simple ways. Further details on how participants analysed the visualisations are in appendix 11 (A).

Figure 8.4: Photo showing events during the first part where participants were drawing their network images.

During the second part, the participants enjoyed working with the ecosystem visualisation tool to design local ecosystem structures. In responding to mapping weak ties, some visualisations did not show contacts on the outer segment of the tool, and instead, they focused more on mapping close contacts, i.e. strong ties. Interestingly, regarding activating key roles, most participants used the tool to identify critical roles, e.g. suppliers and funders, to improve their local ecosystem. Regarding creating shared value, most participants mapped the following; suppliers, customers, skills development, funders and markets. Some participants noted the significance of the tool in showing them opportunities where they might develop their collective capabilities:

> *"I realise that there are other supporting factors and services on the map that I am currently not utilising. It either I am not utilising them as much as I am using LEA, or they are not supplying the things that I want. Maybe something that I need to be looking into is the relationship between me and the guys in the median and outer area of the tool" (LTL).*

Given the above quote, the tool revealed key roles that were hidden from them. This is important in decision making. Some participants did not visualise weak ties at all in their designs. Few actors indicated that the tool was difficult to use, and they needed time to study it:

> *"I was only thinking about the people that are strongly connected to us, such as LEA and the Government. The thing is, I need to study the tool thoroughly because I did not fully understand it" (ITR)*

Regarding the participant's use of the design tool, few did not immediately understand the instructions to complete some design tasks. An example is shown in Figure 8.5**,** where participants did not visualise weak ties compared to Figure 8.6. Not mapping weak ties was because participants did not understand how to determine these from medium and strong ties. They used the tool differently depending on their comprehension. In some cases, they were holding back essential information about their relations because they felt that the competitors present at the workshop might copy their strategies:

> *"We have competitors in this room, and we are doing the same thing, so we fear that if they see our graph, they may be tempted to rush to our partners and snatch our business" (XX).*

The above quote shows that participants lacked the trust to engage openly in the co-design process. Consequently, leading to some holding back vital information during the second part.

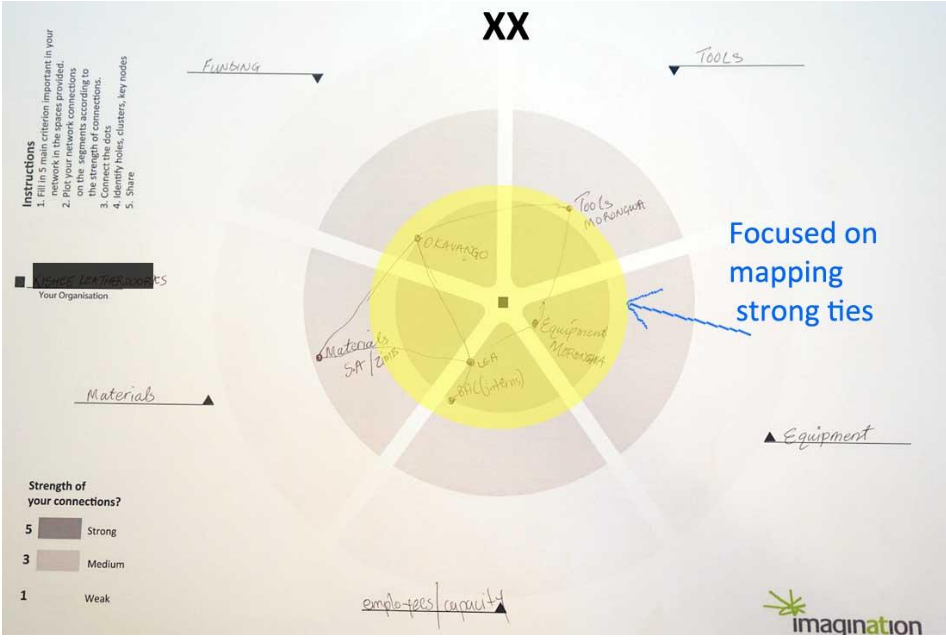


Figure 8.5: Examples of SME ecosystem visualisation output were participants did not visualise weak ties.

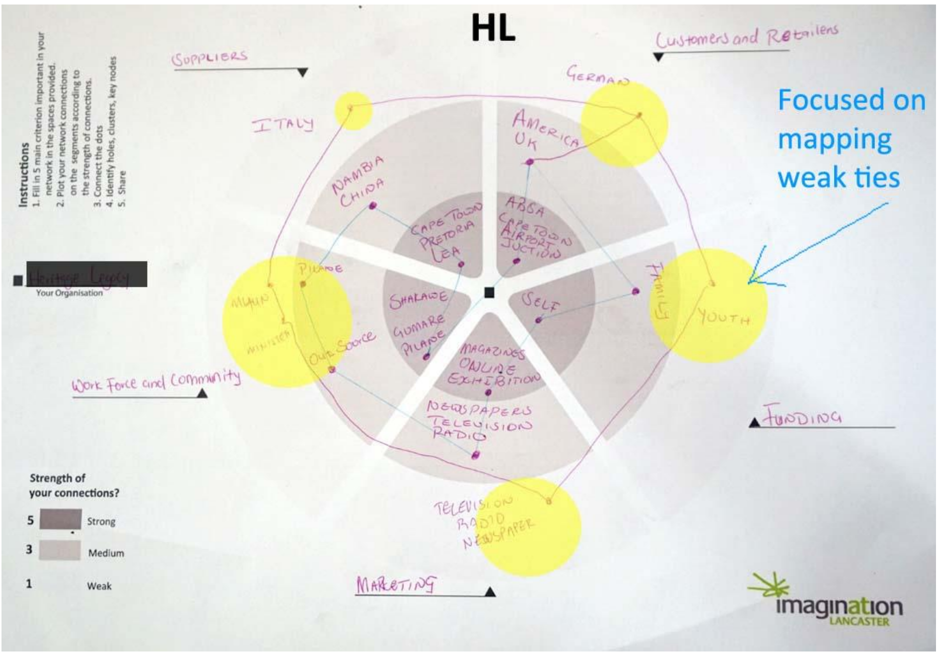


Figure 8.6: Examples of SME ecosystem visualisation output were participants visualised weak ties.

In the third part of the workshop, participants enjoyed working with different manufacturing SMEs on the design tool. Discussions guided those who were struggling in the first two parts. The visualisation outputs were analysed based on the following categories; weak and strong ties, key roles and sustainability. As shown in Figure 8.7, by plotting the data from group visualisations using a force-directed graph, the thesis shows how participants defined shared value in their new ecosystem. Accordingly, all three groups identified funding and suppliers as key roles in the new ecosystem structure. The graph also reveals that marketing and skilled workforce were highly valued in at least two groups. These results were consistent with what was observed in part two. Participants across the three groups suggested new ways to sustain their future ecosystems:

> *"One of the things that we are both weak at is the sourcing of funds to develop the business. So, moving forward, we may consolidate our efforts to apply for funding as a group rather than as individuals. We can also access markets together by combining our resources to reduce costs. Each of us has a different clientele base, so accessing each other's clients may provide more diversity for our clients" (GRP-A).*

Regarding the above quote, participants highlighted the significance of joining efforts as ecosystem actors rather than engaging in unhealthy competition. They recognised this as crucial in developing enhanced innovation ecosystem value, with more diversity and competitiveness.

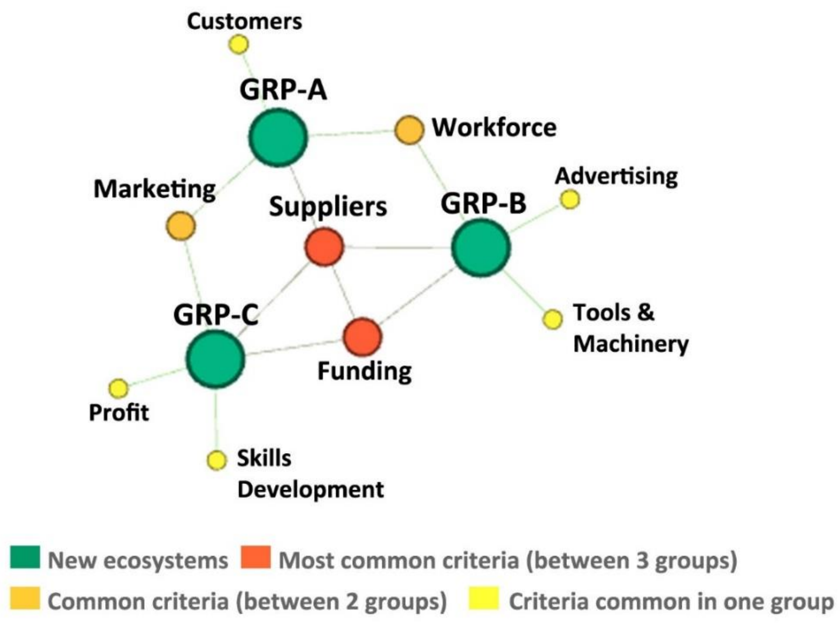


Figure 8.7: Shared criteria/value proposition amongst new ecosystems groups

During the third part, most participants were now familiar with the process of co-designing with the Jigsaw tool. However, some did not finish the mapping and connecting nodes with lines because of the extended group discussions. Although this did not affect the results, it made it more challenging to analyse the visualisations. The way participants used the tool spaces varied considerably in terms of their understanding of ecosystems. As shown in Figure 8.9, GRP-C did not engage much in searching for weak ties compared to other groups, i.e. GRP A. They seemed to be more interested in their close ties, which was unexpected. This made it impossible to identify new links for future ecosystems. The majority of groups used the tool to start questioning their business model:

> *"I think looking at it now [referring to the visualisation] also makes us aware of what we have been giving too much attention to, and things that maybe we should look at more to help us move forward. Because we see that being self-funded, self-managed, self-run, and doing most of the things ourselves, how do we expand in the sense that we have other people doing things that we are not particularly good at" (GRP-B).*

The above quote shows that the design tool helped participants think critically about their business model innovation beyond the boundaries of their firms. At the end of the workshop, participants were more open about their ecosystems. The Jigsaw helped participants to engage openly with others and developed trust.

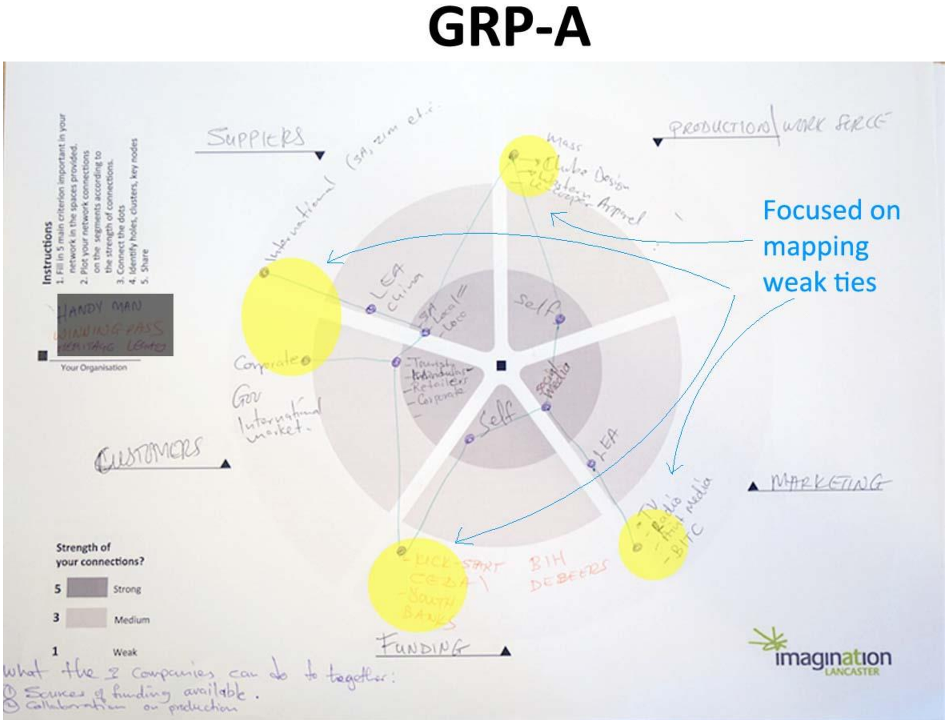


Figure 8.8: Example of the group visualisation from group A

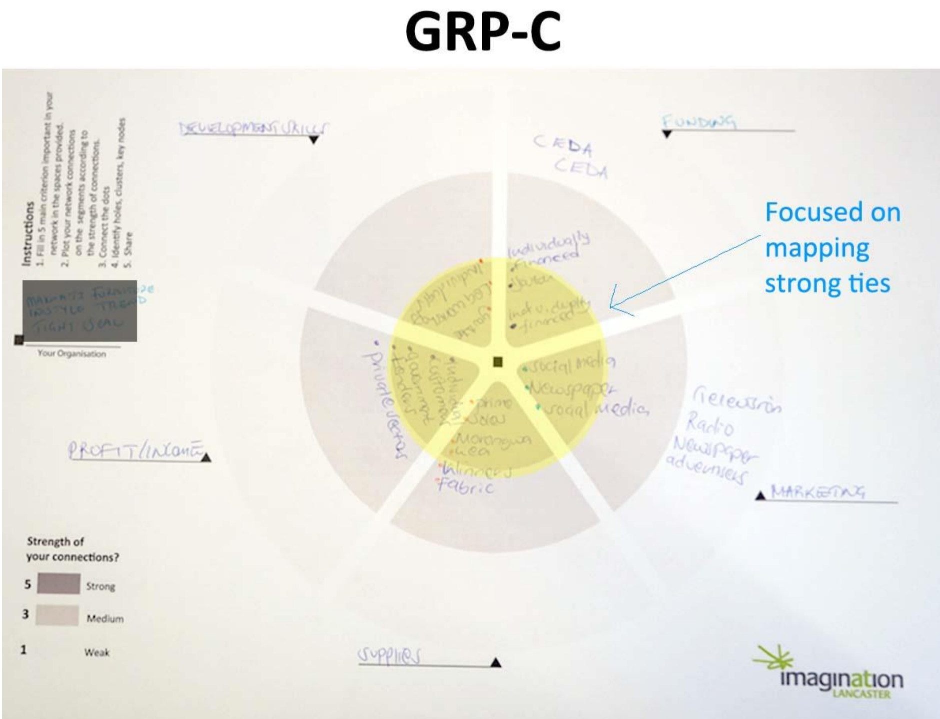


Figure 8.9: Example of the group visualisation from group C

Workshop conclusions

In this workshop, although the tool did not work as expected, which was to promote the mapping of weak ties, it was useful in scaffolding discussions amongst users and the researcher to reveal insights, develop understanding and communicate probable future ecosystem structures. These findings were consistent with previous research in the use of visualisation tools as scaffolds to facilitate co-design activities in everyone (Lengler and Eppler, 2007; Manzini, 2015; Banissi, 2014). Participants were free to frame the local ecosystem criteria to interpret their complex ecosystems. Results from all parts provoked participants to engage with their tacit knowledge of local ecosystems using the Jigsaw design framework. In summary, the main findings from this workshop were as follows;

- Using a completed example of mapping ecosystems at the beginning of the workshop helped speed up the participant's understanding of the visualisation process.
- Linking three parts such that the first and the second outputs were direct inputs into the third provided design prompts for participants.
- Using design tools helped participants engage others in identifying key contacts in their environment and developing a shared value constellation.
- Working with design tools in diverse groups stimulated discussions and idea building around future ecosystems and opportunities.
- Trust levels were improved between participants. They were more comfortable and open, talking about their ecosystems with others.
- Presentations gave the participants a chance to appreciate the outputs from other groups.

Researcher's reflections

As this thesis is about using a design visualisation approach as a structure to help SMEs understand their local ecosystems, the researcher learnt that the framework and practical mapping tools are useful as rigorous heuristics for discussions. The approach was useful in empowering SMEs to start a dialogue and discover knowledge distributed and embedded in their networks. The researcher also learnt that the visualisation technique helped SMEs find their potential and confidence in engaging with different people. For example, the researcher noticed that one SME participant who is deaf could use the visualisation tool easily to communicate his thoughts without the need for sign language.

8.2.2 Co-designing with researchers, policymakers and SMEs across Africa

This workshop had access to a distinct set of participants, unlike in the first workshop. These participants were a group of researchers, University leaders, innovation policymakers, manufacturing SMEs and parastatals. Characteristics of these organisations are shown in Table 3.

Table 3: Participants characteristics in the second workshop

Groups	Members	Characteristics
1	Lectures, directors and postgraduate students	University researchers and management personnel.
2	Manufacturing SMEs	Manufacturing leather products, upholstery and ceramics. Also weaving products, sculpture and fashion design.
3	BDF, Manufacturing SMEs, researchers	Defence and security, leather manufacturing, innovation policymakers.
4	BIH, manufacturing SMEs, Kenya and Malawi researchers	Innovation policymakers, leather manufacturing, researchers from Kenya and Malawi
5	BIH, Zambia and Mozambique researchers	Innovation policymakers, researchers from Mozambique and Zambia
6	Botswana Harvard	Harvard Institute researchers, defence and security

	researchers and BDF and other government departments	and other government departments.
7	BIH, Nigeria and Uganda	Innovation policymakers, researchers from Nigeria and Uganda
8	BIH, BIUST, Harvard researchers	Innovation policymakers, researchers from Botswana Universities and Harvard.

This workshop did not use the ice-breaking tool because of time constraints. Participants were divided into eight groups and asked to discuss innovation ecosystems, whether they felt part of the local ecosystem and how the innovation ecosystem add value to their organisations. Figure 8.10 shows discussions during the first part.

Although most participants did not get the chance to share their views about ecosystems, a sizeable number of participants shared their thoughts on local ecosystems. Part 1 resulted in insights about the understanding of local ecosystems, while part 2 provided insights into how participants from different countries perceived innovation ecosystem structures and how they actively used the tool to visualise their local ecosystems. Whereas part 3 suggested innovative ideas on how future ecosystems might be expanded and sustained across African countries.

Figure 8.10: Photo from the first part showing participants sharing knowledge on the meaning of innovation ecosystems.

From the first part, three themes emerged, as shown in appendix 11(D). The first theme was sharing resources. Most participants highlighted that ecosystems were about sharing resources to grow organisations, mainly where actors have limited capabilities to grow independently. Second, networking was also suggested as key in defining ecosystems. Participants highlighted that networks promote the flow of information, which eventually connect organisations through collaborations and partnerships. Third, most participants emphasised that ecosystems are all about the co-creation of new products and services to deliver shared value.

Regarding the second question on whether participants feel part of an innovation ecosystem, most of them answered on the contrary. The study concluded that although participants understood what ecosystems are, they still did not feel part of local ecosystems. Participants highlighted the value of sharing resources such as equipment and data, especially in Africa, where there is a scarcity of such resources to promote competitiveness.

Most participants from across African countries focused on mapping weak ties than their strong connections from the second part. These were predominantly around research funding, where participants highlighted minimal commitment from their respective Governments to fund research and development. Under the weak ties segment, they identified detachments from local communities, lack of research commercialisation, and private sector investment in innovation research. Participants highlighted a high dependence on donor funds to do research. Across most participating countries, there was no mention of Government involvement in funding research and development.

Regarding the use of the design tool, unlike in the first workshop, participants could use nodes and lines easily to analyse visualisations in terms of the relationship between contacts and the participants. However, the fewer contacts mapped on most visualisations resulted from time constraints; most participants spend more time debating on criteria for ecosystems than on key contacts and ties. Unlike in the first workshop, most participants used the tool to think more about weak relations or things that were missing in their local ecosystems, as shown in Figure 8.11:

> *"This tool helps us to see what we have in terms of strong relations and what we do not have in terms of weak relations. Somehow through this tool, we now see*

where we could start pursuing opportunities to develop our capacity as ecosystems" (KY).

Some participants suggested adding the time variable to monitor the ecosystem changes over time:

> *"The tool helped us to identify our strong and weak relationships. This information could help develop our ecosystem. However, we would like to propose that you add another dimension of time to measure the change of network structure" (BW).*

The above quote indicates that participants also thought deeply about how the tool might be expanded. Participants spend a bit more time figuring out how to design ecosystems in this section. The reason could be that although each group was divided into countries, in every group, most participants were from different organisations, thus making it difficult to agree on common criteria for local ecosystems.

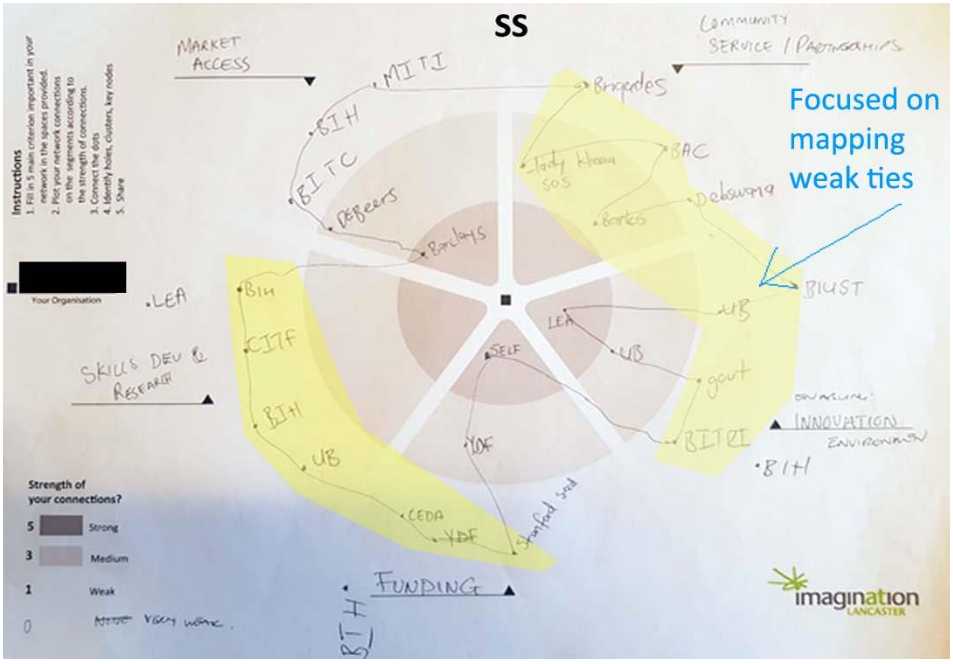


Figure 8.11: Example of the visualisation from SS participants

Participants used the tools to engage in discussions around how they can work together to form new ecosystems. Visualisation outputs from this part were analysed based on the strength of ties, key roles and sustainability. As shown in Figure 8.12, by plotting the criteria for ecosystems from participating groups using the force-directed layout, this thesis synthesises a shared criteria/value system in these ecosystems for ease of understanding. This shared value constellation reveals funding as the most significant factor in their new ecosystems. It was also noted that forming partnerships with local community leaders and skills development amongst participants were common between four to five groups. Opening new markets, co-delivery of programs in high institutions of learning, consultancy work, community service, publications, and infrastructure were shared between two to three groups of participants. These results were consistent with findings from the second part in terms of shared criteria.

Participants used the tools to identify new ways that could sustain their ecosystems. Under the weak ties category, most groups highlighted access to funding bodies as a challenge, i.e. difficulty identifying connections leading to funders. They seemed to agree that the Government's contribution towards research and development funding was insufficient across Africa. Some of the weak ties identified include private sector engagement in research uptake. Participants highlighted the challenges of reaching the outer segment of the tool, and they identified the Government as a potential bridge to leverage new opportunities:

> *"We also managed to use the tool to identify common weak ties where we can collaborate across countries with other researchers, such as co-application of funding from international agencies and partnerships in research. Our respective Governments could facilitate this" (GRP-4).*

Regarding medium and strong ties, most groups identified high dependence on international donor funds. In some instances, few groups indicated having strong ties with mining sector partnerships and working with civil society. Other roles highlighted include partnering with local councils in research uptake, leveraging resources across Universities and research centres in Africa, engaging in research collaborations, and commercialising ideas. All these require identifying and leveraging new actors and roles:

> *"Finally, we see that we can leverage resources from each other across countries and institutions in the SADC region" (GRP-5).*

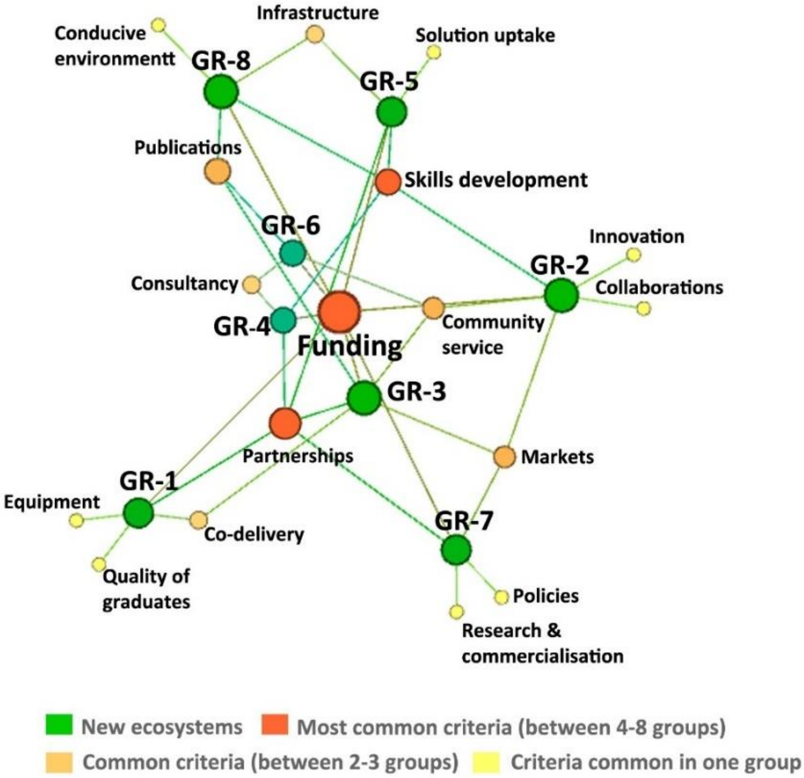


Figure 8.12: Shared criteria for new local ecosystems

The analysis of group activities revealed that much time was spent on discussing shared value than searching for key contacts and connections. This resulted in fewer contacts mapped on most visualisations. However, in comparison to the first workshop, participants had a better understanding of the tool. Analysing some examples of the visualisation outputs, GRP-4 identified four important criteria instead of a minimum of five, as shown in Figure 8.14. This could be ascribed to a lack of consensus on the ecosystem criteria. Groups focused more on the outer segment of the tool because they were interested in new connections than their close ties:

> *"The tool helped us to look at networks in a new way, as an avenue to create opportunities for growth. The tool helped us to visualise our network and to understand that we cannot work in silos, we need partners" (GRP-4).*

> *"We found the tool very useful in helping us to think about our ecosystems, and how we might develop our relationships beyond our traditional contacts. The tool helped us to identify connections and opportunities between what we are strongly connected to and what we are neglecting in the ecosystem" (GRP-6).*

From the quotes above, the tools helped participants to be creative about their business model innovations. At the beginning of this section, participants were confused about the use of colour in mapping, and it was after several demonstrations, they managed to do the visualisations. Figures 8.13 and 8.15 shows GRP-3 and GRP 5 visualisations as examples where participants used the tool differently by mapping more than one criterion in the same segment. For example, GRP-3 mapped marketing and publication in the same segment, suggesting that these criteria could be classified under the same group. In comparison to the first workshop, most groups visualised weak ties:

> *"I found the tool very helpful in identifying strong and weak relationships between our contacts. It took us a bit of time to understand the tool, but overall, this is a good tool that should be used by many people in developing their ecosystems" (GRP-7).*

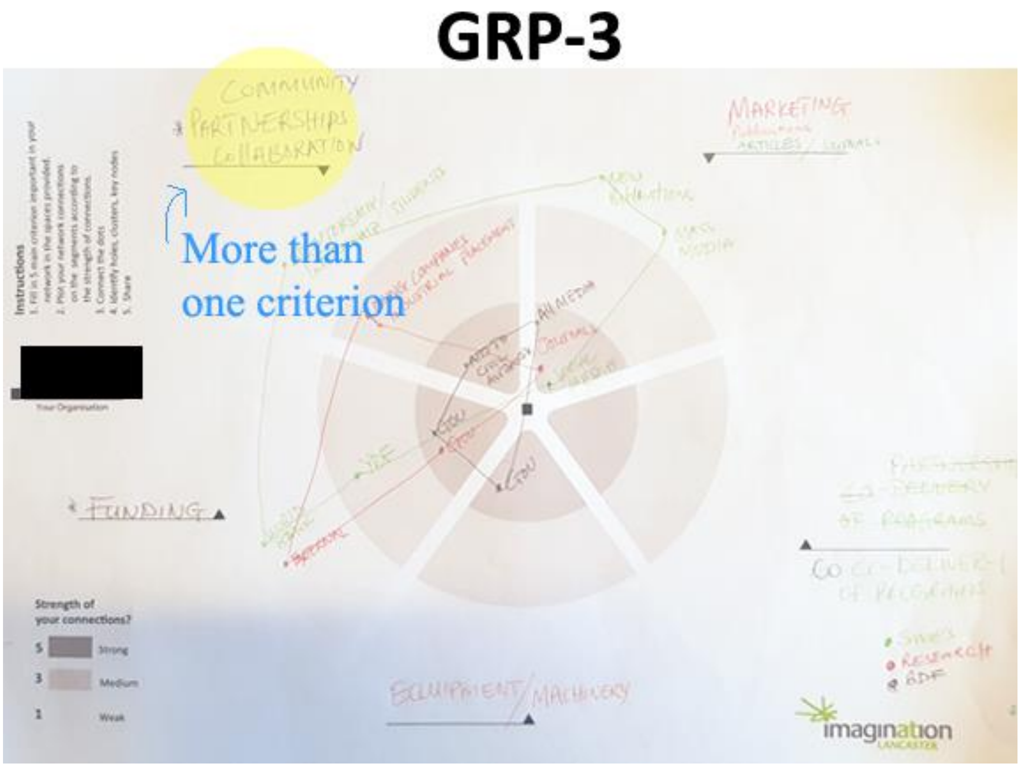


Figure 8.13: Example of the visualisation from group 3

GRP-4

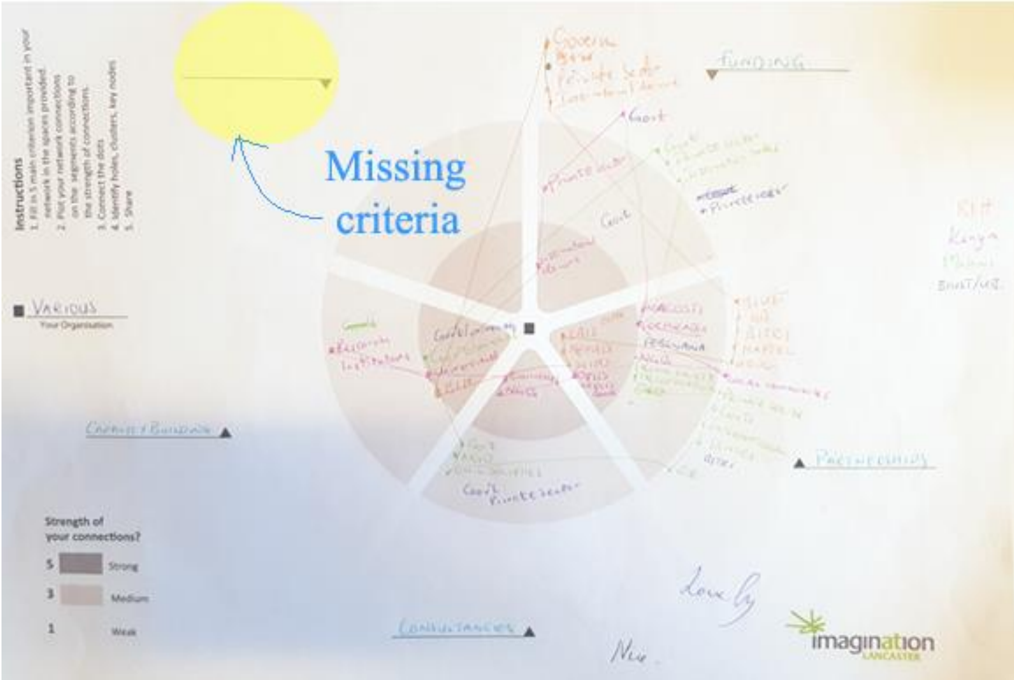


Figure 8.14: Example of the visualisation from group 4

GRP-5

Figure 8.15: Example of the visualisation from group 5

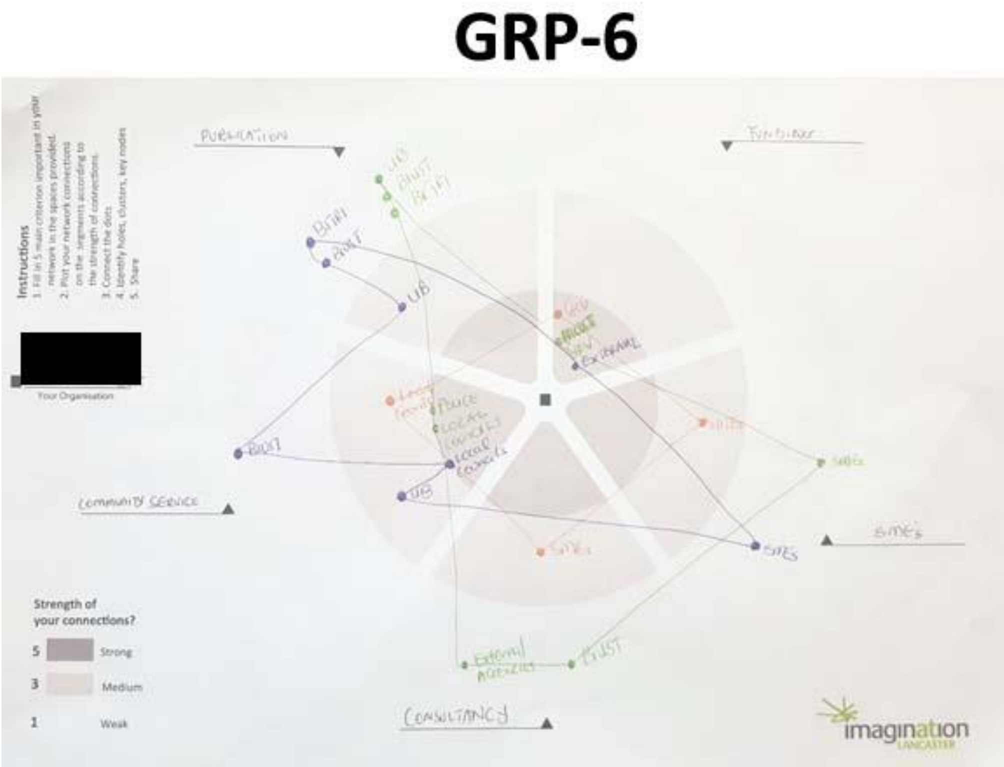


Figure 8.16: Example of the visualisation from group 6

Workshop conclusions

The key points that came out of the first part were the value of sharing resources, and most participants expressed how this may better develop their local innovation ecosystems. During the second part, participants demonstrated enthusiasm, trust and openness throughout the co-design process. They used the design tool to make collaborative decisions (Setiawan et al., 2019). The tool provided users with a structure to better use their ecosystem knowledge through visual means because the ecosystem phenomenon was visible before their eyes in the form of images (Sanders and Stappers, 2014). Therefore, images elicited interesting dialogues amongst participants. In summary, the main findings from this co-design experience were as follows;

- Funding, partnerships and skills development were identified as the most important criteria in researchers, policymakers and SMEs interactions.
- Government involvement across seven African states in research and development funding was reported to be minimal.
- Participants spend more time debating shared criteria/values than on identifying key contacts in the ecosystem. This led to fewer contacts visualised on the ecosystem output and empty segments in some cases.

- Most participants used the design tool to think more about weak ties than strong ties to identify more ecosystem opportunities.
- Participants suggested important modifications to the tool, such as including the time variable to allow for testing of the ecosystem changes.
- The design process also triggered ideas on future ecosystem structures.

Researcher's reflections

The researcher learnt that starting the first part without the visualisation icebreaker made the design visualisation approach difficult for participants during the second part because policymakers appeared less familiar with visuals. So, much time was spent explaining the process in the second part compared to the first workshop. However, connecting the second and third parts so that one leads to the other made it easier for participants to understand the co-design visualisation process during the last part. The researcher also learnt that this approach generated a lot of rich data. Based on this workshop, it is possible to apply the framework to other domains, not just SMEs. Participants used the Jigsaw framework to do creative work in their creative languages, e.g. they used the mapping tool in various ways to develop a dialogue.

8.2.3 Co-designing with SMEs located at the Government funded Innovation Hub

This workshop happened at the innovation hub with a group of entrepreneurs engaged in various businesses ranging from data analytics to coffee manufacturing. Characteristics of these SMEs are given in table 4 below.

Table 4: Characteristics of participants in the third workshop

Grp Name	SMEs pseudo names	Characteristics
II HUB	SPA, MH, LBN, SL, LH	Data analytics, digital marketing, training and consultancy, Branding, and autonomous solutions
Energy X	CAI, SDS,	Artificial intelligence, Augmented reality

	MOE, OT, GK	and real estate, renewable energy, chemical manufacturing.
Innovation links	LAM, SSB, CBH, SBW, SA	Board games, coaching, and training, online stores, renewable energy.
Innovation minds	PSHT, MI, TN, KE, RC.	Telecommunication, health and wellness, bath products, Web-based solutions, coffee manufacturing

This workshop also followed the activities described on pages 215 to 217 to evaluate the Jigsaw framework. Six main categories came from this analysis; funding, marketing, own role, key roles, skills development, and less connected actors. Most participants demonstrated the criticality of funding, marketing, and skills development in innovation ecosystems. They represented themselves at the centre of their visualisations and having weak connections. Most of these participants represented their ecosystems as a less connected network, as shown in Figure 8.17. Participants produced diverse visualisations compared to the first workshop. This diversity could be so because most participants were sparsely distributed across the room. The objective of getting participants to think about their ecosystem structures and roles using a design visualisation process was achieved.

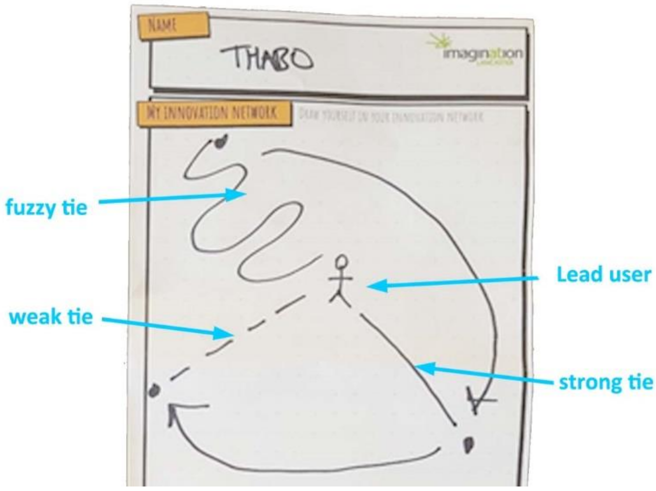


Figure 8.17: Example of a visualisation output of the first part

During the second part, participants were able to agree on shared criteria for ecosystems. Most of them highlighted funding and skills development as the most important criteria for seeking ecosystems. Other criteria that were mapped included exploring partnerships/collaborations and new markets. It appeared most participants were self-funded, so they identified funders as the missing role in the ecosystem. Most participants visualised weak ties with Government departments, private sectors, and Universities in terms of collaborations and expressed the need to find bridging roles to activate these ties. Top of the list was access to the Youth Development Fund (YDF), Botswana Innovation Hub (BIH) fund, and Citizen Entrepreneurial Development Agency (CEDA) loans.

Most participants found the tool useable in comparison to the first workshop. This could be so because the innovation hub-based participants were all degree holders, making it less challenging for them to adapt and use the tools quickly. Participants used the platform to retrospect their innovation relationships with key stakeholders. As shown in Figure 8.18, participants also focused on the outer segment of the tool. This indicates that they understood the value of weak ties in the innovation ecosystem. Participants made the following comments:

> *"This is a useful tool because I can now see opportunities that I took for granted before which are positioned on the outer segment of the canvas" (SBW).*

> *"So, this tool is simplifying my complex network such that I now see that I need to visit certain areas to explore weak relationships. I think putting it down on paper, in a graph like this makes it clearer and more actionable" (SSB).*

> *"So, the tool helped me to think big and recognise the strength in weak ties. This can potentially help me access larger markets" (MI).*

Regarding the above quotes, participants highlighted that the tool was invaluable in showing them opportunities vividly, such that they could see missing roles in the ecosystem which they might pursue in the future.

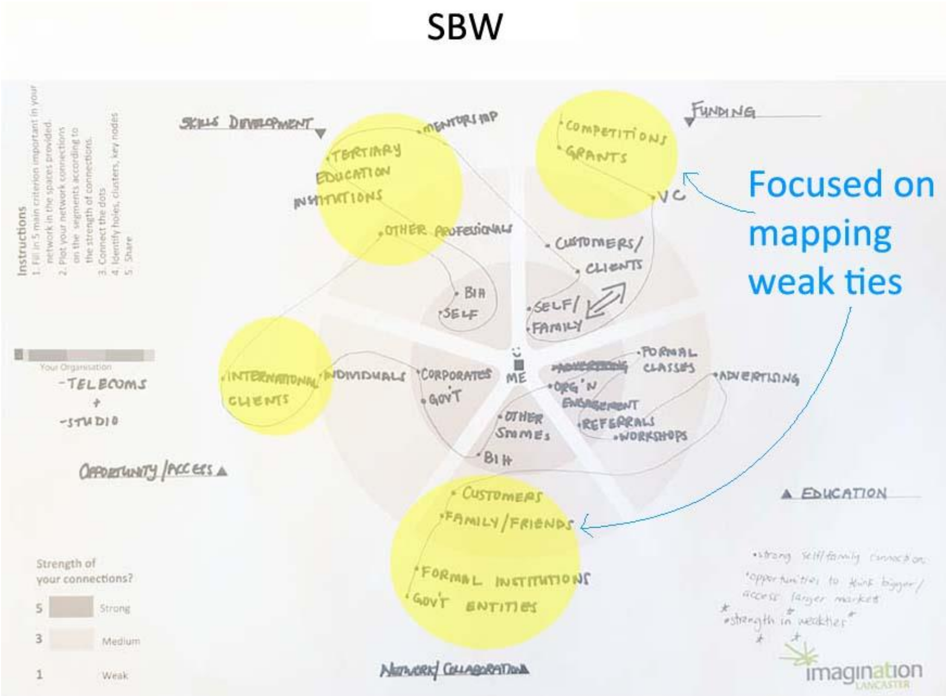


Figure 8.18: Examples of visualisation output for SBW participant

In the third part of the workshop, SME groups came up with new criteria for their preferred ecosystem structures. As shown in Figure 8.19, by plotting the criteria from different ecosystem groups using a force-directed layout, the thesis shows the synthesised shared value constellation. This proposition represents the unification of interests in terms of the criteria for ecosystems. All four SME ecosystem groups identified funding and skills development as crucial. But policies are common to three ecosystems, namely Innovation minds, Innovation links, and II HUB. Participants in II HUB and Innovation links identified access to new markets as crucial to their innovation ecosystem. Other criteria found in this constellation are specific to each group.

Most participants visualised weak linkages with the Government departments in their designs. They also highlighted challenges in finding links with relevant Government departments to support them financially. Apart from funding, most ecosystem actors also highlighted the need to link with the local television and radio stations to market their products. Consistent with the findings from the previous parts, most participants emphasised that they are currently self-funded and in need of financial assistance to expand the ecosystem. Therefore, under key roles and sustainability, participants underscored the need to activate Government partnerships in policy design, identifying and approaching funding partners, banks, and investors to be part of the SME ecosystem. Participants also highlighted that collaborating in projects is important to promote collective capacity instead of working in silos:

> *"This tool-assisted us to see where we can work together as an ecosystem in terms of weak and strong ties in our combined networks. So, we could start by combining our efforts towards accessing funding bodies, collaborating in some projects to expand our capacity, and access to external markets can also be done collectively. We could also collectively lobby the Government for policy reform" (II HUB).*

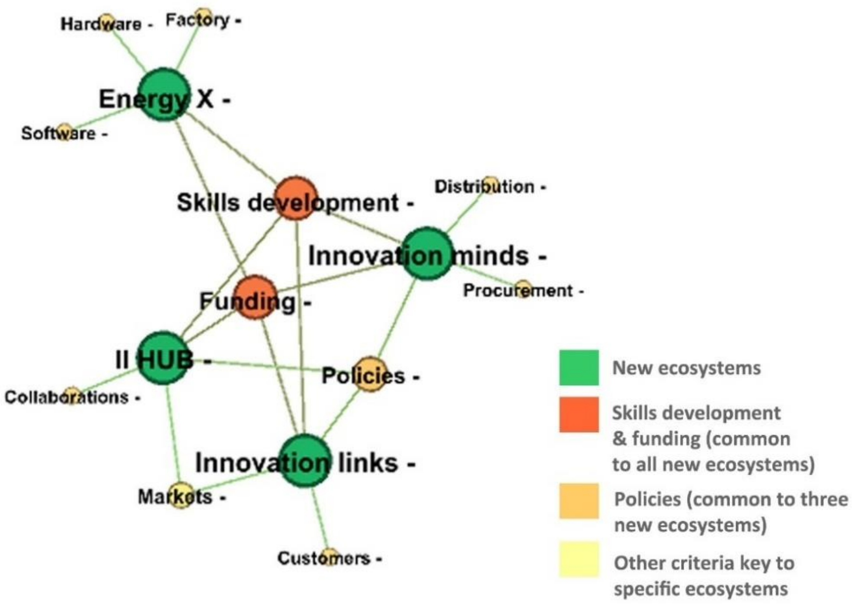


Figure 8.19: Shared criteria for new local ecosystems

Participants used the tool with little assistance compared to the first and second workshops. They spent more time mapping actors and roles and making decisions on the strength of connections. Although most participants were meeting for the first time, they openly engaged with each other. This enabled users to collaboratively identify and plot contacts on the tool and make decisions on strong and weak ties. Participants were enthusiastic about using the tools to understand the ecosystem, thus, making new discoveries on where they could collaborate to expand future ecosystems:

> *"This tool is very useful in helping us to visualise our possible connections in terms of strong and weak ties. We believe that since we are mostly from the IT environment, our collaboration in exploring the software and hardware criteria*

> *is key. There is also an agent need for us to work together in e-manufacturing and digital manufacturing using augmented reality and AI technologies" (Energy X).*

> *"Using this tool, we now realise that we have different relationships, some weak and others strong, and we can use each other's networks to expand our new ecosystems" (Innovation links).*

The design process seems to have triggered the participant's imagination to think beyond their typical business structures. As shown in Figures 8.20 to 8.23, examples of new SME ecosystem outputs are presented.

II HUB

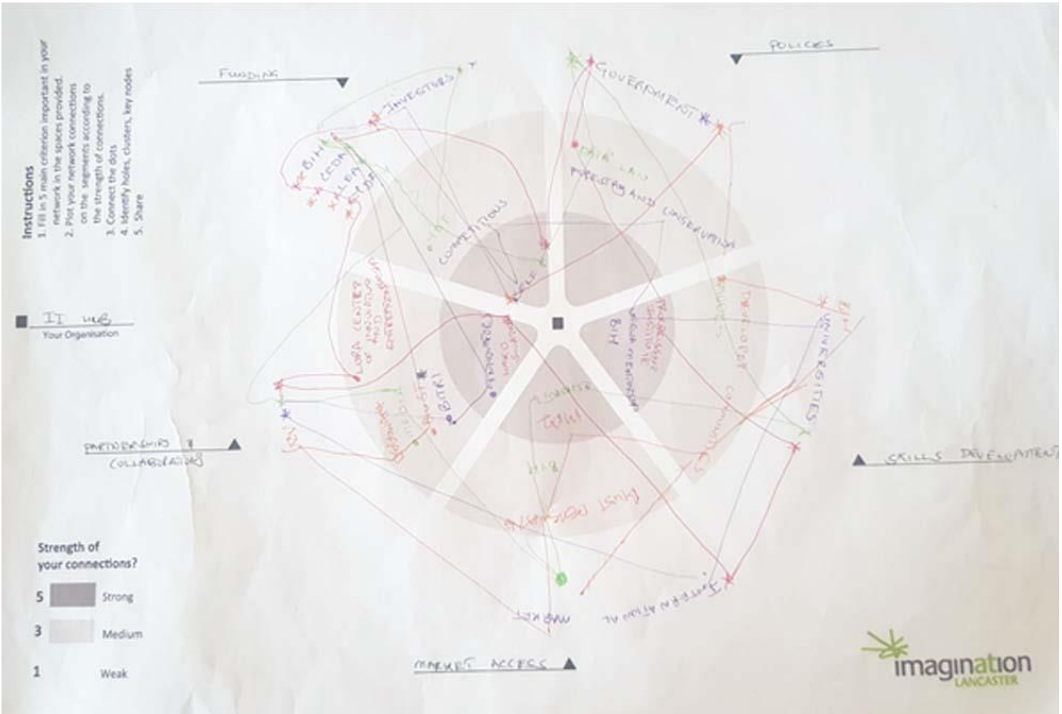


Figure 8.20: Examples of visualisation output for II HUB

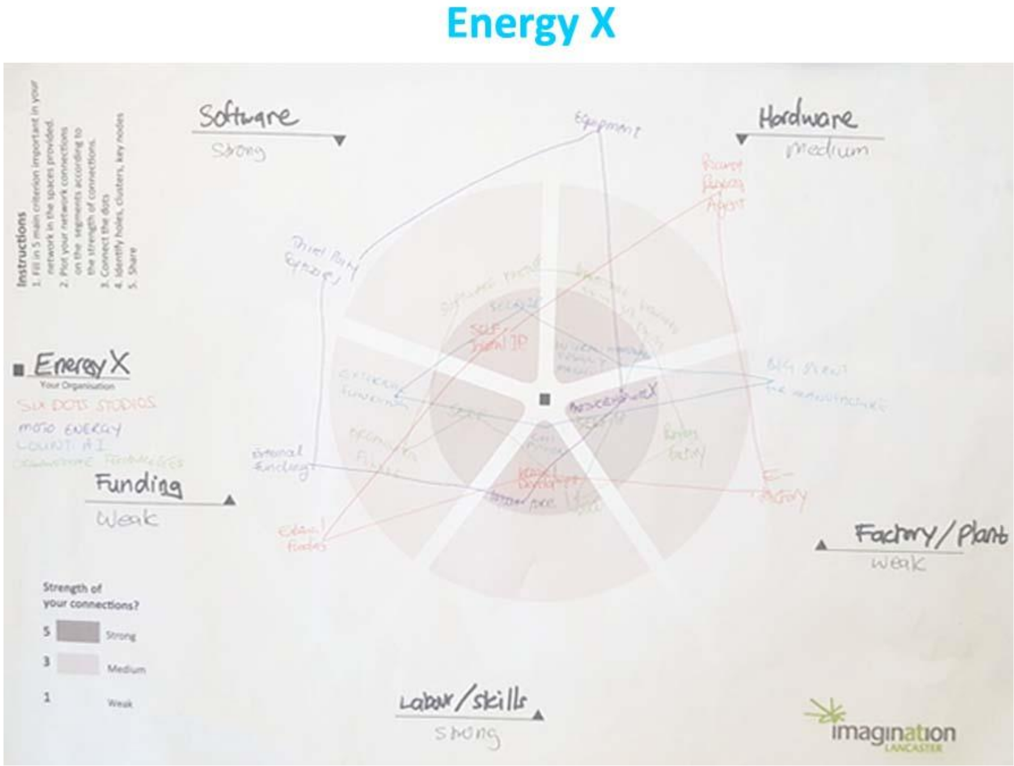


Figure 8.21: Examples of visualisation output for Energy X

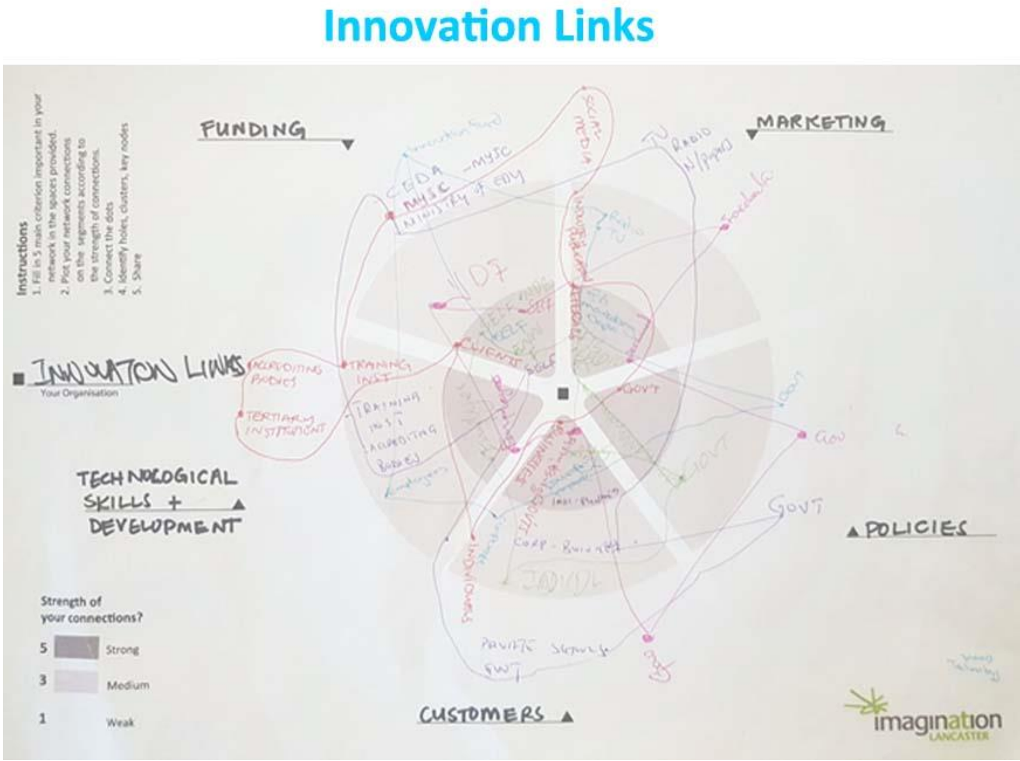


Figure 8.22: Examples of visualisation output for Innovation links

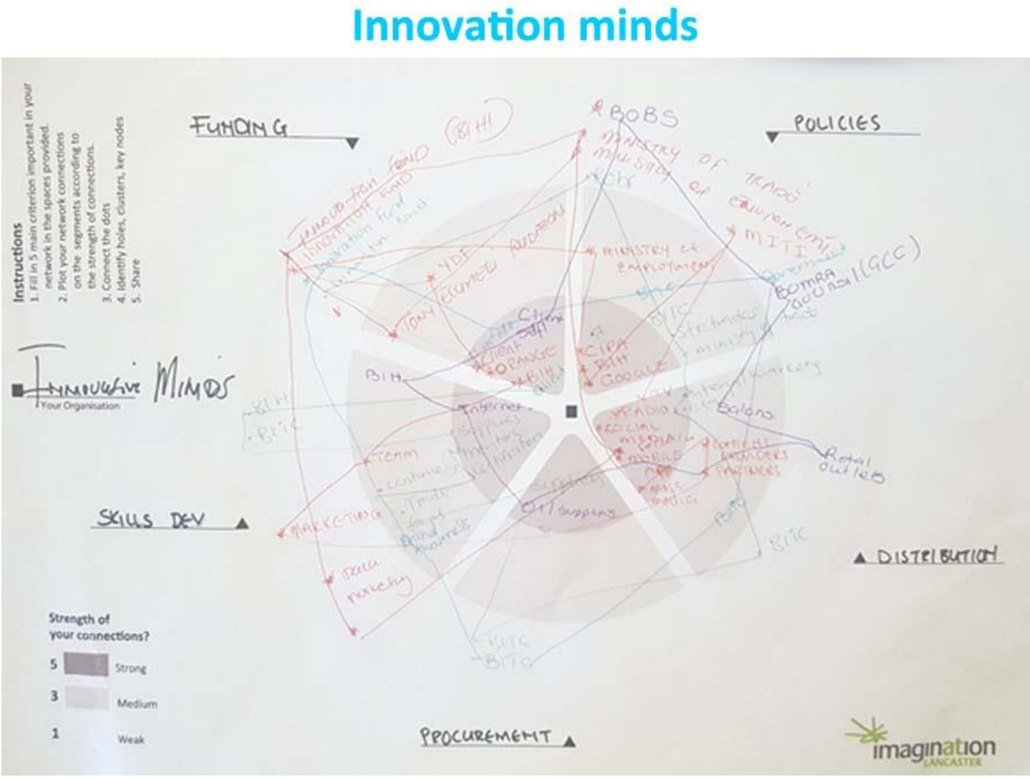


Figure 8.23: Examples of visualisation output for Innovation minds

Workshop conclusions

The way participants used the tools during the first and second parts varied considerably, but there was a slight variation in the last part, as shown in Figures 8.20 to 8.23. This was possibly so because participants were more familiar with the design process. Following the design activities and using design cues from previous sections made it possible for participants to be more consistent. They demonstrated how exploring weak ties across ecosystems might help develop future ecosystems images (Berg-Ridenour, 2016). Participants used the visualisations as heuristics to develop futuristic ideas on how they might leverage each other’s resources and take advantage of social capital (Carpenter et al., 2012; Collins, 2013).

Interestingly, all groups came up with creative names for their future ecosystem visualisations. Although the tools were appropriate triggers for dialogue amongst ecosystem actors, further improvements are needed to engage more effectively with colours to enhance understanding. In summary, the main findings from this co-design experience are as follows;

- Participants produced more detailed and futuristic ecosystem designs because they thought more about their weak ties than their strong ties.
- Using the first and second section outputs as design prompts to inform the third design activities helped participants appreciate the connection between the jigsaw design framework quickly.
- The tool elicited discussions and decision making in developing ecosystem criteria.
- At the end of the design process, it was observed that participants were able to review the designs and suggested future improvements.
- Presentation of visualisation artifacts helped participants and the researcher to appreciate the ecosystem configuration.

Researcher's reflections

The researcher learnt that using the design visualisation approach with entrepreneurs enhanced their understanding of ecosystems much faster, efficiently and easily. This is because SMEs used the framework to find their potential by creating ecosystems with others, i.e. new people who had the most skills and capabilities they needed. From a research perspective, the framework made the process of understanding ecosystems less complex.

8.3 Chapter conclusions

The Jigsaw framework provided a structure to help diverse participants make better use of their tacit ecosystem knowledge. The Jigsaw is about helping ecosystem actors find their potential. To conclude the chapter, the study highlights important findings from these workshops concerning the Jigsaw ecosystem design framework below;

Initiate

Using the design framework proved to be effective in availing a starting point for SMEs to engage in initiating ecosystems. Participants used the tools to identify key contacts and ties which might be leveraged to understand and initiate productive ecosystems. Most participants across three workshops identified funders and suppliers as the most valued roles missing in the local ecosystem. They discussed funding and supply as the main roles essential to initiate ecosystems during the first workshop. The second workshop identified funding, partnerships, and skills development as key roles missing in the ecosystem, while the third workshop identified funding and skills development. The use of design visualisation tools cultivated trust amongst participants such that they were more open during the last parts of the workshops, which indicated that the more they interacted in the co-design process, the better they trusted each other with sharing crucial information.

Design

The second and third parts were about modelling outcomes from participant's individual and group activities. They made decisions on the strength of ties through discussions with other stakeholders. Participants also developed a shared value constellation through discussions on what was important to the ecosystem. Through the design process, users were able to appreciate what they could achieve as a collective. Therefore, this level was about visualising the ecosystem structure and making sense of what value exchanges might arise. Participants identified potential collaborators, e.g. Universities, and barriers hindering them from understanding and fostering productive ecosystems.

Review

Giving participants time to ponder their ecosystem artifacts during the second and third parts allowed them to review their design visualisation knowledge. Presentations of outputs served the participants with a sense of each other’s ecosystem structure. This level was also about building trust by reviewing the meaning of visualisations in groups. Some participants were less open from the beginning of the design process but later became more trusting with information. Assessing visual images in groups prompted most users to think explicitly about how they are connected, how they might improve their connections, who was the missing key role, and how they might build more productive local ecosystems. However, in some instances, the tool did not work as expected because participants only focused on their strong ties, limiting their ability to identify new ones (see Figure 8.5-8.9).

Activate

The third part focused more on testing group dynamics around ideas on activating new relationships. Since participants were provided with the design visualisation tool, it served as a structure for different participants to discuss and reflect on important things and drive their need to connect with others. They discussed key roles needed as a matter of priority to develop new ecosystems. For example, participants discussed collaborating in hosting marketing events for their new products and approaching Universities and the private sector as a collective to seek collaborations. Regarding ecosystem activation, the third workshop highlighted accessing and lobbying for Government schemes, grants, and subsidies as an ecosystem rather than as individual SMEs to increase their chances of success. Participants identified social media groups (WhatsApp) and meetups as excellent ways to start activating their new ecosystems.

Sustain

Most participants centred their activities around how to sustain new ecosystem structures. As participants engaged in creating new ecosystem ideas in groups, they developed new sets of shared values. Participants developed a list of key stakeholders through their collective interests. They also agreed on how they might activate and sustain those new roles, e.g. bulk purchasing of materials to save on transport and tax fees, sharing clients to provide diversity, sharing data and tools to cut down on hiring costs, sharing skills, and joint advertising. Finally, participants highlighted the need to engage regularly to reconfigure the local SME ecosystem.

8.3.1 Chapter contribution

This co-design approach contributes to the development of micro-level capabilities to design the understanding of local SME ecosystems. Since the Jigsaw is about helping local ecosystem actors reach their potential in understanding ecosystems, this chapter has contributed an empirical account of its efficacy. SMEs and stakeholders used the framework to make better use of their collective potential. Through the Jigsaw, ecosystem actors were empowered to reshape their beliefs and assumptions about the reality of their local ecosystems using visualisations as heuristics, thus enabling them to reconfigure future action.

Next, the thesis presents findings from the Design Research Society (DRS2020) virtual workshop.

9 Co-designing the understanding of research ecosystems

The previous chapter discussed findings from the in-person co-design workshops conducted in Botswana with manufacturing SMEs, policymakers, and researchers. In this chapter, the study discusses findings from a virtual co-design workshop with design researchers at a Design Research Society (DRS2020) virtual conference. The study evaluated the useability of the framework in helping researchers to understand their ecosystems.

9.1 Introduction

Design researchers, just like SMEs, are faced with the challenges of understanding their ecosystems. To understand research ecosystems, this chapter addressed the following objective:

> *To evaluate how the Jigsaw framework might support design researchers in the understanding of their research ecosystem.*

As discussed in chapter 4 (p.67), it was difficult to conduct in-person workshops during the Covid-19 pandemic. So, based on the improvement framework for redesigning engagement tools (Galabo and Cruickshank, 2019), this chapter used the co-design principles under three layers of practice, i.e., planning, facilitating, and designing interactive online resources to convert the physical workshop into a virtual co-design plan. This workshop re-design is detailed in the methodology chapter (pp. 67-70).

9.1.1 Workshop plan

Virtual workshop plan: 1-hour

- Introduction: a 10-minute pre-recorded video presenting a step by step design framework in MIRO whiteboard (virtual environment) followed by a 2-minute Q&A.
- Icebreaker: picking up something from the desk and sharing how it relates to the previous participant's 'thing.'
- Participants discuss and agree on criteria needed for an effective research ecosystem: Listing criteria for research ecosystems and choosing five critical ones to use in the design process.

- Identifying key contacts in individual research ecosystems: List contacts necessary for conducting successful research.
- Plotting strength of ties between research contacts: Decide on the strength of your ties using the design mapping tool.

  Analysing visualisation outputs and discussing how to activate and sustain new ties: Looking at the combined visualisation of networks in the tool: (1) identify research network insights and (2) decide how to activate and sustain these insights. Evaluate the tool: Participants complete an evaluation table by responding to questions on the tool's usability.
- Presentation and feedback

9.1.2 Data collection and analysis

Data was collected using the virtual design spaces in MIRO whiteboard since all co-design activities were done virtually. Also, the workshop was recorded with permission from the participants and later transcribed verbatim. Since this was a live co-design activity, the facilitator took notes on how participants used the tools to explore their research ecosystems. The presentation of ideas and discussions were also captured through notes.

Transcribed data and facilitator's notes were loaded in NVivo for a thematic analysis following the coding process described in chapter 4 (pp. 74-82) and based on the Jigsaw levels, i.e., initiate, design, review, activate, and sustain. Since this was a workshop activity to test the Jigsaw framework, the analysis focused on how the participants used the design tool than the contents. Participants were engaged in a visual analysis of their ecosystem outputs based on principles and theories described in chapter 4 (pp. 82-87), e.g., weak ties, bridges, holes, and key actors. Participants also used ecosystem images as heuristics to explore how they might influence future research structures. The findings from this study are discussed in the following section.

9.2 Findings and discussions

Fifteen participants signed up for the online virtual workshop. However, only 5 participants attended the workshop. The time difference partly caused low attendance since most participants were from Australia. Second, some participants had technical problems with joining the Microsoft Teams call, e.g., where to find the links and how to join.

Next, the chapter presents findings and discussions based on the five levels of the Jigsaw ecosystem design framework.

9.2.1 Initiating research ecosystems

Regarding initiating research ecosystems, the tools prompted participants to engage collaboratively using the design spaces provided in Figure 9.1. Participants populated important criteria for engaging other actors in the research ecosystem, which mattered the most in doing productive research. Further, participants used the platform to make decisions with new researchers based on the main criteria for ecosystems. Participants identified several criteria, as shown in Figure 9.1 and agreed on five main criteria to represent their visualisation as follows:

- Complementarity
- Publications
- Nice people/trust
- Organisation support
- Ethical concerns

Complementarity

All participants regarded this factor as key in initiating productive research ecosystems. Therefore, identifying where and who possesses resources which one actor does not have but needs is essential. This was also related to how well researchers fit together to use their collective capabilities to meet each other's shortcomings.

Publications

Most participants highlighted that publishing work in high impact journals was also regarded as a key criterion in research ecosystems. Participants reiterated the need for a researcher to collaborate with other researchers to leverage resources, which might produce superior quality work for publications.

Nice people

Regarding nice people, all participants talked about identifying nice people that can be trusted around the research environment who share similar goals. They agreed that successful research is determined by how researchers enable trusting relationships. This was considered an essential factor in initiating productive research ecosystems.

Organisation support

Identifying local resources in the organisation to support research initiatives was also crucial in initiating productive research ecosystems.

Ethical concerns

All participants also identified and agreed that ethics was a major factor that needs to be initiated to improve research. Participants reiterated that identifying key actors in ethics research might be valuable for improving research ecosystems.

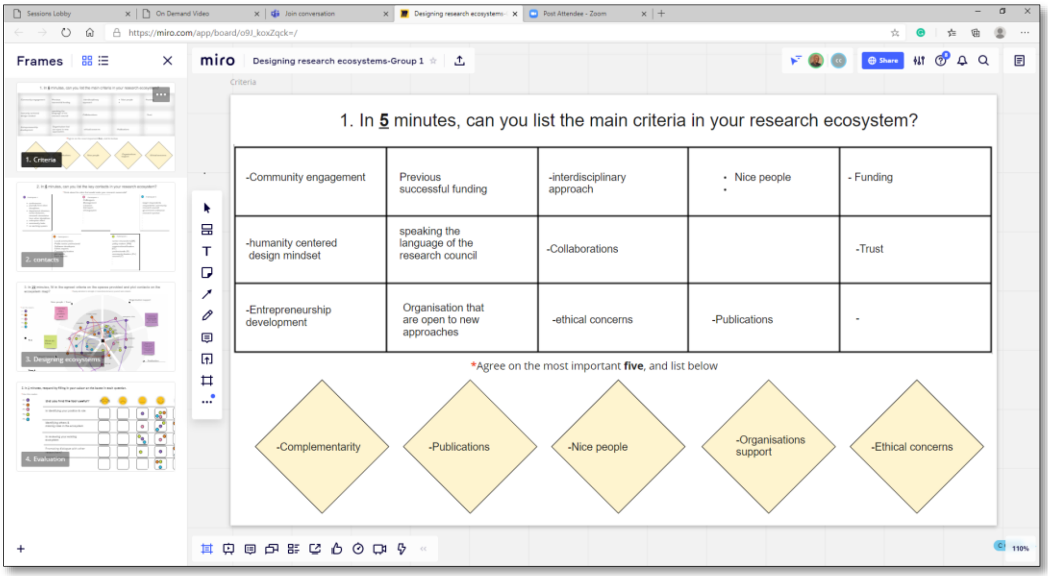


Figure 9.1: Initiating important criteria for research ecosystems

The second activity was about identifying key actors or roles in each participant's research ecosystem. As shown in Figure 9.2, participants identified different actors or roles that they thought were crucial and would make their research more successful. All participants used the design space to identify at least five main roles in their ecosystem in less than five minutes. The researcher observed that the space provided a similar experience as would otherwise be using sticky notes to think about key research ecosystem roles. Although the participants were using the same platform, they came up with diverse roles to represent a real picture of their research ecosystems. Further, working in the same space helped in that participants who were confused about what to do could see clues from others and open a dialogue with researchers during the thinking and design task.

Again, starting with key criteria for research ecosystems aided participants in coming up with roles linked to important criteria for research. For example, participant-1 noted that to achieve complimentarily, identifying and initiating actors such as research associates from other disciplines may increase the diversity needed in interdisciplinary research. Another example was given under nice people or enabling trust, where participant-2 talked about enabling and building relationships with the local community based on trust.

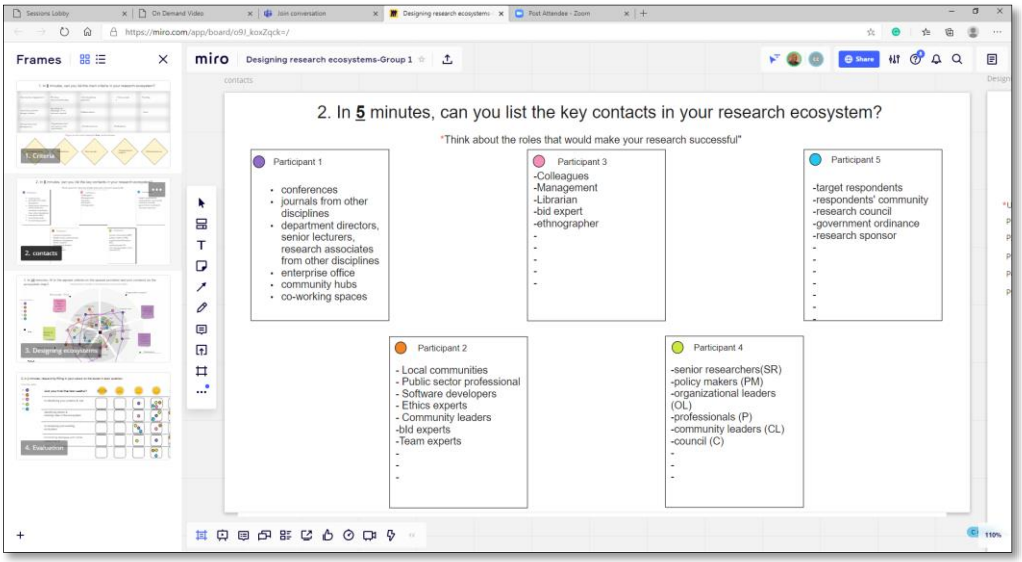


Figure 9.2: Identifying key actors and roles for successful research ecosystems

9.2.2 Designing & reviewing research ecosystems

Regarding design and review levels, this task was the most taxing because participants were required to build an image of their research ecosystem based on the common criteria and their support roles. Making judgement and decisions on where contacts are located in the design tool was not easy from the beginning of the exercise. However, dialogue with other design researchers aided participants to grasp the process quickly and map contacts against the main criteria. As shown in Figure 9.3, by designing customised node icons for the Jigsaw framework in MIRO, the researcher made it easy for participants to use the virtual space. Further, participants did not need new digital literacy skills during the workshop, and it was easy for them to move nodes around by merely copying and pasting and using the text and line tools to define nodes and roles. Participants used the design tool to define their understanding of the research ecosystem based on their current perceptions and knowledge.

Ethical concerns

As shown in Figure 9.3, most participants mapped ethical concerns at the medium and weak segments, suggesting that it is significant in promoting effective research ecosystems. When participants reviewed the combined visualisation, they highlighted challenges with handling research ethics and the need to identify experts in the area to complement their research capabilities, especially when working with community-related projects. For example, Participant-1 indicated the need to develop ethical guidelines in community-hubs, where community actor's ethical concerns are addressed. Participant-5 also highlighted the need to address the community's ethical concerns in research. Participant-3 observed that working with colleagues knowledgeable in ethics is key to delivering successful and impactful research. Ethical issues seemed important to the design researchers in enhancing their research.

Nice people/Trust

Under these criteria, participants talked about the significance of identifying where nice people are located and how to leverage their good character and trust to do collaborative research. Participant-2 identified medium relations with community experts and local community leaders and explained the need to use nice people in ecosystems. This mapping indicated that although the participant is aware of the experts in ethics, they lack bridges to reach them. Using conferences to forge relationships with other research partners was highlighted as crucial. All participants reiterated the need to work with nice people from the communities to enhance the research impact.

Organisational support

As shown in Figure 9.3, most participants, i.e. participant 2, 4 and 5 mapped strong relationships with support organisations. This implies that participants value research support from colleagues, community leaders, and sponsors by positioning the contacts closer to their positions. Another area of development highlighted as a weak tie was the enterprise activities, which participant-1 reiterated as having intellectual property issues. Participants agreed that there was a need for a new role to support research innovation and, at the same time, protect stakeholder's creativity.

Publications

Having publications as one of the main criteria for research ecosystem networks was not a surprise because it seems to be the main goal of many scholars. One participant wrote;

> *"Depends on whether you are reading or co-authoring with colleagues in other disciplines."*

This statement indicates that publishing in high impact journals, as discussed by participants, is significantly affected by interdisciplinary work, such that there is more value in collaborative work across knowledge domains. Therefore, participants 1, 3, and 4 have medium ties with high-impact journals, librarians, and senior researchers, respectively. Participant-3 mapped a strong connection with colleagues regarding co-publications. Therefore, participants agreed that working together as researchers to leverage each other's capabilities may increase their research output.

Complementarity

When reviewing the complementarity criteria, it was found that participant-1 mapped co-working spaces, and participant-2 mapped the kitchen as key spaces to promote complementarity. They indicated that research ecosystems lacked these spaces. Participant-3 also indicated that having FabLabs as complimentary spaces to promote collective creativity was important, although the participant indicated weak connections with the FabLab. Participant-2 and 4 indicated that they have strong connections with team-building experts and professionals, respectively, who are actively helping ecosystems to build trust. One participant wrote;

> *"Trust needs to be built, and this takes time (managers or contact person change)."*

Most participants agreed that to promote complementarity, spaces such as kitchens and co-working spaces need to be shared by diverse people from different domains to promote cross-pollination of ideas.

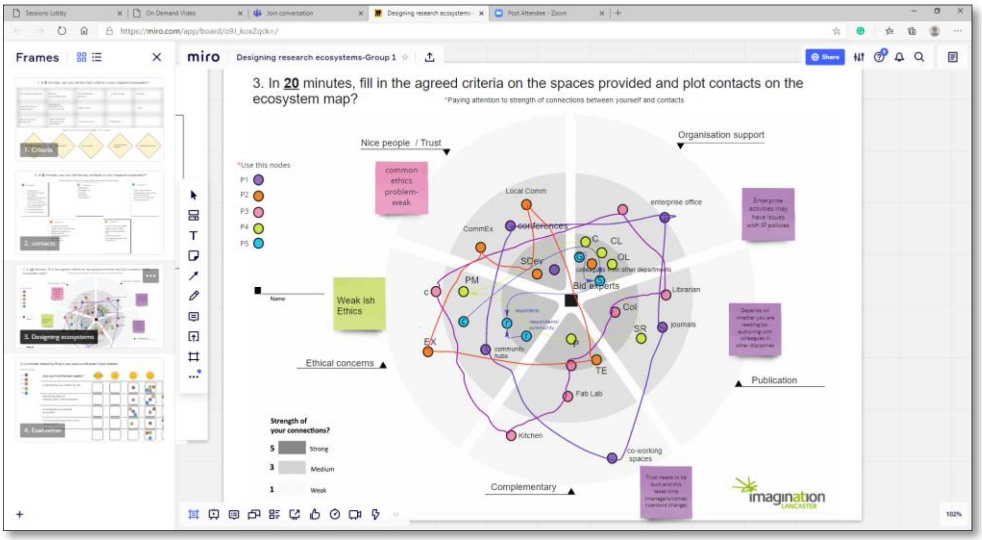


Figure 9.3: Designing and reviewing research ecosystems

9.2.3 Activating & sustaining research ecosystems

Having identified collective capabilities in a combined visualisation, participants discussed 'low hanging fruits' and how these might be activated into new collective capabilities. They agreed that activating complementarities across Universities may increase the chance for successful research grant applications, thus leading to enhanced research ecosystems. They also highlighted that ethical challenges need collaboration with researchers who are much knowledgeable in the area to leverage the skills and experiences of dealing with ethical concerns. When discussing how future research ecosystems might be sustained, participants agreed that data protection and security are becoming a paramount issue for them with the increase in digitisation. Building more activities around ethics awareness through more co-design activities was considered key in building sustainable research ecosystems.

9.2.4 Evaluating the Jigsaw ecosystem design tool

As shown in Figure 9.4, by designing the evaluation space using a combination of questions, node icons and emojis, the thesis made it easy for participants to evaluate the usability of the Jigsaw by simply coping nodes and pasting actions. When evaluating the tool, participants thought it was very useful in helping them to think about their research stakeholders and where they might be located within the complexity of research ecosystems. However, participant-1 said the following;

> *"The mapping was done about contacts and not my role within the ecosystem."*

This comment indicated that although the participant appreciated the useability of the tool in the understanding of the research ecosystem, the first evaluation question could be rephrased to reflect the understanding of contacts, not participant position in the ecosystem.

Nevertheless, the tool achieved its goal, which was to aid researchers in understanding their research ecosystems by identifying contacts and defining shared criteria, mapping actor's positions, reviewing the design, discussing how the emerging insights might be activated and sustained to enhance the research ecosystem.

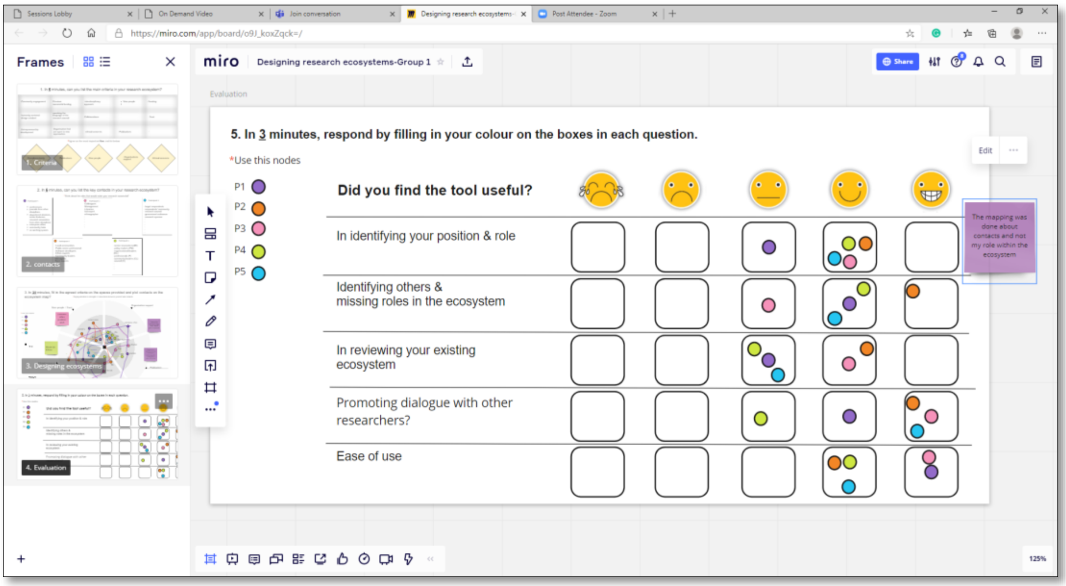


Figure 9.4: Evaluating the Jigsaw tool

9.3 Chapter conclusions

There was a low attendance of participants than expected across many conference sessions, including in this workshop. This was due to technical issues of finding workshop links and challenges associated with different time zones. The low attendance resulted in the adjustment from the original plan of having three parts to one main part, where 5 participants were all doing the design together in a single MIRO whiteboard instead of the initially planned three whiteboards. This reduced the complexity of navigating between breakout rooms and whiteboards, thus making the facilitation much easier.

In virtual environments, just like in-person workshops, things do not always go according to plan. For example, the icebreaker activity was not done because the workshop started a bit late, waiting on participants to join in the Microsoft Teams call. Operating in one space enabled the facilitator to address all design questions promptly by doing, e.g. copying and pasting contacts on the tool. Deciding and mapping criteria, contacts, and the strength of connections was a challenge for some participants. This was resolved by demonstrating the process on the same design space, thus providing design hints to guide participants.

Participants and the facilitators used the MIRO whiteboard to engage each other creatively. Although the virtual workshop was the first of its kind, participants developed mental images to represent their understanding of research ecosystem networks. The combined visualisations were used as heuristics for scaffolding a dialogue on how research ecosystems might be enhanced to maximise impact. Participants used the tool output to think about how future research ecosystems might be structured to improve research. Participants thought the tool was handy in aiding engagement with new actors, as shown in Figure 9.4.

Researcher's reflections

Since this was the fourth co-design workshop conducted based on the Jigsaw framework, the researcher learnt that the approach was very useful to help people find their potential in ecosystem networks. Although the tool was not initially designed to be applicable in various domains, it proved useful and efficient in this workshop to help design researchers in being creative in their research ecosystem thinking.

9.3.1 Chapter contribution

This chapter contributes knowledge of how the Jigsaw framework might be useable and transferable to other ecosystem environments. Although the framework was developed based on the manufacturing SMEs data in local ecosystem settings, it was evaluated in research ecosystems with design researchers at a virtual Design Research Society (DRS2020) conference workshop and proved usable and transferable to other ecosystem settings.

In the next chapter, the thesis presents the discussion chapter focusing on how the UK and Botswana findings shape the understanding of local ecosystems.

10 Discussions

Previously, the thesis presented findings from the exploratory inquiries and co-design activities in both an industrialised and a developing economy context, including proposing and testing the Jigsaw framework as an essential design visualisation tool to support the understanding of local SME ecosystems. This chapter discusses the new concept of design for disruptive innovation ecosystems, the Jigsaw design framework and how these relate to existing literature. The chapter concludes by discussing improvements to the framework and possible implications for practice.

10.1 Introduction

This chapter answers research question 5, which is:

> *Where could the design visualisation approach be improved to enhance the understanding of local innovation ecosystems?*

To address the above question, this chapter is divided into three main sections. Section 10.2 discusses the new concept of design for disruptive innovation ecosystems. Section 10.3 discuss the design framework against existing literature Section 10.4 highlights improvements in the Jigsaw framework based on findings from the evaluation activities. Finally, section 10.5 concludes the chapter by discussing the expanded Jigsaw framework, highlighting the tool transferability and contribution to practice.

10.2 Design for disruptive innovation ecosystems

As discussed in chapter 3, although part of the innovation ecosystem is self-evolving, conscious decisions shape part of it. Therefore, in this thesis, “design for disruptive innovation ecosystems” is presented as a new concept about developing a process of understanding and influencing ecosystem configurations for disruptions. Configurations mean how ecosystem actors and roles are arranged in a network of networks (ecosystem).

Design partly shape ecosystems to human desires through ecosystem practitioners' conscious decision-making. Managers give form to organisations through everyday decision making, far beyond their firms (Boland and Collopy, 2004). These practitioners are challenged to characterise and exploit ecosystem attributes defining value in their local networks (Bianchi and Vignieri, 2020). Employing “design for disruptive innovation ecosystems” approach mean that practitioners can actively design inter-organisational relations to promote serendipity for disruption. This can be achieved through participatory activities where ecosystem actors use design tools to meet, visualise, understand and act upon emerging opportunities that may disrupt existing business models, as demonstrated in previous chapters (7 & 8).

Through co-design workshops (chapters 8 & 9), the thesis demonstrated that design research could play an important role in developing conditions for disruption in local ecosystems. This is because we found that participants from different firms could think and act differently, questioning their current world and having the desire to change it to create new opportunities for entrepreneurship. Because designers are now confronting systemic and organisational challenges (Salmi and Mattelmäki, 2019), they are relevant in creating intentions for disruptions in local ecosystems. Cruickshank (2014) argues that the role of a designer as a gatekeeper and a central figure in the creation of new products, services and systems is ebbing away (Cruickshank, 2014). For example, the advent of digital technologies affords anyone or a group of individuals to design, customise and sell products without physical meetings (Cruickshank, 2014), thus affecting how the design profession is evolving. Many professional designers developed frameworks in the past to augment capabilities for non-designers to engage in open design and innovation effectively on their own (Lee, 2008; Sanders and Stappers, 2008; Manzini, 2015; Cruickshank et al., 2016). The design role help understand interactions between key actors in a system (Karadima and Bofylatos, 2019).

Based on the co-design workshop findings (chapters 8 & 9), the local ecosystem is made up of various actors who make decisions that rapidly give form to the ecosystem. As Boland and Collopy (2004, p.8) highlighted, “managers as form-givers care deeply about the world that is being shaped by a business and refuse to accept the default alternatives”. Therefore, design for disruptive innovation ecosystem requires collaborative designers who are key actors in the local innovation systems. Examples of actors in Botswana entrepreneurial ecosystem include SMEs, Universities, local councils and consumers, who make conscious decisions that reconfigure the ecosystem form and function. They are co-designers and form-givers because their decisions are linked through the local ecosystem networks. Hence, leveraging these connections is crucial to create serendipity for disruption, although this requires all key players in the local ecosystem because their choices and decisions are interdependent.

However, in Botswana, the thesis also found that building national innovation systems is often the government's prerogative through a top-down hierarchical policy structure, as elaborated in chapter 2. Building a national innovation system is also widely adopted in international organisations such as the Organisation for Economic Co-operation and Development and other industrialised countries, e.g. in the UK, where the process seems more democratized (Fransman, 2018). Whereas in Botswana, the Government is the sole designer of the innovation policy, with other stakeholders such as SMEs and universities acting as idle partakers. Consequently, this affects innovation implementation (Moalosi et al., 2016).

The concept of “design for disruptive innovation ecosystems” aims to empower people to meet, visualise, understand and act upon opportunities that may lead to disruptive ideas, as demonstrated through workshop activities (Chapters 7&8). Like process engineers who use laws of nature to transform energy into useful products to society, collaborative designers use design methods and tools to bring people together, to innovate and solve unmet societal needs. Furthermore, visualising ecosystem attributes enables communication of new opportunities in networks and offers an alternative mode of thinking about complex systems such as ecosystems. This approach is important because it enables actors to create visuals that they can see and use to think, analyse and identify opportunities for innovation, which are previously hidden from sight.

Although SME ecosystem actors are experts in their respective domains, the workshop findings highlighted that they lack the professional rigour of a trained designer to use design methods and tools in the first instance in decomposing the complexity of local ecosystem structures. This is key in understanding innovation ecosystems to deliver disruption in a developing context. Sanders and Stappers (2008) add:

> *"In the near future, designers will find themselves involved not only in the design of stand-alone products but in the design of environments and systems for delivering healthcare..." (Sanders and Stappers, 2006, p.15).*

The above quote suggests that the role of design is growing into other domains. Therefore, although ecosystem actors and form-givers, i.e. manufacturing SMEs, policymakers, researchers, users, NGOs, funders, and others, are discussed in this thesis as co-designers because of their everyday connected actions that give from to the local ecosystem, professional designers are essential in facilitating the understanding of these local ecosystems. The key issue is for designers to work with ecosystem actors to emancipate and empower them with tools to understand local ecosystems beyond the presence of trained designers (Ballantyne-Brodie and Telalbasic, 2017). The following section discusses the Jigsaw framework as an empowerment tool and design framework that may lead to disruptive innovation ecosystems.

10.3 Discussing the Jigsaw ecosystem design framework

To elaborate on each step of the design visualisation process, the chapter uses the five levels of the Jigsaw framework, as shown in Figure 10.1, to develop a cross-case discussion between ecosystem contexts.

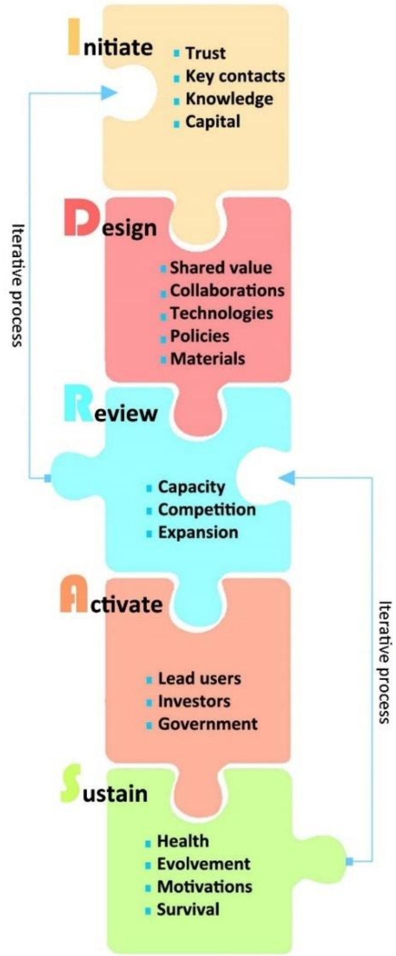


Figure 10.1: Jigsaw ecosystem design framework

10.3.1 Initiating SME innovation ecosystem

This section discusses the significance of understanding factors related to the initiation of local SME ecosystems. The section first discusses enabling trust, followed by key actors and roles, and compares funding challenges across the two contexts.

Enabling trust in local ecosystems

The studied UK makerspaces are unified by the ethos of openness, trust and maker culture in the innovation process (p.122), thus leveraging social capital through synergies and cross-pollination of ideas. This social capital is partly achieved through collaborative activities based on a shared set of skills and digital fabrication tools, e.g. 3D printers, laser cutters and Arduino electronic kits. So, having a set of self-driven actors to share knowledge, co-create ideas, and learn by doing is key in initiating local ecosystems (Niaros et al., 2017).

Botswana incubators are faced with challenges such as SMEs working in silos, as discussed in chapter 7 (p.176). This is contrary to the history of the country's manufacturing culture, which was predominantly anchored on trust and socio-economic mechanisms, e.g. "*mafisa and letsema"* as discussed on page 18. While learning from the UK context provide important insights, Botswana local ecosystems need to reinvigorate the lost socio-cultural mechanisms to fortify local ecosystem structures (Moalosi et al., 2008). Other scholars show that makerspaces and incubators form bridges of seamless resources across ecosystem actors (Buckley and Davis, 2018). This observation is inconsistent with the findings from Botswana incubators, where trust issues are attributed to high levels of idiosyncratic attitudes in chapter 7 (p.172). The study also found that inculcating a local culture that promotes trust and risk-taking may support the flow of resources across actors. This finding is consistent with previous studies (Spigel and Harrison, 2018).

The differences in contextual factors (UK and Botswana) are varied by how actors understand and enable trust. As stated in (Von Stamm and Trifilova, 2009, p.248), *"the higher the risk, the higher the need for trust is"*. Enabling trust is also influenced by how diverse business cultures are aligned, i.e. how actors relate with partners and their motivations. Hwang and Horowitt (2012, p.162) said, *'one person must take the first risk to trust the other'*. This thesis found that although actors are in the same physical incubators, they appear to be risk-averse in engaging other ecosystem actors (p.185). Mistrust is associated with uncertainty avoidance (Hofstede, 1984), where actors are generally uncomfortable with uncertainties associated with operating in ecosystems. Actors in Botswana incubators lack the trust to share resources, co-create ideas and build contracts that lead to shared value. Enabling trust through a mix of collaborative activities is important to initiate ecosystem actors and promote mutualism (Chapters 8 and 9). This finding also corroborates those in (Geert and Michael, 2004), who highlighted that individualism opposes collectivism. Activities like open workshops, maker festivals, maker nights, hackathons, meetups, among other interventions, seem to be building a weak uncertainty avoidance (UK case). This is necessary to initiate open environments where SMEs and other actors could meet, build trust, identify leaders and ultimately initiate productive ecosystems.

The study found that the UK ecosystem cases also have challenges with enabling trust and sharing ideas, particularly between established entrepreneurs and start-ups, e.g. 3D printing bureau case in chapter 5. Using collaborative activities listed above makes local ecosystems better at enabling trust. Findings from co-design workshops (Chapter 8) show that using visualisations enable actors to build trust. This is because ecosystem visualisations help actors see and feel like they are part of a whole and collectively influence change.

Key roles and actors

While acknowledging that innovation ecosystem roles partly emerge organically (Dedehayir et al., 2018; Jacobides et al., 2018), understanding ecosystem roles is important because human choices and actions partly influence the ecosystem configuration. From previous chapters, visualisations were used as heuristics to enhance the understanding of ecosystem role structures based on Iansiti and Levien (2004) strategic roles. Other researchers suggested actors who may be critical at the early stage of building ecosystems (Cusumano and Gawer, 2003; Dedehayir et al., 2018; Rabelo and Bernus, 2015), such as universities, research centres, entrepreneurs and suppliers amongst the key actors. But it is still challenging to prescribe roles because this is based on contextual factors and other ecosystem dynamics, e.g. bridging roles, structural holes, high degree actors and other mechanisms discussed in this thesis. Further, this thesis found that there is a limited understanding of key roles in local ecosystems. Knowing where key actors and roles are in the ecosystem structure helps define the ecosystem value proposition and how actors can participate in the local ecosystems. For example, the analysis on page 194 shows that SMEs located at the incubators depend on keystone support, i.e. basic resources such as office space, equipment, raw materials, training interventions and personnel.

The analysis of the findings on page 182 shows that SMEs cannot adequately explore other potential keystones, hubs and niche roles in and outside the incubators in Botswana. Contrary to what Dedehayir et al. (2018) refer to as the entrepreneur’s initial role to establish links with suppliers, customers and complementors, it appears SMEs are only concerned with suppliers and customers. This is also contrary to the UK makerspaces that rely on space to design roles and coordinate interactions between them and take the initiative to seek partnerships with other SMEs. This may be so because the results on page 132 indicate that makerspaces use various networking activities to enable serendipitous connections between registered and potential actors. The findings also indicated key bridges present in makerspaces that create linkages between actors (p.149).

Although previous literature points to the need for expert and champion roles to be initiated at the beginning of the ecosystems (Dedehayir et al., 2018), this appears to be absent in SME incubators in Botswana. Based on visualisation results in Chapter 7, SME incubators are only targeted for specific sectors, unlike in most makerspaces, where random actors are accepted. Opening the ecosystem and utilising bridges like banks, government, and social events (e.g. maker festivals) may allow a set of new actors, e.g. niche actors from outside, to interact with incubates (p.146). This is necessary to initiate new relations and roles going beyond the incubation period.

In the UK, the analysis showed that directors are making efforts to engage regional university leadership, researchers, students, local councils, and diverse entrepreneurs to build a critical mass of actors with diverse knowledge (p.148). However, more effort is needed to contribute to regional economic development. Chesbrough et al. (2006) also emphasised that open innovation happens when firms leverage external knowledge sources. This is also demonstrated in (OECD, 2017), where the report suggests an increased knowledge-based network for SMEs increases competitiveness in local markets and increases disruptive effects. Makerspaces demonstrated the expediency of linking with universities as crucial in growing the local ecosystem. This is because universities play a complementary role by providing additional space for conferences, tinkering activities and makers, i.e. researchers and students. Whereas in Botswana, universities are detached from the local ecosystem. As a result, this creates knowledge vacuums in incubators.

In the UK, makerspaces are running STEM programs to promote collective creativity at the grassroots level; this is important in building a foundation for future ecosystem understanding. Other researchers support STEM programs in stimulating grassroots creativity (Blum-Ross et al., 2019). So, raising awareness about local ecosystem shared benefits is important to build expectations amongst ecosystem actors. Identifying, leveraging key actors and understanding their roles in the ecosystem structure, e.g. linking with universities, other SMEs and local authorities, is significant in defining the local ecosystem agenda.

Access to funding

Makerspaces and incubators are facing financial challenges. Privately owned makerspaces are more financially challenged than most Botswana manufacturing incubators which the Government fully funds. Even so, Botswana entrepreneurs are performing poorly in terms of creating innovations. This could be attributed to the difference between ecosystem approaches, where makerspaces implement diverse income-generating interventions, e.g. running courses for corporates, renting equipment and co-working spaces, and Botswana incubators seem to be aloof and overly dependent on Government grants. Most makerspaces seem to depend on co-director funding, loans, equity investment and grant funding except for the Bank-owned makerspaces, which are fully funded. External funding allows makerspaces to purchase state of the art digital fabrication tools and hire technicians to maintain the space. Even so, the findings suggested that funders often come with difficult conditions (see chapter 6). The UK Government set the agenda for promoting makerspaces through R&D funding, but it is usually based on competitive bidding. Contrarily, although the Government of Botswana fully funds incubators, minimal collaborations are happening to transform social problems into system changing solutions.

Although previous research emphasises the high possibility of cultivating sustainable development with flexible, open-ended funding support (Smith and Light, 2017), most makerspaces are facing financial problems. This is in line with findings from chapter 6, which show that dealing with IP issues in open design environments increases dangers of IP loss. This requires much money to manage (Howells, 2008). Teece (2018) further this point by highlighting that IP alone may not be appropriate to capture value because it is not self-enforcing, and in most developing countries, law enforcement is weak. Therefore, makerspaces need income to initiate key actors through various innovation activities. Meanwhile, according to Marc et al. (2013), having government funding allow SMEs and other actors to “test the waters” by experimenting with ideas without a significant loss of revenue. Interestingly, the findings in Chapter 7 seem to contradict Marc et al. (2013) because although SMEs are in a funded incubator, they are risk-averse to experiment with ideas.

Due to lack of government funding, some UK makerspaces attract funders with conditions departing from the ethos of makerspaces, thus limiting the initiation of productive ecosystems in those milieus (p.141). As a solution to these complex situations, the study found that promoting a closer connection between the makerspaces and users (e.g. hobbyists, artists, manufacturing SMEs), councils, universities and students may drive the makerspace agenda while generating enough capital to sustain the ecosystem. Furthermore, an SME embedded in makerspace networks may significantly lower transaction costs and attract more partners to its innovation process. This is supported in (Brem and Radziwon, 2017). Insights from the UK makerspace activities, e.g. maker nights and collaborative experiments between SMEs could be augmented into the incubators in Botswana to promote co-creation.

This section indicates variations in sampled case studies in terms of initiating productive local ecosystems. This is mainly due to different contextual factors such as trust, openness, actor’s alignment and roles, and access to funding.

10.3.2 Designing SME innovation ecosystem

This section discusses findings related to the design of local ecosystems, which is the second level of the Jigsaw framework. Next, the section discusses establishing shared value, forming collaborations, and using technologies—finally, collective creativity, the use of local materials and policies.

Establishing shared value in local ecosystems

Establishing value in local ecosystems is about promoting a collective impact approach (p.176). The core values are empowering people to make things, solve social problems, play with materials and tools and share knowledge (Sheridan et al., 2014). Marc et al. (2013) show that defining a social purpose within a group is crucial in co-creation and building trust. Others show that makerspaces allow people to make profound business ideas and come together to play, socialise, and exchange life ideas (Taylor et al., 2016).

Considering that value is contextually determined (Vargo and Lusch, 2011; Akaka and Vargo, 2013), In the context of sampled UK makerspaces, although creating shared value is about generating economic and social benefits for actors (p.135), most makerspaces tended to lean towards economic benefits. This is not a surprise because Adam Smith long highlighted that entrepreneurs act in pursuit of profit, although they may generate value for society (Smith, 1977). Consequently, in this present thesis, the findings show that shared value is also about promoting interconnectedness and network effects, such that businesses emerging from the SME ecosystem give back to the local ecosystem where they are embedded. This answers the key questions on shared value, i.e. 'for whom is value created and by whom' posited in (Lüdeke-Freund et al., 2016).

Manufacturing SMEs lack a shared value approach. This was found to be due to their isolated actions (p.181), economic motivations and lack of awareness about the significance of social capital. Designing is about figuring out how to define ecosystem benefits and what collective capabilities are needed to deliver these benefits. The analysis shows that creating shared values may be designed around existing resources like physical equipment or technologies, workspaces, business customers and parts of the supply chain (p.177). These findings corroborate previous literature (Manzini, 2015). The key goal at this level is understanding collective capabilities and a shared vision. This is important to inculcate the spirit of sharing, which creates benefits for the entire ecosystem. Sharing resources is also emphasised in chapter 8 as crucial in local ecosystems. Makerspaces and incubator models provide a platform for promoting a shared value proposition. This is also supported in (Schmidt, 2019), where the author shows that integrating a more comprehensive community into the makerspace ecosystem beyond just space users but value creators is critical. In the next subsection, the study discusses collaborations in local ecosystems.

Forming Collaborations

The findings from the analysis of incubators suggest a lack of collective impact approach in creating shared value, which, according to Porter and Kramer (2011), requires delicate forms of collaboration. Aside from lack of trust and openness, as alluded to in this chapter, lack of collaborations is attributed to the failure to champion collective impact through engagement with manufacturing SMEs (p.176). Findings indicate that incubator managers fail to facilitate shared value creation and decision-making processes at the incubation level and amongst SMEs to reconceive and align diverse business model innovations. The failure is also caused by a lack of understanding of local ecosystem dynamics. Chapter 7 shows that it is challenging to align SMEs to work together.

Some challenges identified are that SMEs lack a shared vision and commitment before formalizing clusters around shared projects. Another challenge is that local ecosystems are detached from knowledge centres as critical roles. Previous literature points to the significance of forming ties with universities (Valkokari, 2015; Siikonen et al., 2011; Witte et al., 2018). As pointed out by (Nylund et al., 2019), innovation is not limited to the capabilities of one actor. It is about fostering collective effort.

Similarly, looking at the analysis findings from sampled UK makerspaces, although they are engaging in more collaborations than incubators in Botswana, they also lack clarity on perceived benefits and a deep sense of individual capabilities and roles, which seems to disintegrate efforts to collaborate. As a result, most sampled UK makerspaces utilise their strong ties with local universities and leverage digital fabrication tools to attract actors and promote collaborations (p.138). Furthermore, makerspaces are using social activities like meetups and coffee sessions to activate SME interactions. This finding is in line with that of Mortati et al. (2012), who highlight a significant correlation between socialisation activities and the creation of social connectedness. This social connectedness leads to more trust-building and collaboration amongst ecosystem actors. Next, the chapter contrasts the role of technologies in two contexts (Botswana and the UK).

Using technologies

The use of fabrication technologies, e.g. 3D printers and laser cutters, is highlighted in this thesis as key in shaping the local ecosystem. In the UK makerspaces, a combination of digital and conventional manufacturing technologies promote mutual dependences amongst makers. This is so because makers tend to leverage the diversity of skills specialisation with different technologies and actors. This finding is consistent with (Akaka and Vargo, 2013), who assert that technologies influence institutions and human actions, thus shaping the ecosystem. Interestingly, the findings from chapter 6 indicate sampled makerspaces having similar sets of fabrication tools, e.g. 3D printers, laser cutters, Arduino electronic kits and other conventional tools like pottery wheels. However, although 3D printers are hyped amongst makers, they are not widely adopted compared to laser cutters in makerspaces because of a steep learning curve associated with 3D design software for modelling ideas before print (p.138).

Other reasons for low adoption reported include constrained surface finishes and build space of machines which limit product dimensions. These findings are in line with other researchers (Weller et al., 2015). The presence of 3D printers attracted the attention of makers to the space. This is particularly necessary to mobilise people to the makerspace even though most do not use printers. Therefore, the analysis finding implies that combining technologies attracts actors from multidisciplinary fields (Vuorikari et al., 2019), providing much-needed diversity in shaping local ecosystems.

Botswana incubators rely primarily on conventional manufacturing processes and tools, predominantly through handcrafting skills, e.g. weaving, pottery/ceramics and leather manufacturing. The results revealed that handcrafting processes create a niche market in the tourism industry (p.179). This seems to validate the evolutionary growth theory, particularly on the argument that latecomer economies (Botswana) may profit from the advantage of using old technologies to create innovations. This was a surprising finding, contrary to expectations. It is interesting to note that ceramic and visual arts incubators are unique from other cases because tourists (i.e. main actors in these spaces) value interactions with material properties to produce customized products than buying from shelves. This finding corroborates those in (Devendorf et al., 2016), who argue for a de-emphasis in precision manufacturing and promote hand-material interactions. Also, this finding is in line with those of sampled UK makerspace ecosystems, where most actors are involved with spaces for personal fulfilment, which may later lead to entrepreneurship.

Other incubators in Botswana, i.e. leather and multi-sector incubators, prefer digital fabrication technologies to enhance their products and services because of diverse customers and users who demand quality and precision. The analysis of the results in chapter 7 shows that most SMEs in incubators are experiencing challenges producing quality products to compete with large retailers, hence their willingness to adopt emerging technologies, e.g. 3D printing and laser cutting.

Promoting a combination of digital and conventional manufacturing may significantly improve the quality of products in the leather and multi-sector incubators. In contrast, in the ceramic and visual arts cases, the adoption of digital fabrication tools may likely destroy the niche tourism market (p.179). Consequently, contextual understanding of the local ecosystems is paramount in designing and enhancing SME innovation ecosystems, especially before introducing adopted technologies. This is in line with previous studies about ecosystems in developing countries (Khavul and Bruton, 2013; Mrkajic, 2017), where knowledge of local ecosystems based on local context is emphasised. This leads to the discussion on how creativity and the use of local materials influence local ecosystems.

Collective Creativity

From the analysis of the sampled ecosystem cases, creativity emerged as significant in the UK makerspaces than in Botswana incubators. The results show that the UK makerspaces promote a relaxed attitude in their ecosystem to allow SMEs to tinker and experiment with new tools and business models (see chapter 6). Whereas sampled Botswana incubators are more formal, less open, less creative and less experimental in their approach, thus restricting SMEs from interacting and co-creating with peers (see chapter 7). This seems to be the main differentiator between UK makerspaces and Botswana incubators. This lack of creativity could also be ascribed to high levels of institutional isomorphism, where SMEs in Botswana are accustomed to mimicking products from their counterparts within the incubator (mostly in themed incubators) and in the mainstream market than creating new things. This behaviour was also observed in a related study with SMEs in neighbouring South Africa (Masocha and Fatoki, 2018). Another reason for low levels of creativity is attributed to lack of access to tinkering, experimental tools, design skills and lack of awareness on differentiating products for competitiveness. The study found that SMEs are used to their products and lack the impetus to create new things. This is in line with what Holm (2015) highlight as a trend in SME owners who are complacent in their roles as bosses and less interested in collective creativity and innovation. However, contrasting these findings with the UK makerspace ecosystems, most actors in makerspaces are self-directed, thus making it plausible to blend with peers in collective creativity.

From the sampled UK findings, collective creativity is about tinkering and developing innovative ideas as a group of diverse, interconnected actors in an informal setting. As suggested under the UK findings (see chapter 6), makers benefit from opening access to a wide array of actors and also by gaining access to digital fabrication tools for tinkering, thus leveraging on actor's heterogeneity to shape the ecosystem. In addition, previous research highlights the importance of culture and indigenous knowledge in creating culturally oriented innovations to increase creativity and competitiveness (Moalosi et al., 2016). Other researchers also found the significance in combining social and material resources to support engagement and creativity (Blum-Ross et al., 2019), thus attracting many SMEs to work with local materials, which is the subject of the next discussion.

Local materials

In contrasting the makerspace and incubators, the findings show that most incubators in Botswana use imported materials, although the same materials are available locally in unprocessed form, e.g. ceramics and leather materials (see chapter 7). However, the UK findings show that the sampled makerspace actors often re-claim scrap or recycle materials, e.g. electronic circuit boards, to regenerate products through tinkering activities. This finding corroborates those of some SMEs located outside incubators in Botswana, who are interested in re-using plastic materials from landfills to manufacture automotive engine parts. Other researchers support the significance of turning everyday scrap materials into usefulness, i.e. building computers and structures (Gershenfeld, 2007).

Under other conditions, the significance of using local materials in Botswana may potentially create shared value for local communities either in recycling or reclaiming materials from landfills. Furthermore, the development of local manufacturing industries, e.g. ceramic and leather processing, may also shape the future of local ecosystems by reviving communities of makers, e.g. in basketry, weaving and ceramics. Related literature on makerspaces extends this argument (Han et al., 2017), emphasising that the makerspace materials and tools need to fit the needs and capabilities of areas where makerspaces are geographically placed.

Therefore, shifting the focus towards developing local materials may further sustain the local ecosystems in Botswana. This could also reduce high uncertainty levels associated with delays in the supply chains caused by cross border issues (p.191). The findings point to reforms in government regulatory policies based on local needs to shape the local ecosystems to further strengthen the local ecosystem. This is the subject of the next discussion.

Policy support

The findings regarding policies and resource support in sampled incubators suggest a lack of a robust policy framework to curtail dominators seeking advantage rather than fairness in local markets. Other researchers highlight the significance of friendly policies in accelerating the development of innovation ecosystems (Rong et al., 2011; Laureate and Spence, 2017). This seems to be a problem because manufacturing SMEs find it challenging to compete with established ecosystems in the local markets, partly due to high costs of tax compliance which seem to be disproportionate with SMEs cash flow. Although the Government of Botswana developed a few policies to regulate unfair business practices (see chapter 2), implementation remains a huge challenge.

One explanation for the policy failures is corruption, e.g. an officer responsible for law enforcement taking bribes from big retail stores. However, in terms of resource support, the results from Botswana incubators show that the Local Enterprise Authority (LEA) is providing business incubation support as an enricher or keystone to most manufacturing SMEs. Moreover, there are many schemes, grants and subsidies, as elucidated in chapter 7, that support the SMEs. Surprisingly, the findings from the analysis show that most SMEs still fail to unleash the great potential to survive within and outside incubators. This failure is ascribed to disconnected ecosystem actors (i.e. SMEs, policymakers, researchers, suppliers), weak policy implementation, lack of knowledge about local ecosystems, misaligned policies and reasons related to high costs of tax compliance. The high tax compliance costs are highlighted as a deterrent to SME ecosystem growth (OECD, 2017).

SMEs and other actors connected to the makerspaces pay a fee to use the tools, except for open days. This is a different entrepreneurship environment from Botswana incubators, where most services are available freely. The UK makerspaces do not have a clear-cut budget from the UK Government; instead, they often bid for competitive grants from charities and other organisations. Therefore, these makerspaces need to be self-sustained to survive. Although some makerspaces run timed incubator and accelerator programs within their holistic models, the most preferred idea is to promote long-term support for businesses (chapter 6). Most makerspaces widen access to digital fabrications tools to the community to attract non-professional participation into the maker ecosystem. This is in line with one of the open design initiatives highlighted in (Cruickshank, 2014; Smith, 2017), where both authors suggest that making the means of production available to everyone promote open design and innovation. Other researchers also found that attracting dense networks create new ideas (Holm, 2015) and unleash great economic power (Sun et al., 2019).

The analysis between makerspaces and incubators reveal differences between the UK and Botswana contexts. It appears that designing the understanding of local ecosystems may require incubators to focus on promoting shared values, activities that lead to collaborations, the use of a combination of conventional and digital fabrication technologies, local materials development and friendly policies. However, innovation theories also show limitations in the overuse of policies by the government (Sun et al., 2019). The findings from the co-design workshops demonstrated the significance of using tools to support policymakers in understanding local ecosystems through the Jigsaw framework (see chapter 8). The next section discusses the review of local ecosystems.

10.3.3 Reviewing SME innovation ecosystem

This section discusses findings related to the review of SME ecosystems, which is the third level of the Jigsaw framework. The section seeks to develop the understanding of how makerspaces and incubators activities shape the review of the ecosystem in terms of capacity, competition and expansion.

Capacity in local ecosystems

The analysis of SME incubators revealed that capacity is more about the development and management of the relationship between actors than material needs, e.g. technology and tools. SMEs and incubators related poor ecosystem performance to lack of knowledge in managing inter-firm relations, lack of skilled labour, irrelevant incubator programs, limited access to new technologies and the internet and other factors (chapter 7). SMEs and managers are disjointed, thus limiting their capacity to diagnose and develop the ecosystem as a whole. The Botswana findings highlighted a lack of understanding of interrelationships in incubators as a challenge. Despite an appeal from Gomes and colleagues on developing understanding in managing ecosystem complexities (Gomes et al., 2018), little has been done to date to capacitate decision-makers with relevant tools, particularly in SME incubators. One interesting finding in this study is that SMEs seem to view relationships with external actors as a simple list of inputs into their innovation funnel rather than strategic ecosystem partners (p.182).

Nevertheless, the makerspace findings suggested a different approach on what capacity means. Here, capacity is about exploring ecosystem funding and other roles to increase resources without compromising the ethos of the ecosystem, i.e. getting more commitment from funders and community users. Although in some cases, external funders have conflicting conditions misaligned with the visions of the makerspaces. The key contrast with incubators is in the makerspace capacity to engage the community. To create shared value, incubators need to promote community engagements. Reviewing ecosystem structures is key in revealing inefficiencies and opportunities to determine and build collective capacity (p.141 and p.181). Findings from co-design workshops in chapter 8 show that the Jigsaw framework enhances the creation of mental models of the local ecosystem, thus allowing actors to see interdependences and make collective decisions on future ecosystem potentialities.

Competition in local ecosystems

Competition amongst SMEs in incubators is important to increase innovation. Therefore, it is necessary to coordinate actors to compete in clusters than as individual SMEs. While it is generally acknowledged in innovation management literature that sharing financial risks increases mutual commitment amongst co-innovating actors (Adner, 2012; Zulu-Chisanga et al., 2020), the analysis of the results in SME incubators revealed a different picture. SMEs collaborating in projects still fail to commit to their cluster tasks because of reasons discussed on page 177, e.g. lack of commitment, aggression, and mistrust. Another overarching factor in SME competitiveness is dominating ecosystems in the local market, i.e. large retail stores. Due to weak policy implementation, retail ecosystems are not motivated to engage local SMEs, thus starving the local ecosystem. From the analysis of the results, the Government of Botswana, as the largest SME market, negate SME growth by its procurement inefficiencies (see chapter 7).

Contrarily, the UK actors seem to be better at leveraging network externalities and cooperation to improve their competitive advantage. SMEs and makers compete and collaborate in making activities, turning rudimental ideas into business innovations (see chapter 6). Notably, makerspace actors leverage keystone resources to cut down on experimental costs and benefit from economies of scale from partnerships and mergers. Although the makerspaces provide serendipity for coopetition, challenges such as IP rights and patents are highlighted as problematic, specifically in the bank makerspace ecosystem, where SMEs compete for the same market segment.

Manufacturing SMEs in themed incubation spaces compete within themselves to produce similar products and target similar markets, thus starving their local ecosystem. Whilst competition is necessary for stimulating the emergence of disruptive ideas, without proper mechanisms, this may spiral into a destructive competition, i.e. where the same product saturates the market such that prices go down and no one is making a profit. One solution to the overpopulation of SMEs in a small market is to introduce new markets in new milieus, which forms the subject of the next discussion.

Expansion in ecosystems

In relation to expanding the makerspace ecosystems for SME, the results show that using social media applications and close-knit interrelationships grow a critical mass of makers and tinkerers. One possible explanation for the presence of a close-knit community of makers is because most makerspaces host free maker nights and social events in their localities, thus attracting SMEs from the same area. This corroborates results from previous studies (Nylund et al., 2019), where gaining a critical mass of actors is encouraged in nascent ecosystems. However, these results differ with findings from incubators. Although incubates are located in the same premises, they lack a close-knit community because incubators are devoid of social and open events. Creating open events for makers effectively builds connectedness and discovers new blood, i.e. niche players, in makerspaces (p.149). This finding is in line with (Jucevičius and Grumadaitė, 2014), who highlighted that niches are radical actors who may bring bottom-up solutions to local interests and values. Another key finding shows that SMEs lack the skills to form valuable connections with other actors outside their main manufacturing domain, who may provide diverse inputs to the innovation process. The analysis of the ecosystem visualisation results from incubators revealed structural holes in the SME ecosystem, which may be bridged to connect with new actors outside reliable ties (pp.193-205). Nevertheless, previous literature emphasises the need to share a value creation and appropriation guideline to attract new actors to the ecosystem (Rong et al., 2018). This could also be applied to expand the local SME ecosystem towards creating value based on local needs.

10.3.4 Activating SME innovation ecosystem

This section discusses findings related to the activation of ecosystems, the fourth level of the Jigsaw. The section first discusses ecosystem users, and then it focuses on investment partners and the government's role in activating local ecosystems.

Activating ecosystem users

Users in this thesis are actors motivated to develop ecosystemic solutions to address their individual SME needs, inspired by Von Hippel's classic definition of lead users (Von Hippel, 1986). The study discussed the need to initiate, design and review the local ecosystems, but to ensure that local ecosystems are productive, ecosystem users, i.e. key actors, need to be activated to act. The analysis of the UK makerspace visualisations show that many actors are involved in the SME ecosystem, e.g. successful entrepreneurs, investors, community leaders, universities and others, who contribute value through their influence in makerspace ecosystems (Chapter 6). One explanation of greater involvement is that, unlike in Botswana, SMEs in the UK are exposed to new technologies at the makerspaces that attract many users. In contrast to incubators, manufacturing SMEs are less informed about activating their dormant relationships in the local ecosystem. Educating the ecosystem actors is highlighted as important in promoting productive ecosystems, especially educating investors about the local ecosystem potentialities. Chapter 7 suggest activities that might be used to promote continual learning and sharing. This corroborates the findings from (Nylund et al., 2019), who found that using word of mouth, online webinars, and hospitality tips were key in educating Airbnb ecosystem users.

Activating investors

Investors play a significant role in activating the local ecosystem. This is so because organising and activating makerspace activities to promote the ethos of making and entrepreneurship is costly (p.136). Although investors are acknowledged as key actors in the makerspace ecosystem, identifying those that share the same ethos with the makerspaces is challenging (Chapter 6). In Botswana incubators knowledge and understanding of the local ecosystem dynamic factors, i.e. markets, cultures, work ethics, trust, and education, is crucial in activating the local ecosystem. Nevertheless, investors are still reluctant to invest in incubates because of their initial level of development which is uncertain and unpredictable. Another reason is that less is known about these manufacturing SME ecosystems, unlike in the UK where most of their makerspace activities are publicly shared online. Although other researchers also found that investors are reluctant to fund early-stage firms (Nylund et al., 2019), they argue that knowledge about the firms needs to reach financiers, government and other key stakeholders to activate investors. The next section discusses how the government might be activated to grow the local ecosystems.

Activating the government

The UK sampled makerspaces have a close-knit relationship with local councils regarding funding and active engagements in their activities. This is because the makerspace owners recognise the significance of local authorities in growing the local ecosystem and vice versa. Contrarily, Botswana incubators are isolated from local authorities. This is because there is a lack of trust and confidence between the local government workers and SMEs located in incubators to deliver on projects (p.172 and p.189). Organising events between the two communities may develop trust, understanding and confidence, leading to the activation of local SME ecosystems. From the analysis of Botswana cases, the government officials responsible for entrepreneurial policymaking need to be educated about the local ecosystem dynamics to support the activation and sustainability of ecosystems. Findings from co-design workshops indicated that using visualisation tools promote trust, openness and confidence amongst actors (Chapter 8). Understanding the sustainability of SME ecosystems is the subject of the next section.

10.3.5 Sustainability SME innovation ecosystem

This section discusses findings related to sustaining SME ecosystems, which is the final level of the Jigsaw framework. The section seeks to understand how SMEs sustain ecosystems by discussing the UK and Botswana ecosystem health, evolvement, extra-rational motivations and survival.

Ecosystem health

The UK makerspace actors are embedded in a diverse ecosystem of makers. The analysis of the findings revealed that different actors collaborating in innovation projects lead to a healthy ecosystem. However, makerspace directors also acknowledged the risks associated with collective creativity, i.e. intellectual property sharing (p.139). One actor's adverse action may affect others, thus leading to the collapse of the whole. This concept of shared fate is elaborated in (Iansiti and Levien, 2004). Shared fate was also found to be why most ecosystem actors are hesitant to work with others. In the UK, several actions are taken to enhance the ecosystem health, e.g. working with schools to integrate STEM subjects into the maker community through learning by doing initiatives at some makerspaces. This is important because it promotes innovations at the grassroots level.

In Botswana incubators, manufacturing SMEs fail to sustain healthy relationships when working in shared projects because of a lack of trust and commitment (Chapter 7), which leads to high uncertainties. Another reason ascribed to lack of commitment is a laisser-faire attitude amongst SMEs, which affect the entire ecosystem health. The analysis of the findings shows that cultivating a healthy ecosystem is the purview of incubator managers, and their understanding is thus needed to improve the health of incubators. This can be achieved through continuous learning of SME ecosystem structures via collaboration events. This is also discussed in chapter 6 as crucial. Co-design events, e.g. workshops, provide a chance for actors to bond and foment networks, leading to productive ecosystems. This is important to sustain healthy interrelationships and interdependences.

Ecosystem evolvement

One key difference between how ecosystems are evolving in the UK and Botswana is based on the physical spaces. In the UK, rental prices are hiked every year, meaning that makerspaces are forced to evolve with these radical changes. This seemed to be the main source of uncertainty in sampled makerspaces. In Botswana, incubators are not concerned with rental prices because the Government pays for the space and provides subsidies to SMEs. Nevertheless, this does not seem to help SMEs at the end of the incubation period because they are then forced to rent spaces in the city at a market rate, which is a massive upset in their ecosystem structure. Findings from incubators show that most SMEs barely survive outside incubators (p.192).

As a solution to the shortage of spaces in the city, the UK makerspace directors suggest collaborations with City Councils to regenerate slums and ghetto spaces into makerspaces to be used by community makers in creating shared value. Another solution is to incentivise makerspaces through government subsidies and rebates based on shared value propositions. Regenerating slums and ghettos to accommodate SMEs is also applicable to Botswana context as a solution to post-incubation disruptions to sustain the SME ecosystem.

Extra-rational motivations

The analysis of the makerspace ecosystem shows that all the interviewed makerspace directors were involved from the beginning of the makerspace movement, i.e. in the last ten years, thus showing a great deal of passion on their part in driving the makerspace visions. This is so because for these ecosystems to thrive, owners and actors need to be self-directed, self-motivated and altruistic in their approach to creating shared value (Chapter 8). This finding is in line with (Wolf and Troxler, 2016), who argued that it might be useful for corporates to use the above makerspace values in their strategies. Unlike in government-funded incubators where technicians are hired to assist SMEs, in most UK makerspaces, it is about peer to peer exchange of ideas, fixing culture and volunteerism. Users take ownership of the space (p.139). This idea is suggested as essential in building shared value amongst makerspace actors. To build sustainable ecosystems in Botswana, extra-rational motivations such as volunteerism, altruism and networking activities may help build trust and robust ties between actors (p.192). Such motivations are demonstrated as highly effective in sustaining interrelations (Presenza et al., 2019; Hwang and Horowitt, 2012; Wolf et al., 2014).

Survival of local ecosystems

The survival of makerspaces seems to be largely dependent on physical spaces to host workshops and co-working activities. In contrast to government-funded incubators, makerspaces are confronted with the considerable challenge of securing sustainable spaces to continue operating (p.147). In order to address these uncertainties, makerspaces are diversifying their revenue streams through offering training courses, e.g. coding, virtual reality and STEM programs (see chapter 6). The uncertainties in makerspaces affect the entire ecosystem because most SMEs thrive on the resources provided by the space as a keystone actor. These findings corroborate those found in Botswana incubators. Although the government funds incubators, SMEs are only incubated for a maximum of two years. This is a problem because most SMEs are unable to survive outside the incubators. One of the reasons for this is attributed to high office rental in the city, just like in the UK makerspace cases. Therefore, insights from the UK, such as diversifying manufacturing SME offerings, is important to sustain the local ecosystem. Connecting with the local government to share the spaces and universities to expand innovation resources is crucial to local SME ecosystem survival. Finally, survival is about the continuous learning and reshaping of the ecosystem structure.

The next chapter discusses the Jigsaw design framework as a tool to support "design for disruptive innovation ecosystems" based on the findings from co-design workshops to promote serendipity and disruption in local ecosystems.

10.4 Validation of the Jigsaw as a framework for promoting "design for disruptive innovation ecosystems"

The validation of the Jigsaw framework was done through co-design workshops (see chapters 8 and 9). The workshop activities demonstrated that the Jigsaw framework was useful in empowering actors to find their potential and better use it. Although every ecosystem actor has a diverse value expectation from the SME ecosystem, there was a convergence point amongst actors created through dialogue. Using the Jigsaw, local ecosystem actors, e.g. SMEs and policymakers, became progressively open-minded and trusting (chapter 8), thus enabling a smooth dialogic engagement.

Co-design workshops conducted in Botswana and at the DRS2020 virtual conference provided a platform to test the functionality and practicality of the Jigsaw framework. SMEs used the framework to co-create mental models of local ecosystems and engaged these models as rigorous heuristics for understanding current and future ecosystems (see Chapters 8 and 9). Next, the chapter highlights improvements in the Jigsaw ecosystem design framework by discussing how pieces connect to form a whole picture of a design visualisation approach.

10.4.1 Initiating SME innovation ecosystem

Figure 10.2 shows how ecosystem designers and leaders can use visual tools and dialogue in a co-design environment (physical and virtual workshops) to characterise ecosystems to understand actors and their roles. Figure 10.2 shows that this design approach can help initiate the ecosystem to enable trust, identify actors, knowledge centres, and capital. The thesis shows how the first level is expanded by modelling the connection between initiation and co-design visualisation approaches.

To achieve the goals of ecosystem initiation under the first level of the Jigsaw, the co-design workshop activities allowed ecosystem actors to act in concert in identifying primary criteria for engaging each other and with whom to engage in creating shared value. Actors developed value propositions to represent an idea for creating shared value. At this level, the workshops used visualisations to create mental models of ecosystem networks. Then participants used the models to scaffold dialogue on common criteria for networking in ecosystem environments (see chapters 8 and 9). Dialogue promotes sharing of information about key stakeholders and roles which is essential in understanding the values and visions of ecosystem actors at the initial stages.

Ecosystems are networks of interdependence (Adner and Kapoor, 2016). Co-designing visualisation activities form the mechanism by which actors proactively participate in enabling trust and open relationships with key partners, e.g., university researchers, community leaders, and policymakers who participated during the co-design workshops reported in chapter 8. Engaging in open sharing environments and activities build collective capabilities in ecosystem actors to initiate trust with key stakeholders as the first step in the Jigsaw design framework. Across the three workshops conducted in Botswana (see chapter 8), actors identified funding, partnerships and skills development as critical roles in the initiation stage of the SME ecosystem. Hence the need to initiate these roles before developing a value proposition. In Chapter 9, the Jigsaw framework was used to identify key roles such as ethical factors, enabling trust, support organisations and complementarities as vital in initiating research ecosystems. As demonstrated in (Vink et al., 2019), shared mental models allowed actors to interact effectively; this was also demonstrated in Chapters 8 and 9 workshops.

Suggested improvements to the framework include the addition of a value proposition at the end of the initiation process leading to the design level, as shown in Figure 10.2. This is to enable participating actors to agree on common criteria that might expedite the creation of value. Also, on the Jigsaw design framework, the design visualisation approach is added to demonstrate its significance in generating continual learning of ecosystems.

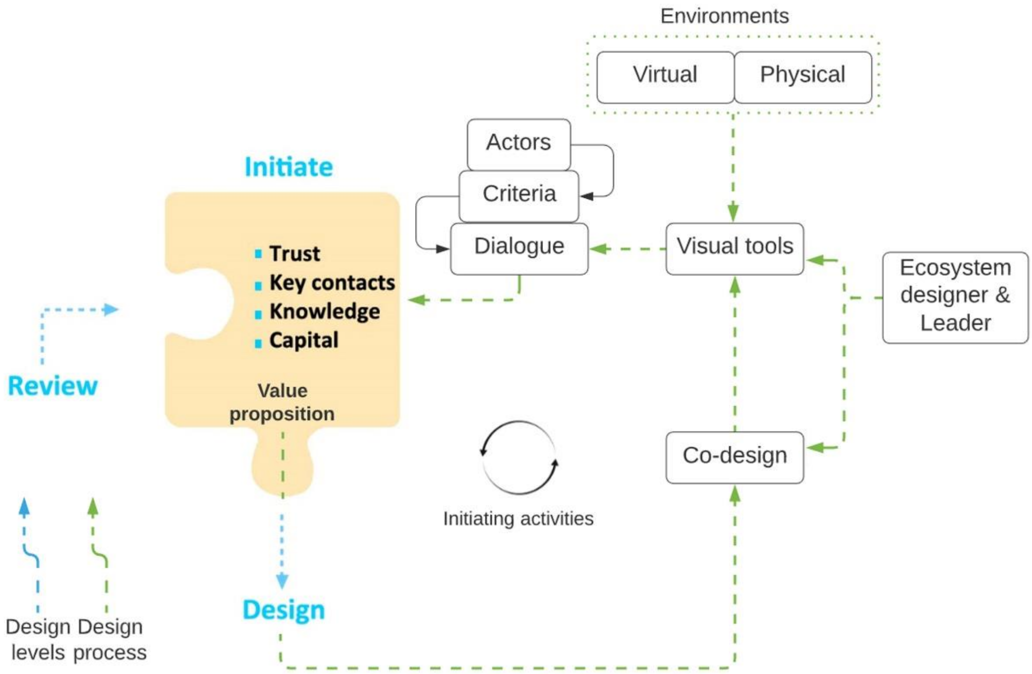


Figure 10.2: Improving the process of initiating ecosystems

10.4.2 Designing SME innovation ecosystem

Figure 10.3 also shows how ecosystem designers and leaders can use visual tools and dialogue in a co-design environment (physical and virtual workshops) to characterise ecosystems. This is done to make sense of and reveal ecosystem attributes (clusters, bridges, roles, positions, holes and ties) in the network. Figure 10.3 shows that this design approach can help shape the ecosystem in terms of creating shared value, building collaborations, leveraging technologies, developing relevant policies and using indigenous materials.

The co-creation experience across physical workshops in Botswana brought actors together to share knowledge on solving their problems. As shown in Figure 10.3, the design level guides the planning on how creating shared value might be achieved through discussions with different actors from the community (chapter 8). At this level, dialogue promotes compromise between different business models and visions, thus aligning ideas and motivating actors to link their values. The design level aims to use visualisation tools to plot ecosystem stakeholders against the main criteria identified as the ecosystem value proposition, as shown in Figure 10.3. Then use the generated visualisation outputs as heuristic models to identify points of convergence between diverse actors and possible ties between distant actors.

This stage builds an understanding of where strong and weak ties are located in the ecosystem structure. The visualisation spaces provide actors with a structure to decipher complex ecosystems, i.e. ideate positions of key actors, identify where key roles are located, make decisions on the strength of ties based on the existing relationship with contacts in terms of resource exchange and future ecosystem spaces based on the insights from ecosystem heuristics (see chapters 8 and 9).

The Botswana workshops brought diverse actors who are disconnected, e.g. from government policymakers, researchers, university administrators and innovation centres. This was important to promote dialogue and collaborative sensemaking to inform the understanding of ecosystem-friendly policies (chapters 2 and 7). Insights from visualisations both in virtual and physical workshops suggested that ecosystem actors, e.g. SMEs, policymakers and researchers, think better by doing, thus validating the use of design visualisations as a powerful approach to make sense of local ecosystem structures. SMEs located at the incubators could understand their capabilities, such as digital technology tools in their incubator that they were not aware of, skilled entrepreneurs that they did not know existed in their milieu, and even the fact that they were getting supplies from the same source. Understanding the ecosystem configuration is vital in strategic ecosystem-level decision making. Ecosystem actors need to engage other stakeholders in the ecosystem more frequently, as shown in Figure 10.3, to re-configure positions and roles as ecosystem-level strategies.

Suggested improvements to the design level of the Jigsaw framework include having a leader and a designer in the SME ecosystem. The former drives the system-level strategies and the latter as the ecosystem designer to provide support in the design strategy for the SME innovation ecosystem. This is because having incubator managers operating at a macro-level of the innovation ecosystem leading the micro-level SME ecosystem was ineffective. The leader and the ecosystem designer were suggested as micro-level ecosystem orchestrators to organise activities for the ecosystem, i.e. design workshops, events and conferences to keep the ecosystem vibrant through a dialogic approach. Lack of strategies in SME ecosystems is highlighted as a barrier to competitiveness (Temtime, 2008).

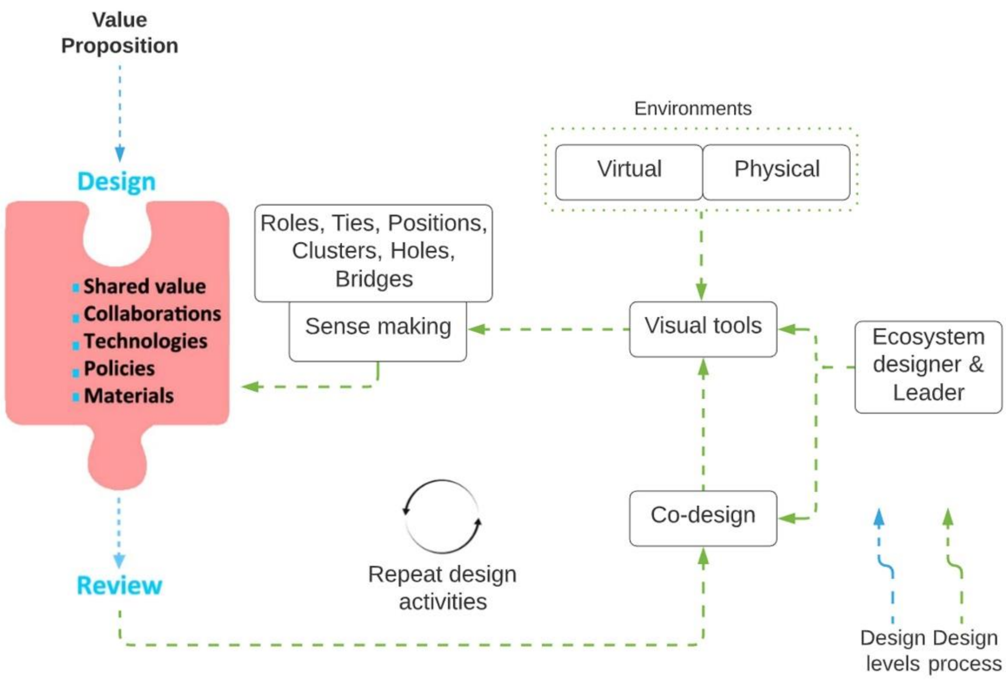


Figure 10.3: Improving the process of designing ecosystems

10.4.3 Reviewing SME innovation ecosystem

Figure 10. 4 shows how ecosystem designers and leaders can use visualisation outputs to review their local ecosystems in a co-design environment (physical and virtual workshops) to characterise ecosystems. At this level, the ecosystem actors need to use visual outputs as rigorous heuristic models to identify roles, ties, positions, clusters, structural holes and bridges emerging or not from the combined visualisations. Figure 10.4 shows how sense-making is connected to reviewing capacity, competition and expansion.

Collaborating with co-designers and ecosystem actors is essential in collective creativity to explore insights from visualisations. This is important at the ecosystem micro-level to review the SME ecosystem capacity, i.e. resources available in the ecosystem, how actors might leverage resources to expand and improve competitiveness, as discussed in chapters 8 and 9. Since the resource-based view focuses more on firm-level capabilities, reviewing ecosystem-level resources, as seen from Botswana workshops, point to critical roles, ties, positions, clusters, structural holes and bridges which can be leveraged to support the understanding of local ecosystem mechanisms (see chapter 8).

As demonstrated from the virtual and in-person workshops, the use of visualisation models in group discussions prompted actors to engage others, in some cases, their competitors. Reviewing ecosystem structures challenged both policymakers and managers in Botswana to appraise how local SME ecosystems are structured. This proved to be a quick and uncomplicated way to see interdependences and make crucial ecosystem decisions.

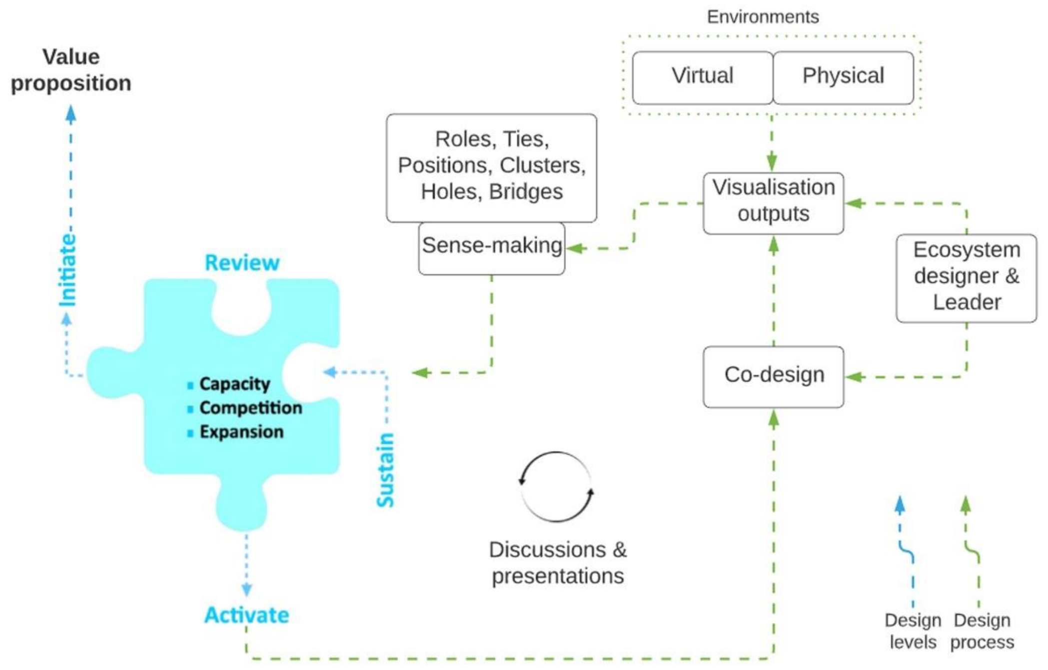


Figure 10.4: Improving the process of reviewing ecosystems

10.4.4 Activating SME innovation ecosystem

Like in the previous design levels, Figure 10.5 shows how ecosystem designers and leaders can use strategies from co-design activities (physical and virtual workshops) to characterise ecosystems (roles, clusters, bridges, holes, ties and position) and activate collective creativity in local ecosystems. This is about using visualisations to identify and prioritise decisions based on collective capabilities. The objective is to interpret the meaning of insights emerging from the review level and motivate ecosystem users, i.e. manufacturing SMEs, community leaders, researchers and others in the community. This level is about activating critical actors, e.g. investors and government authorities, who are motivated to solve the bottom of the pyramid need to understand local ecosystems at micro-levels. Botswana workshops demonstrated the significance of government and private investors to engage in co-design activities with SMEs (chapter 8). This Jigsaw framework empowered actors in the understanding of local ecosystem potentialities through co-creation and visualisations. The significance of this level has been demonstrated in detail in chapters 8 and 9, where actors co-created and shared ecosystem models to guide their understanding of current and future ecosystem structures.

Insights from the online virtual conference discussed in chapter 9 also suggested improvements to the activation level, where the emphasis is now needed in building complementarities and ethical issues in engaging local ecosystems. This also applies to SME ecosystems understanding because researchers and universities are part of the local SME ecosystems. Consequently, their roles need to be in sync with the ethos of the local communities to create shared value. As demonstrated in the co-design workshops, actors need to understand the existing structures and use the heuristic models to develop collective capabilities. All critical stakeholders need to partake in the local ecosystems' activation, contributing to a mindset shift from firm-focused to ecosystem thinking.

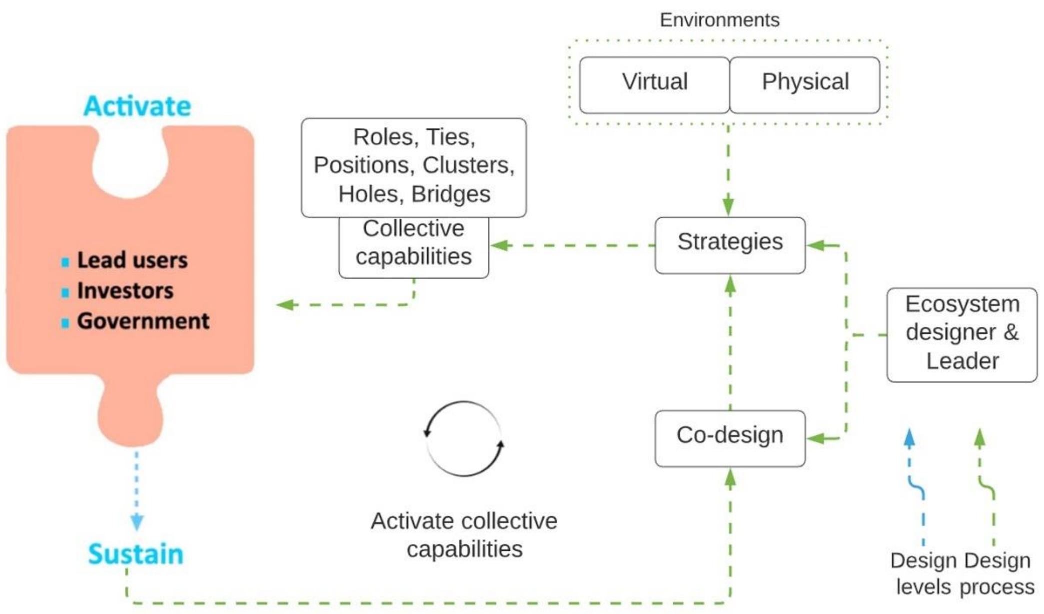


Figure 10.5: Improving the process of activating ecosystems

10.4.5 Sustaining SME innovation ecosystem

Developing sustainable activities using the Jigsaw framework is vital. Figure 10.6 shows how ecosystem designers and leaders can use visualisation outputs to imagine future ecosystem structures in a co-design environment (physical and virtual workshops). Imagining futures include identifying how ecosystems might be configured in terms of roles, ties, positions, clusters, holes and bridges. As shown in Figure 10.6, these ecosystem configurations are connected to ecosystem health, evolution, motivations and survival. This level help SME ecosystem actors in discussing and agreeing on what needs to be done next to build future sustainable ecosystems. This was demonstrated in co-design workshops in Botswana. Some entrepreneurs decided after the workshops to implement the outputs, starting with choosing the experienced entrepreneurs to lead the new strategies. This later culminated into meetups and collaborations with a commercial bank accelerator (see chapter 8). Therefore, this level aims to prioritise roles to drive sustainability objectives, i.e. ecosystem health, positive change, to motivate ecosystem actors and achieve collective survival.

This level is connected to review, as shown in Figure 10.6. This is to ensure continual learning and sharing through the guidance of ecosystem designers and leaders and the use of design tools to redefine shared value, stakeholder commitment and collective capabilities. Although predictive and based on potentialities, visualising future ecosystem models is a plausible process that may aid actors in creating an environment for serendipitous innovation and disruption.

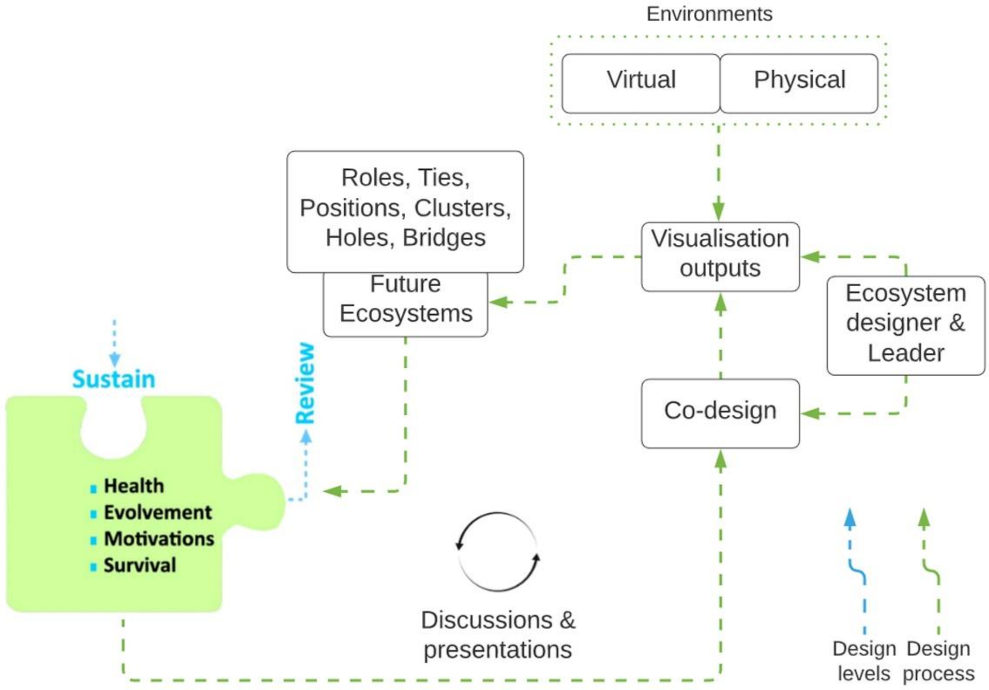


Figure 10.6: Improving the process of sustaining ecosystems

10.5 Chapter conclusions

This chapter discussed "design for disruptive innovation ecosystem" as a new concept about developing a process of understanding and influencing ecosystem configurations through visualising, evaluating, understanding and acting upon opportunities to promote disruption. This chapter also discussed the Jigsaw as a framework to bridge a gap in strategy literature on how interdependent actors can enhance the understanding and activation of local ecosystems to promote disruption. This was achieved by drawing together research on innovation ecosystems, design and visualisation techniques.

As shown in Figure 10.7, by combining the findings from exploratory case studies and design activities reported in this research, the thesis synthesises the expanded Jigsaw framework. The Jigsaw highlights the connection between crucial ecosystem design levels as pieces of the Jigsaw and the design visualisation approach as a designerly process of assembling the pieces to illuminate new knowledge and understanding. The framework integrates the practice of co-design, designers (both ecosystem actors and professional designers), sensemaking activities and dialogue to understand current and future local ecosystem configurations. Therefore, this integration represents a structure that may support the evaluation, understanding and activation of local ecosystems.

Starting the Jigsaw with a shared understanding of criteria and roles from local ecosystems gives participants a space to reflect on their innovation systems and capabilities common to them as a whole. This idea also includes defining a value proposition through a co-design approach, where the professional designer facilitates engagement and ecosystem actors interact with design tools to develop criteria and roles necessary to reframe the local ecosystems. The use of visual models reduces implicit misunderstanding, varied interpretations, and goal conflicts, thus leading to consensus building, trust, and inter-firm connections.

The second Jigsaw piece is characterised by co-creation as a follow-up from a dialogic process. Sensemaking is defined by Klein et al. (2006) as putting effort to understand connections, anticipate and act effectively. As shown in Figure 10.7, sensemaking is the centre of the Jigsaw framework. This process is done on ecosystem mental models generated through a co-design visualisation process and designer involvement. This is done to enhance the understanding of ecosystem attributes (roles, ties, positions, clusters, holes, bridges) and to anticipate and shape future ecosystems. Other authors also found that design can make future ideas tangible (Evans, 2010).

The third Jigsaw piece connects the initiate and design levels with activation and sustaining levels. Reviewing is also about understanding, revising and iterating emerging ecosystem models. The aim is to assess the value proposition developed through the first and second levels by making sense of ecosystem attributes emerging from the visualisation models and discussions. This level involves juxtaposing and aligning conflicting organisational logics using visualisations as rigorous heuristics for new ecosystem knowledge.

The fourth Jigsaw piece is about sensemaking of collective capabilities in local ecosystems. Through ‘what if’ techniques (Stickdorn and Schneider, 2011), discussions at this level focus on what will happen to ecosystem structures and value creation new ecosystem models are activated. To answer these questions, discussions centre around the co-creation of strategies for collective capabilities by combining insights from visualisation outputs, future goals and consensus.

The firth Jigsaw piece is the sustain stage. This is about what the sustainable future of innovation ecosystem might look like. The discussions on collective capabilities are centred around what is possible based on the ecosystem mental models from the previous ecosystem levels. As shown in Figure 10.7, collective capabilities and design strategies shape future ecosystems. At this last stage, discussions focus on resource commitment, prioritisation, and promoting sustainable conditions for disruption.

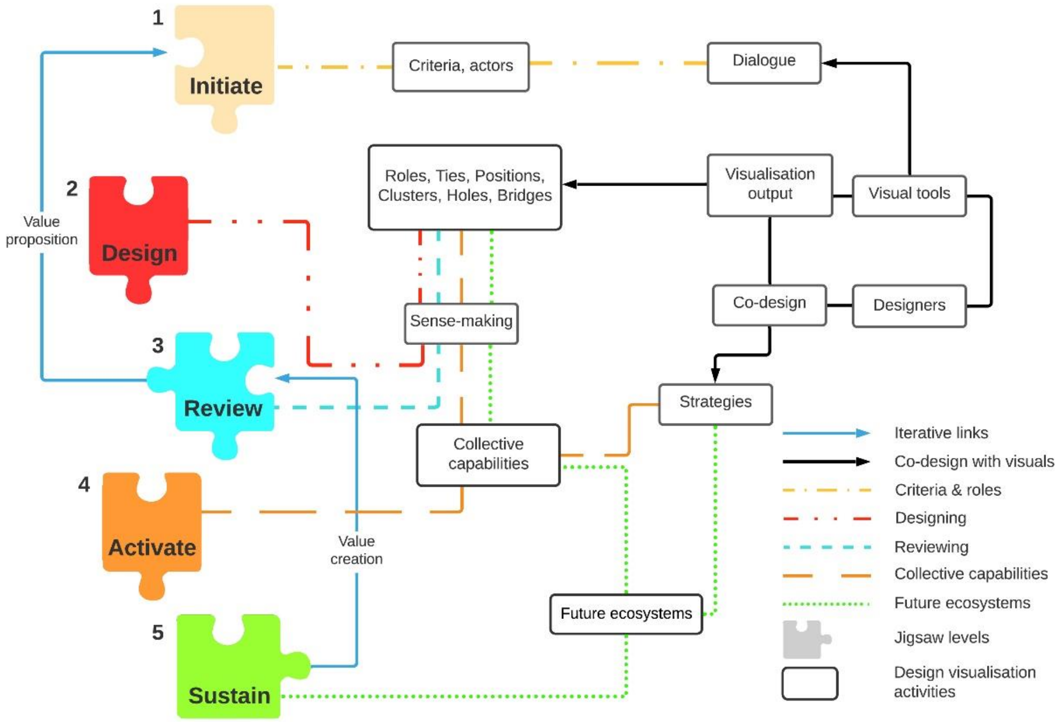


Figure 10.7: Expanded Jigsaw ecosystem design framework for enhancing the understanding of SME innovation ecosystem.

10.5.1 Transferability of the framework

The Jigsaw ecosystem design framework for enhancing the understanding and activation of local ecosystems has been developed and tested through co-design activities. The framework was tested through engagement with manufacturing SMEs, policymakers, researchers and university administrators across seven African countries. The study also tested the framework through an online workshop at the Design Research Society (DRS2020) virtual conference. Although the framework was not initially intended for helping design researchers in understanding their ecosystems, it was highly effective in aiding researchers to engage their research ecosystem structures (Chapter 9). Therefore, the Jigsaw framework supported ecosystem actors to visualise, making sense of and build ecosystem mental models in a designerly way to evaluate and act upon opportunities in their local ecosystem.

10.5.2 Chapter contribution

This chapter discussed a new concept of "design for disruptive innovation ecosystems" as an approach to shape the understanding and configuration of local ecosystems. This was achieved through using design tools to help actors visualise, evaluate, understand and act upon new opportunities in their networks. This chapter also contributes new knowledge to the existing understanding of local SME ecosystems by highlighting contextual factors that shape local ecosystems in both the UK and Botswana contexts. The Jigsaw framework also helps SMEs understand complex interactions between people, firms and sociocultural forces that shape local ecosystems. This framework contributed to practice by aiding manufacturing SMEs, policymakers, researchers and private organisations to convene, dialogue, and model their local ecosystems through collective creativity.

11 Conclusions

In the last chapter, the thesis presented a new concept of “design for disruptive innovation ecosystems”, discussions between the UK and Botswana contexts and the Jigsaw framework. This chapter aims to present the conclusions, limitations and further research. The significance of this chapter lies in highlighting how the thesis has addressed the research questions, major contributions, limitations and further research.

This chapter is divided into seven sections. Section 11.1 provides a synopsis of the major findings of the thesis. Section 11.2 highlights the theoretical contributions of the thesis. Section 11.3 discusses the implications of the findings to manufacturing SMEs, incubators, policymakers and researchers working with SMEs. Section 11.4 highlights the limitations of this thesis. Section 11.5 discusses theoretical generalisability. Section 11.6 proposes the future research direction, and finally, section 11.7 concludes the chapter and thesis.

11.1 Findings

In this section, the thesis presents a synopsis of the findings in line with the research questions outlined in Chapter 1 (pp. 7-8). The thesis briefly outlines how the research questions have been answered to achieve the research aim: developing a design visualisation approach to enhance the understanding of local SME ecosystems in Botswana.

11.1.1 Research question 1

What is an innovation ecosystem, and how does this fit within the manufacturing SME environment in Botswana in terms of contributing to socio-economic development?

Question 1 aimed to explore SME support's status in terms of policies targeted at growing the local SME ecosystem. The findings indicate a poor understanding and awareness of what ecosystems mean in manufacturing SMEs spaces. Although policymakers understand the value of growing local ecosystems, they lack the skills and understanding of developing policies to better address the ecosystemic needs. This was demonstrated in chapter 2 by mapping the policy timeline to demonstrate the government’s efforts towards developing SMEs. The findings show that current policies are less effective in growing SME local ecosystems. The thesis also found a limited understanding of how Botswana socio-cultural factors influence local SME ecosystem structures.

11.1.2 Research question 2

In what ways might local manufacturing ecosystems in SME environments be supported to create shared value?

Question 2 aimed at exploring the growing body of literature around the innovation ecosystem concept and how these might be used to support the understanding of SME ecosystems which may lead to creating shared value and disruptive innovations. Based on the analysis of shared value, disruptive innovation and innovation ecosystems, the thesis proposed a new concept of disruptive innovation ecosystems, i.e., an innovation ecosystem capable of delivering disruptive innovations and how co-design and visualisation methods can be essential in developing local ecosystems in underserved markets. These findings are detailed in chapter 3.

11.1.3 Research question 3

How might insights from decision-makers in 3D printing-based innovation ecosystems in the UK be augmented to support the understanding of the manufacturing SME innovation ecosystem in Botswana?

Question 3 was addressed in three parts; first, it explored 3D printing-based innovation ecosystem cases through engagement with experts in three ecosystem case studies to build an understanding of how ecosystem structures are configured. The project identified critical factors that constitute the understanding and functioning of local innovation ecosystems. Further, the project tested local ecosystem attributes that define ecosystem structures through different opensource visualisation tools. The findings suggested that the FabLab ecosystem was more suitable to promote serendipity for collective creativity and innovation, thus providing more opportunities for interconnected SMEs than in other ecosystem cases. This finding influenced the selection of makerspaces as examples of local ecosystem cases to compare with Botswana incubators. Details of these findings are reported in chapter 5.

Second, makerspaces were explored as examples of local innovation ecosystem cases in the UK through interactions with experienced makerspace owners and some affiliated makers/SMEs. Findings from makerspaces highlighted key themes enabling the understanding of ecosystem structures such as initiating, designing, reviewing, activating and sustaining ecosystems. The study also identified critical factors under each theme to explain the dynamic factors influencing each stage of understanding local ecosystems. Further, this question also identified interventions applied to makerspaces to make them more productive as local ecosystems.

Third, the question further explored how manufacturing incubators as local innovation ecosystems in Botswana might enhance innovation through interactions with manufacturing SMEs and incubator managers. Findings suggested similarities with makerspaces in terms of main themes influencing the design of local ecosystems. However, there were differences in factors that were determined by context-specific dynamics discussed in chapter 7. Combining insights from both the UK and Botswana ecosystems, the thesis proposed the Jigsaw design framework to summarise how ecosystems might be augmented to support the understanding of local ecosystems in Botswana to answer question 3.

11.1.4 Research question 4

How might ecosystem design and visualisation approaches support and enhance the understanding of local SME ecosystem structures in Botswana?

Question 4 aimed at testing and evaluating the proposed Jigsaw framework from question 3 via co-design workshops with manufacturing SMEs, researchers and policymakers in Botswana. Key findings from workshops demonstrated the role of visualisation tools in promoting interconnectedness by aligning ecosystem actor's interests and expectations in shaping the understanding of local ecosystems. This was achieved using co-designed ecosystem visualisation models as heuristics that elicited dialogic interactions between otherwise distant actors. The social relations between the researcher and participants created goodwill that was mobilized to facilitate transformative action in understanding local SMEs ecosystem structures. The findings highlighted important results in relation to the Jigsaw design framework, as detailed in chapter 8.

The value of the Jigsaw was in providing a structure to help SMEs and key stakeholders to understand their interconnections better.

11.1.5 Research question 5

Where could the design visualisation approach be improved to enhance the understanding of local manufacturing SME innovation ecosystems?

Question 5 was addressed in three parts; first, this question tested the Jigsaw design framework in a DRS2020 virtual workshop with design researchers to evaluate the approach with different ecosystem contexts. The findings generated important mental ecosystem models produced in collaborations with participants and the facilitator representing how research ecosystems are configured. The combined output visualisation created dialogue on how ecosystem structures might be enhanced to maximise research output. The research actors used the Jigsaw to think explicitly about future research ecosystems and how they may take active roles to influence future configurations and understanding. Details of the findings are reported in chapter 9.

Second, a cross-case discussion of the Jigsaw design framework based on both the UK and Botswana insights was done to explore different contextual factors. Findings from the cross-case discussions were used to improve the understanding of local manufacturing SME ecosystems in Botswana and how the local ecosystems might be enhanced to create shared value.

Third, improvements were made to the proposed Jigsaw design framework following co-design workshops findings discussed in chapters 8 and 9. The value proposition was added as part of the expanded Jigsaw to signify the importance of actors agreeing on important criteria for ecosystems. The visualisation approach was also added to the Jigsaw design framework to facilitate continual learning through visualisations to initiate, design, review, activate and sustain ecosystems. The design role was added to the Jigsaw framework to emphasise the significance of designerly approaches to understanding local ecosystem configurations, thus emphasising the new concept of design for disruptive innovation ecosystems.

“Design for disruptive innovation ecosystems” is about how ecosystem actors can be supported as form-givers and co-designers to design conditions for disruption innovations in local ecosystems. This approach focuses on visualising, evaluating, understanding and activating new ideas in networks. The findings from co-design workshops indicate that the Jigsaw provide a structure to fragment and characterise theory into real-world ecosystem attributes, which provide actors with a model to evaluate their local ecosystems.

11.2 Theoretical contributions

This research expands on the systems theory, which has argued for strategies to improve the generation of new products, services and business models predominantly from the perspective of the firm’s internal resources. This thesis emphasises and expands the work on the ecosystem-level understanding of interconnected agents, firms, and socio-cultural forces through a practical design visualisation approach. The thesis presents a new concept of “design for disruptive innovation ecosystem” as a process of understanding and influencing ecosystem configurations through visualising, understanding and activating new opportunities in local ecosystems instead of passive participation in designing local ecosystems.

In order to bridge the theory gap highlighted in chapter 1 (p.4-6), this study proposes the Jigsaw framework, which offers five essential design levels for visualising, understanding and activating local ecosystem structures. This includes dynamic factors at each level and how these ecosystem boundary mechanisms might enhance the understanding and activation of productive SME ecosystems. Five levels of the Jigsaw framework are initiate, design, review, activate and sustain. These levels were confirmed to be significant and valid in enhancing the process of creating new knowledge, understanding, and activating local ecosystems in a series of co-design workshops. In this respect, the contribution to knowledge is stated as the Jigsaw framework that enhances the understanding and activation of local SME ecosystems, promoting serendipity for disruptive innovation ecosystems.

Based on the previous literature, design plays a significant role in creating effective platforms to enable diverse actors to collaborate in innovation (pp.35-38). The Jigsaw framework contributes an analytical tool and structure to describe local ecosystems, thus helping actors navigate entrepreneurial ecosystems' complexities.

11.2.1 Role of the context

This thesis found that understanding local ecosystems is significantly affected by context. Therefore, the Jigsaw framework reveals local conditions by convening different actors and visualising ecosystem networks, thus helping actors assess and characterise their local ecosystem structures based on their context and knowledge. In chapter 2, the thesis found that Botswana entrepreneurs lack social and cultural values that were used to bring people together in the past (p.18) to promote connections, sharing and trust in local ecosystems. This is because entrepreneurs in Botswana have different goals, characteristics and often preferring to work alone. The Jigsaw framework brought entrepreneurs together to see the value of collaborations based on their local values.

The Jigsaw framework was also tested with design researchers to evaluate their research ecosystems at the Design Research Society (DRS) conference and other African researchers and entrepreneurs. This approach proved effective in helping actors to assess their contextual conditions affecting ecosystem growth. Therefore, although the framework was designed for helping manufacturing SMEs, it proved effective in different contexts to describe innovation ecosystems. This is a key contribution to frameworks for understanding innovation ecosystems.

The thesis also contributes an exploratory approach to qualitative data through opensource visualisation tools. Using empirical data and visualisation methods provide an accessible way to search for hard-to-find ecosystem characteristics.

11.3 Contributions to practice

Throughout the development of the Jigsaw framework, this thesis claims to have contributed to manufacturing SME ecosystem understanding, particularly in Botswana. This thesis design output led to developing a memorandum of understanding (MOU) between Imagination Lancaster and the Stanbic bank, Botswana Accelerator. This is an initiative to support entrepreneurship in Botswana. When asked about how the knowledge gained during this research has influenced their thinking so far during a follow-up impact review, some SMEs said the following:

> *"It has given me a broader perspective on ecosystem actors and the importance of these actor's relationships in building a vibrant and sustainable SME ecosystem. This has allowed me to rethink and adjust plans on how to communicate and address ecosystem bottlenecks and challenges through strengthening weak network relationships and seeking room for collaborations instead of competing in some cases." (Innovation hub-SME)*

> *"Since your interventions, I am happy to say that the design approach to SME ecosystems project you did change the way I look at ecosystems. The approach was practical, and we are now applying most of this knowledge and interventions to grow the SME ecosystem. The approach broke down areas to problem solve and seemed to relate easily to matters in hand." (Incubator-Manager)*

> *"I find that your research work on the entrepreneurial ecosystem is materially useful, particularly its context to Botswana whose ecosystem is still finding its feet. Given that the country is still trying to build a solid ecosystem to ensure a successful platform, this research work being one of the few in the space locally and possibly the only one would help add reference material to space." (Stanbic bank acceler8)*

Below are some ways the Jigsaw framework might further contribute to the local manufacturing SME ecosystem.

11.3.1 Manufacturing SMEs and incubations

This thesis claims that the Jigsaw framework can benefit manufacturing SMEs and incubators in Botswana in the continual learning and design of their local SME ecosystems. The framework provides a structure as a starting point to guide local ecosystem actors and incubator managers on engaging each other and reaching their potential. The framework suggests key factors and interventions that SMEs and managers may need to enhance their ecosystems, and this area has been blurry in practice.

11.3.2 Policymakers

The thesis claims that the Jigsaw framework can contribute a structure that policymakers in innovation might use to engage manufacturing SMEs to understand the local innovation ecosystem better. This is important because policymakers in developing economies often lack the tools to understand local ecosystems and engage various stakeholders, e.g. SMEs, funders, researchers, and managers.

11.3.3 Researchers

This thesis is important to the research community in many ways. First, it uses case studies from a developing economy, thus providing new perspectives on how the under-researched environment shapes local innovation ecosystems. This extends the limited body of knowledge on manufacturing SMEs ecosystems in developing countries. Researchers who wish to understand how local ecosystems are shaped may use the framework to further develop their contextual knowledge. Second, researchers interested in designing innovation ecosystems in their contexts may expand the Jigsaw framework to suit their contextual needs. This is important to capture the needs and expectations of interdependent actors. The Jigsaw framework highlights the relationship between the innovation ecosystem and design practice, thus providing a meaningful approach to understanding local ecosystems' mechanisms.

11.4 Limitations of the study

Although the thesis has successfully achieved its intended objectives by answering the posed research questions, it is vital to highlight some research limitations.

11.4.1 Sample size

The total number of semi-structured interviews was 31, i.e. 12 in the UK and 19 in Botswana. The study also conducted four co-design workshops, three in Botswana and one virtual international workshop. This sample was limited to the UK and Botswana context only, except during the validation workshops where participants from seven African countries were involved in testing the framework. Using different contexts would have provided the research with more depth and diversity given more time and resources.

11.4.2 Research approach

This research followed a qualitative approach by imploring a case study design. Considering the advantages of using a mixed-method approach, it would have been more plausible to use other quantitative approaches such as surveys to triangulate the findings further. However, given that this was an interpretive study that emphasised more on depth than the breadth of coverage (Yin, 2009), the case studies were investigated through semi-structured interviews and exploratory visualisations. Also, because there was a limited theoretical understanding of local SME ecosystems, a qualitative research approach seemed more appropriate to explore the depth of how manufacturing SMEs understand their local ecosystems.

11.4.3 Research methods and access to data

Since the study was investigating local ecosystems by asking questions related to participants' contacts and relationships, this proved problematic in some areas, thus leading to irrelevant data being collected. Some participants were unwilling to share data with the researcher, especially the makerspace users in the UK. Therefore, most of the information obtained from the makerspace users was not included in this thesis because it was considered informal and not relevant. Using data from focal actors, e.g. makerspace owners, SME owners, may have limited the scope of the findings.

However, the use of visualisation tools helped to collect relational data on ecosystem actors. Although visualisation methods helped triangulate the qualitative data, this was based on the participant's perceptions and point of view. It would have been better to get other ecosystem actor’s views on the local innovation ecosystem, although this was not feasible due to limited time and resource constraints.

11.4.4 Data Analysis

The data were analysed through thematic and visual network analysis. Both the processes were subjective and mostly influenced by the researcher's decisions. Qualitative research is criticised for been biased and less rigorous by other groups of researchers, as highlighted in (Creswell, 2009; Miles and Hubberman, 1994; Bryman, 2008). Negative researcher bias was, in part, addressed by engaging a second coder during the analysis of interviews. Further, the study also implored three visualisation methods to analyse the ecosystem datasets. Engaging design researchers, manufacturing SMEs, policymakers and other stakeholders during the design and validation of the framework also checked the negative bias of the researcher.

Considering the above limitations, the strength of this thesis lies in the depth, richness and co-designed framework that contributes a practical and explicit approach to understanding local ecosystem structures. Through the Jigsaw framework, the study provides a new way of engaging ecosystem actors to co-create the understanding of present and future ecosystem structures.

11.5 Generalizability of the research findings

Generalizability is conceptualised in different ways in the literature. The most common conceptualisations are i) generalising to the population and ii) theoretical generalizability (Allen and Richard, 2012; Yin, 2012; 2014). According to Allen and Richard (2012), generalising to a population applies to statistical inquiries, thus not relevant to this study. Under theoretical generalisability, the aim is to generalise a specific theory to a specific set of settings (Allen and Richard, 2012). This type of generalisability is often applicable to case study research (Yin, 2014). Therefore, this study generalizes the Jigsaw framework to local SME ecosystems involving manufacturing SMEs, policymakers, Universities, and researchers under which it was tested. As such, caution must be exercised when applied to other settings besides these.

11.6 Future research

Given the study's limitations, further work is now needed in testing the framework with other innovation ecosystem settings to develop it for applicability in different settings. In this regard, the following actions are proposed:

- To continue applying the Jigsaw framework with manufacturing SMEs in Botswana to build the local ecosystem by fomenting a partnership between Lancaster University and a commercial bank accelerator project. This project is ongoing.
- Further work is also needed in developing a dynamic tool to capture both qualitative and quantitative data on the activities of the local ecosystem. This was suggested by the manufacturing SMEs to enable continual learning of the dynamics of ecosystem structures.

- More work is also needed in engaging diverse ecosystem actors to refine the Jigsaw framework for applicability in other settings. This can be achieved by testing the framework with diverse users to make it flexible and customisable to any form of innovation ecosystem setting, e.g. connected healthcare systems.

- To support work in digital platforms, more research is now needed to transform the Jigsaw framework into a software application to be used digitally to support data visualisation and sharing. Ecosystem actors may also use the application to communicate decisions that affect all key ecosystem stakeholders in real-time.

11.7 Conclusions

This thesis has contributed to understanding local manufacturing SMEs innovation ecosystems in Botswana, where there is limited knowledge of local ecosystems. This was achieved by exploring and identifying key factors that influence the understanding of local SME ecosystems. The thesis also developed the Jigsaw framework to help ecosystem actors visualise, understand, and activate opportunities for entrepreneurship. The growing notion of ecosystems now influences innovation. As the world gets more connected, understanding these interconnections and interdependent networks of firms, people and settings is increasingly becoming crucial to local and regional innovation strategies.

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13 Appendices

Appendix 1 Business model Interdependencies (Sánchez and Ricart, 2010)

	Isolated business model	**Interactive business model**
Main actors in the interdependencies	The competitors, either local or global, are influential actors in the business model configuration	Fringe stakeholders are participative actors in the configuration and implementation of the business model
4. Intensity of the interdependence	5. High with competitors 6. Low with complementers	7. Low with competitors 8. High with complementary actors
Nature of the interdependencies	Negative-competitive character	Positive- cooperative character
Effects on the ecosystem	Incremental improvements due to more efficient systems of manufacturing and distribution	Systemic changes due to the introduction of, or connection between, new actors, new technologies and new incentives that alter actors behaviour Positive impact on development thanks to the interaction with fringe stakeholders and local partners
Underlying behaviour	The firm individually identifies and exploits the opportunity as fast as possible. Company choices are focused on activating as quick as possible the virtuous cycles of its own business model	The firm creates the opportunity jointly with local actors and partners through an iterative learning process. Company choices are focused on activating the virtuous cycles from its partners as mechanism to activate its own virtuous cycle

Appendix 2 Selecting data collection methods

Methods	Features	Function	Suitable	Feasible	Comments	Decision
Interviews	Unstructured and open-ended questions to small samples	Understanding experience and perceptions by asking questions	✓	✓	Interviews are suitable and feasible to use because they can be applied to small cases. Data can be gathered in a short period of time and requires less logistics.	✓
Websites and Documents	Setting materials	Understanding settings structures, technology and business.	✓	✓	Websites and Documents will be used where possible to get relevant data through permits.	✓
Observation	Observing processes in a setting	Understanding interaction between people and	X	X	Observations are not feasible and suitable for	X

		systems			studying ecosystems.	
Audio & video recording	Recording conversations and interviews	Audio record of interactions	✓	✓	This is a suitable way of keeping recordings during data gathering.	✓
Workshops	Getting opinions from a small group of people through a workshop.	Draw respondents' attitude, feelings beliefs, experience and reactions.	✓	✓	Workshops are suitable in gathering data on feedback from participants	✓
Visualisations	Visual structures of ecosystem actors	Understanding other stakeholders connected to the focal actor	✓	✓	Visualisation mapping is suitable to co-create connections with focal actors	✓

Appendix 3 Selected cases for phase 1 project

Ecosystem Cases	No of People Interviewed	Position	Interview (Mins)	Main product manufacture	Experience (years)	Focus
1. Artists	2	Owners	65	Ceramic manufacturing	10	Ceramic 3D printing
2. FabLab	1	Co-founder & director	60	Fabrication laboratory/space	12	Digital fabrication tools
3. 3D printing bureau	1	Co-founder & director	60	3D printing bureau service	10	3D printing of various things

Appendix 4 Semi-structured interview protocol for phase 1 project

Research Introduction

Thank you for agreeing to meet with me today. I have us scheduled for 1 hour together. Does that still work for you? As you may already know I am a PhD student researching on innovation ecosystems at Lancaster university. This interview aims to understand your innovation ecology. How you understand your innovation ecosystem structure. During the interview, feel free to share and elaborate on any information you deem necessary.

Semi Structured Interview Questions

1. Opening questions

Before starting the interview, would you please tell me a little about yourself, name and affiliation?

What are your main roles and responsibilities in the company?

2. Project Questions

What do you understand by ecosystem/innovation networks?

Prompts: connecting with other firms, co-creation, collaborations

Do you feel part of an innovation ecosystem?

Prompts: do you your connections, networks, partners around you

How do you initiate ecosystem relations with others?

Prompts: forms of exchange, co-working, co-experiments, workshops

How do you identify key ecosystem actors?

Prompts: friends, conferences, exhibitions, online

How do you understand ecosystem shared value?

Prompts: giving back to community, sharing resources amongst firms, community projects

What is the role of technology in helping you to co-create with others?

Prompts: digital technologies value, access to new technologies

How do you expand your networks to reach more resources to support your innovation?

Prompts: Collaborations, network events, workshops

How do you manage ecosystem relations and actors?

Prompts: Data, privacy, power relations

How do you sustain your relations?

Prompts: Niche actors, evolving relations, motivations

What are the threats in your relations with stakeholders?

Prompts: uncertainties in ties, end of relations

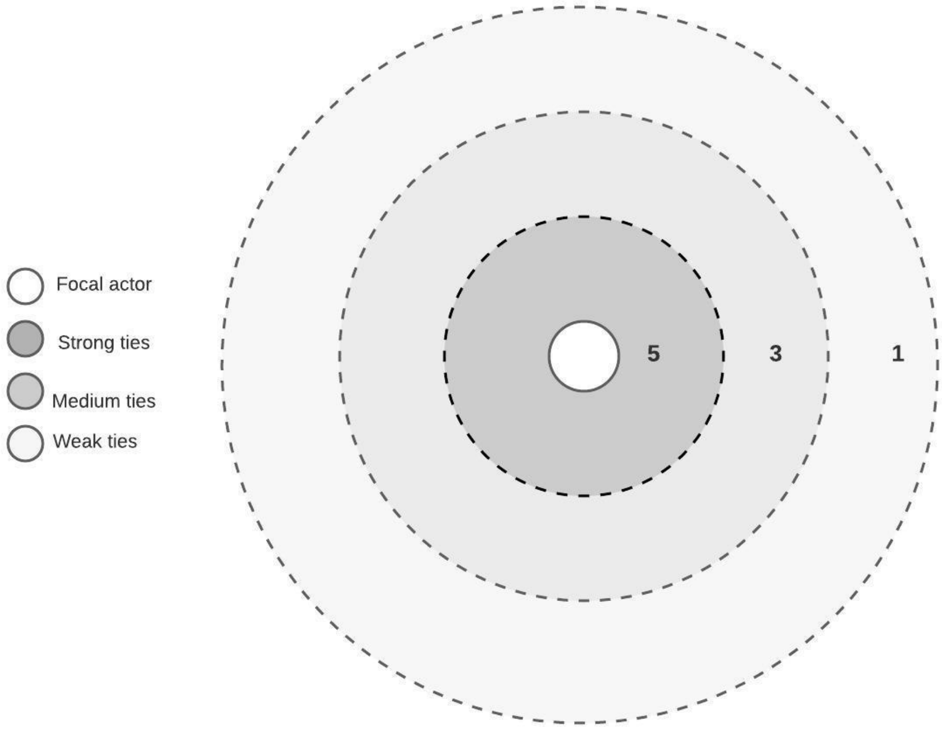
3. Closing Questions

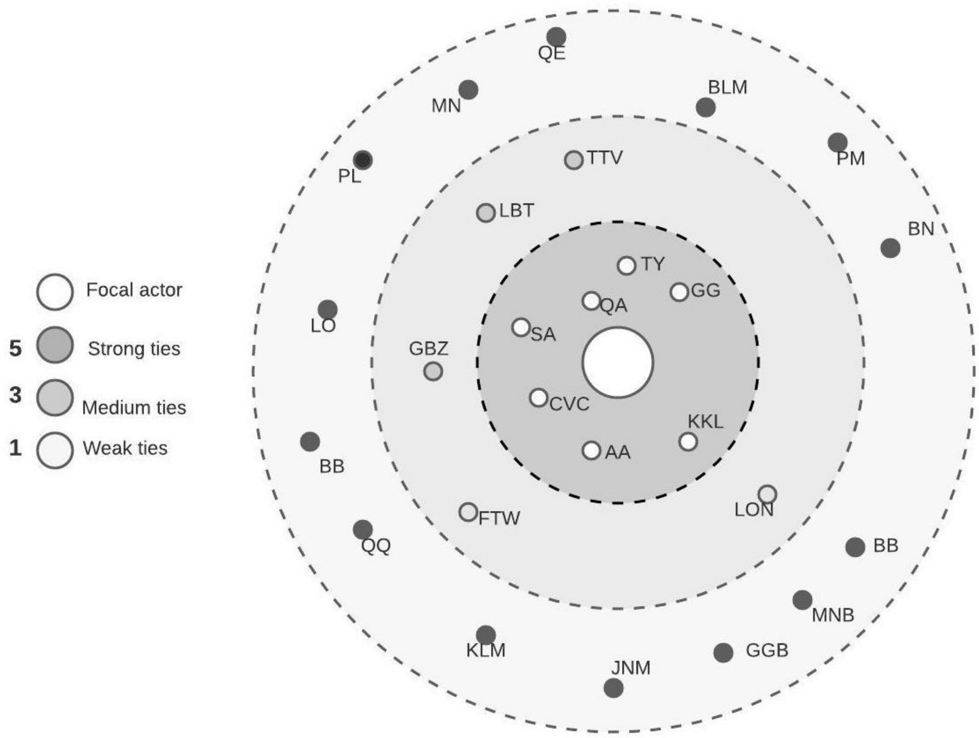
How do you see ecosystems affecting your innovation processes in the future?

Do you have any questions regarding the interview?

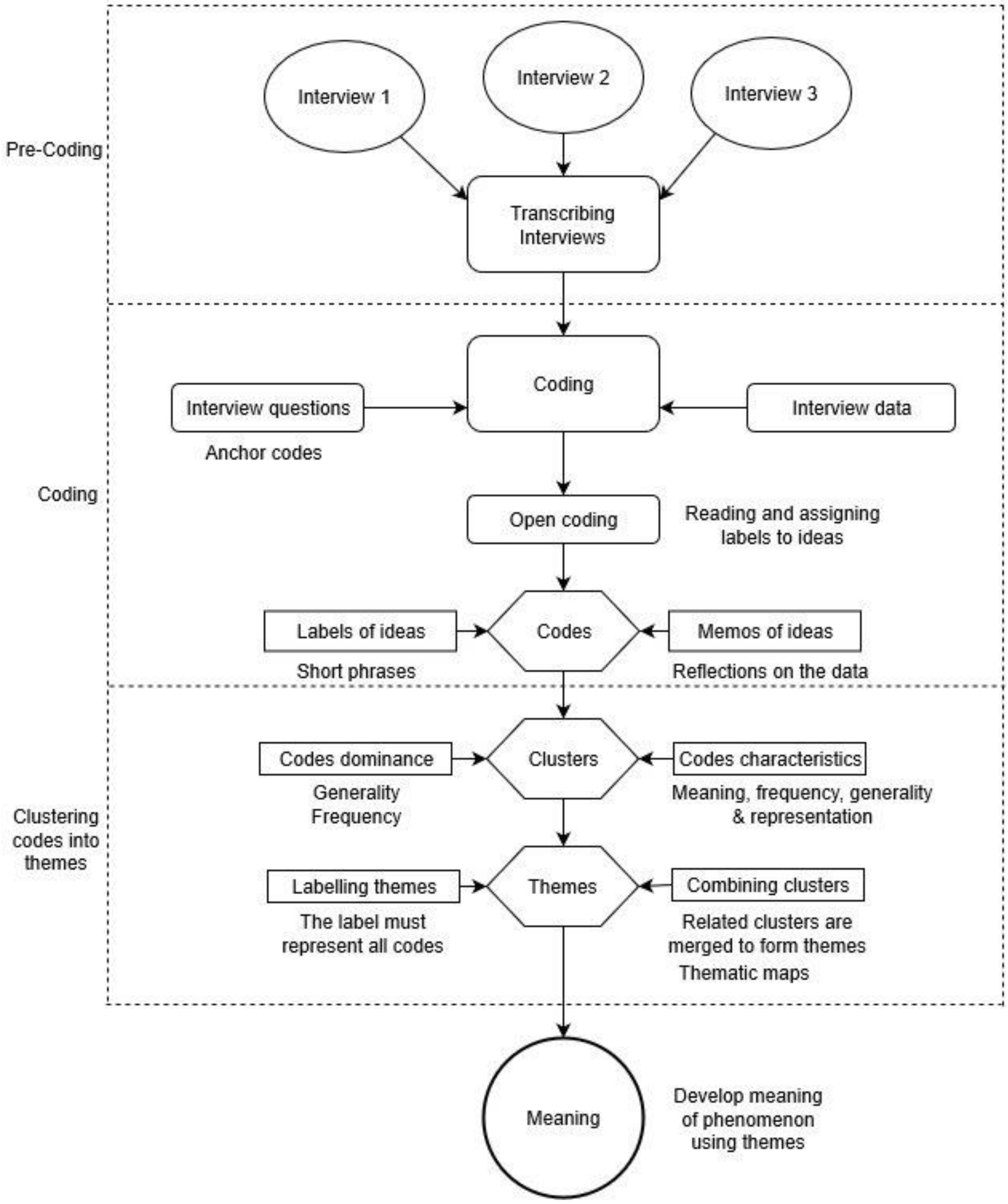
Thank you for your time and efforts

Appendix 5 Mapping tool





Appendix 6 Thematic analysis structure



Appendix 7 Example of some initial codes with descriptions from the conceptual framework and pre-coding of transcripts

Initial Codes	Description
Initiating a value proposition with other actors	This code is about sharing the same understanding of value creation and appropriation by ecosystem actors
Enabling trusting relations	This code is about enabling trust as a key factor in promoting social capital amongst interconnected actors reducing costs associated with legal contracts.
Tolerating other actors	This code is about having tolerance to diversity within the ecosystem to promote innovation.
Sharing data across firms	This code is about shairng data with actors located outside actors firms.
Promoting emergence of relations across firms	This code relates to activities that promote connections between distant actors in the ecosystem.
Shared visions	This code relates to actors having the same goals and aspirations to create and share the value
Experimenting with others	Actors engaging in tinkering and experimental activities to try out ideas.
Coopetition	This code is about promoting more cooperation in innovation activities.

Appendix 8 Summary of the selected makerspace participants

Space Pseudonyms	No of People Interviewed	Position	Interview (Mins)	Spaces	Size	Year of establishment	Focus	Location
Space-A	1	1 x Co-founder	120	Makerspace	More than 10k participants every year	2011	Software and internet of things	Liverpool
	1	SME artist	20	Makerspace	7 employees	2016	Weddings and decorations	
	1	SME packaging	20	Makerspace	5 employees	2017	Packaging design & man	
Space-B	1	1 x CEO & Co-founder	60	Maker space	More than 15k participants every	2009	Project & delivery based digital fabrica	Manchester

					year		tion tools	
	1	SME	15	Makerspace	freelancing	2013	Jewellery	
	1	SME	25	Makerspace	3 members	2012	Automotive parts	
Space - C	1	1 x Ecosystem manager + 2 x SMEs actors	60	Incubator & makerspace	**-**	2012	Business incubation and makerspaces	Manchester
	1	SME	20	Makerspace	3	2017	Digital manufacturing start-up	
	1	SME	15	FabLab	2	2018	3D printing bureau	

Appendix 9 Summary of the selected Botswana manufacturing SMEs participants

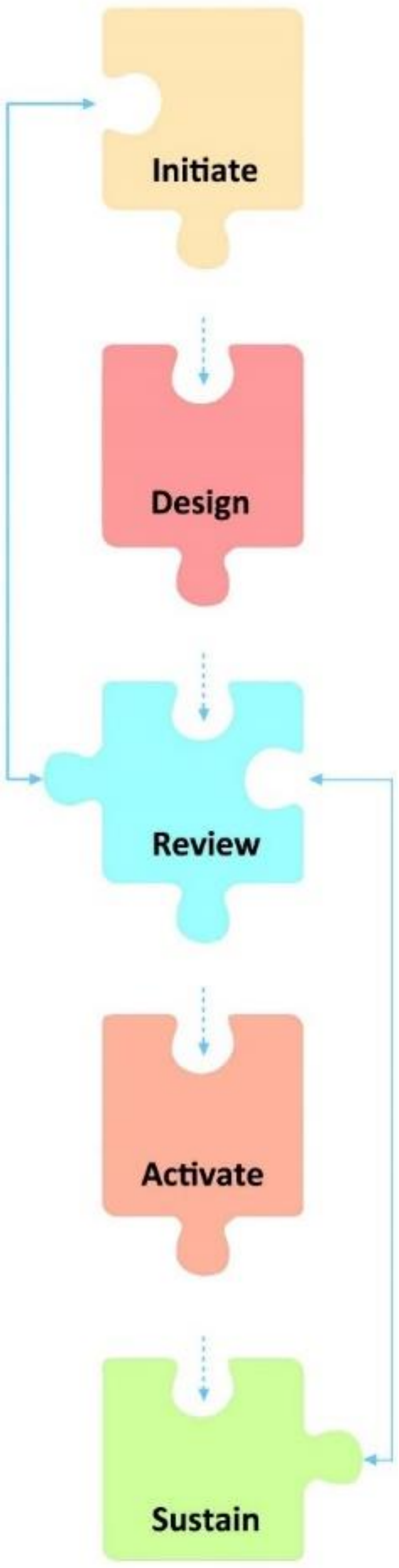
SMEs Pseudonyms	No of People Interviewed	Position	Interview (Mins)	Spaces	Age Range	AM Awareness (Years)	Main product manufacture
SME-A	1	Owner	60	Leather Incubator	20 - 35	5	Handcrafted products
SME-H	1	Manufacturer	60	Leather Incubator	36 - 50	0	Shoemaking
IM-A	1	Technology Executive manager-Leather	60	Leather Incubator	36 - 50	1	LEA leather incubator manager
SME-I	2	Owners	30	Leather Incubator	20 - 35	1	Bags, shoes and upholstery
SME-J	1	Owner	30	Leather Incubator	20 - 35	0	Leather bags
SME-N	4	Directors	60	Leather	36 - 50	0	Furniture

				Incubator			
SME-B	1	Marketing	30	Multi-sector Incubator	20 - 35	0	Blinds
SME-G	2	Marketing and Manufacturer	30	Multi-sector Incubator	20 - 35	2	Engraved products
SME-C	1	Owner	35	Ceramic Incubator	20 - 35	0	Ceramic products
SME-D	2	Owner and worker	60	Ceramic Incubator	51 - 70	0	Ceramic products
SME-O	1	Director	60	Ceramic Incubator	36 - 50	0	Ceramic products
SME-E	1	Owner	30	Standalone	51 - 70	0	Auto parts
SME-K	1	Owner	30	Standalone	20 - 35	0	Leather supplier
SME-L	4	Owners	60	Standalone	36 - 50	0	Roof sheets

SME-M	1	Founder-Director	35	Standalone	51 - 70	0	Beads
SME-P	1	Owner	35	Standalone	20 - 35	0	Couches and chairs
SME-F	1	Owner	35	Visual arts Incubator	20 - 35	0	Metal weaving & sculpture
IM-B	1	Coordinator	30	Visual arts Incubator	51 - 70	0	Incubator manager
SME-Q	1	Owner	35	Visual arts Incubator	20 - 35	0	Cloths

Appendix 10 Jigsaw ecosystem design framework

Initiate- Participants were asked to think about their main criteria for engaging or wanting to engage in ecosystems and then to think about their stakeholders, whom they collaborate with or trying to connect.



Design- To start designing positions and links in the ecosystem, participants were asked to think about stakeholders and where they are in the ecosystem and what each entity is trying to achieve using visualisations. To explore past, present and future stakeholders and their relationships, thus giving a clear picture of the ecosystem shape.

Review- To review design decisions, in terms of strength of ties, stakeholder's positions and roles, what actors are trying to achieve and what resources (materials, technologies) are available to them. To analyse the visualisation outputs for uncertainties such as empty segments, weak and strong ties. To discuss the gaps and revisit the initiation process.

Activate- Discussions amongst stakeholders on how the ecosystem design can be implemented. This was more of positioning themselves in the future and imagining what critical roles (e.g. investors, local councils, government) needed to be activated first to nurture the ecosystem, what value exchanges might emerge through new ties.

Sustain- Discussion amongst participants on how they could pursue some of the niche roles to grow the ecosystem and sustain it. To review the ecosystem for inefficiencies and align new actors, promote interactions and co-innovations to make the ecosystem healthier.

Appendices 11 Summary of workshop visualisation findings (A to I)

A

Participants	Categories visualised			
	Weak ties	Strong & medium ties	key roles	Shared criteria/values
HM	Investors and funders, TV, Radio, Research, mass production, international markets	LEA, Social media, Government, Technologies	Marketing partners, suppliers, new technologies	Skills development, funding, innovation, suppliers, production, innovation
WP	No weak ties mapped	Suppliers, self-funded, tools and materials, furniture shops	Distribution partners, funders/investors	Community service, funding, skills development, materials, suppliers
HL	Radio, TV, newspapers, funding bodies	Customers, shopping malls, marketing online platforms, suppliers	Distribution partners, marketing partners	Suppliers, workforce, customers, funding, markets

LTL	Products Standardisation, technologies, research centre	LEA, Media,	Suppliers, research and technology	Skills development, branding, funding, suppliers, customers
TF	No weak ties mapped	Local suppliers, City Council	Funding partners, Gender affairs	Community service, funding, skills development, workforce, publications
XX	No weak ties mapped	LEA, Suppliers, equipment, funding, technologies	New technologies	Technologies, funding, workforce, materials
MT	Did not do individual mapping	Did not do individual mapping	Did not do individual mapping	Did not do individual mapping
MF	Radio, private sectors, online platforms	LEA, suppliers, customers	Incubation centre	Profit, skills development, funding, marketing, suppliers
ITR	No weak ties mapped	Government, LEA, banks,	Government, LEA	Community service, funding, skills

		interns		development, workforce, publications
TSL	No weak ties mapped	Chain stores, community, local suppliers, technical colleges	Retail stores	Materials, suppliers, funding, skills development, community service

B

Categories Visualised	**Ecosystem participants**									
	HM	WP	HL	LTL	TF	XX	MT	MF	ITR	TSL
Funding partners	No	No	No	Yes	No	Yes	No	No	No	No
Marketing partners	Yes	No	No	Yes	No	Yes	No	Yes	No	No
Own role	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Key roles	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No
Supply partners	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No

Less connected	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No	No

C

Groups	**Categories visualised**			
	Weak ties	Strong & medium ties	key roles	Sustain
GRP-A	Suppliers, TV, radio, print media, BITC, Dept of Youth, CEDA, banks, corporate clients, Government, international markets.	LEA	Training, social media, tourists, suppliers	Access to funding (group application), accessing markets as a group, sharing clients to provide diversity, outsourcing work within ecosystems, sharing data.
GRP-B	Colleges, TV, billboards, CEDA, MYSC, Local councils, international suppliers.	Local suppliers, SA suppliers, LEA, online platforms, radio, expos	Skills development, advertising, suppliers	Bulk buying, clustering, joint advertising, sharing tools, skills exchange.
GRP-C	TV, radio,	Local	Skills	Access to funding

	newspapers, print media, CEDA	suppliers, social media, Dept of youth, customers	development, funding, suppliers	(group application), working with colleges

D

	What is an innovation ecosystem?	Do you feel part of an innovation ecosystem?	What's the value of innovation ecosystem to you?
P1	When organisations combine resources to create new products and services.	But I don't feel part of an innovation ecosystem now	In sharing resources such as tools and data that I don't have.
P2	I really don't understand much about innovation ecosystems	I don't feel part of it either	Did not say anything about value
P3	I don't know much about it	I don't feel part of it	I can benefit from it by accessing new information from other organisations.
P4	I think it is to do with working with other firms to co-create products.	Currently I don't feel part of an innovation ecosystem	But I believe its value may be in sharing expertise, equipment and tools

P5	It is about interdependences on other researchers for me.	I feel part of the research ecosystem because I am collaborating in my research work.	Yes, its valuable because I participant in interdisciplinary research.
P6	It's about networks	I am experiencing it now because I am in an ecosystem of researchers and policy makers	Knowledge exchange

E

Countries	Categories visualised			
	Weak ties	Strong & medium ties	key roles	Shared values
BW	Research grants, external funding, innovation funds, local councils, SMEs, international markets, regional networks	Government, BDF, BITRI, LEA, mining industry	Marketing partners, suppliers, new technologies, funding bodies, community partnerships	Quality graduates, co-delivery of programs, funding, equipment, partnerships, collaborations, raw materials, suppliers
ZN	Government funding,	Local councils, mining industries,	R&D funding, private sector	Skills development,

	Government R&D, SMEs, private sectors, communities	infrastructure, international donors	engagement.	Infrastructure, funding, partnerships, solution uptake
NG	New markets, commercialising research outputs, forming research partnerships, Innovation funds	No strong ties mapped	Innovation in markets, commercialising research, forming research partnerships, Innovation funds	Partnerships, funding, market access, policies, research commercialisation
ML	Private sector organisations, Government, international donors	Local universities, research centre, mining industry	Private sector engagement, Government policy	Funding, partnerships, consultancies, capacity building
UG	Commercialising research outputs, new markets, partnerships, innovation funds	Research administration	Commercialising research outputs, new markets,	Partnerships, funding, market access, policies, research commercialisation
KY	Government funding, local communities, Private sector, research institutions	Universities, NGOs, SMEs, DFID, world bank, corporates, international donors	Government funding, local communities, Private sector	Funding, partnerships, consultancies, capacity building
MZ	Government	International	R&D funding,	Skills

	funding, donors Government R&D, SMEs, private sectors, communities		private sector engagement, communities.	development, Infrastructure, funding, partnerships, solution uptake

F

Groups	Categories visualised			
	Weak ties	Strong & medium ties	key roles	Sustain
GRP-1	Local councils, SMEs, External funding, BIH fund, HRDC fund, partnerships, Government R&D funding, private sector	Government, BDF, BITRI, BHP, BUAN, Industrial attachments, teaching staff, mining.	R&D funders, Local councils, partnerships, private sector	Access to funding through partnerships, private sector engagements, partnering with local authorities
GRP-2	Universities, Innovation centre, SMEs, research centres,	LEA, Barclays bank, Mining companies	Research partners, mining sectors	To partner with mining companies in terms of R&D
GRP-3	Media, high impact journals,	Community partnerships	R&D funders, policy makers	SMEs to partner with the innovation centres

	World bank, external funders, internship programs, Government, suppliers, innovation funding, policy makers			and Government in R&D. Government to provide funding
GRP-4	International funding, research partnerships, private sector, universities, Government. Private sector	Strong international donors, NGOs, World bank	R&D funders, private sector partners	Co-application of international funds, R&D partnerships
GRP-5	Governments funding, communities' engagements, private sectors, universities collaborations	International donors	University Resources, funders	Leveraging resources across the institutions in SADC region,
GRP-6	SMEs support, Universities, research centres	Government funding, international donors, Local communities	Funders, research collaborations	Supporting SMEs, engaging in research collaborations
GRP-7	Universities administrators,	Policy makers	Funders, university	Universities to collaborate with

	innovation centres, funding bodies		partnerships	innovation centres and funders.
GRP-8	Institution to institution relations, institution to research centres relations, external funding	Private sector, civil society, ICT	Institution partnerships, R&D funders	Working across borders in Africa in terms of commercialisation and partnerships.

G

Categories Visualised	**Innovation SMEs**																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Funding partners	Yes	No	No	Yes	No	Yes	Yes	No	No	Yes	-	Yes	No	Yes	No	Yes	-	No	Yes	No
Marketing partners	No	No	Yes	Yes	Yes	Yes	Yes	No	No	No	-	Yes	No	No	No	No	-	No	Yes	No
Own role	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	-	Y	Y	Y	Y	Y	-	Y	Y	Y

	es	es	es	es	es	es	es	es	es	es		es	es	es	es	es		es	es	es
Key roles	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	No	Yes	-	Yes	Yes	Yes
Skills dev	Yes	No	No	Yes	No	No	Yes	No	No	No	-	Yes	No	No	No	No	-	No	No	No
Less connected	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No	-	Yes	Yes	No	Yes	Yes	-	Yes	Yes	Yes

H

SMEs	**Categories visualised**			
	Weak ties	Strong & medium ties	key roles	Shared values
KE	Ministry of Tertiary Education, Ministry of trade, Office of the President.	Self-funded, international funders	Explore relationships with Ministries.	Data & information, Innovation, Policies, Funding, Markets
SA	Ministry of trade, industry, BITRI, Land boards	Self-funded, markets, BIH, Ministry of Education	Industry and BITRI	Funding, policies, land, technology adaptation, markets

SBW	CEDA, BIH, Ministry of Youth, sprint couriers, Botswana post, 3G mobiles, Sefalana stores	Private investors, banks, DHL, FEDEX, Government, students, Alibaba	Courier services to increase distributions channels	Funding, Service providers, Markets, Internal environment, Competition
LAM	Government business, Policies	Self-funded, Youth development fund, tourism industry	Pursue Government departments to support his business	Education, funding, markets, Price, Support
SSB	Government policies, Corporate firms, Ministry of Youth, banks and CEDA, publishing co, radio, other ministries,	Self-funded, individual customers,	Identify funding partners, advertising partners and develop links with Government departments.	Business environment, Investment, Funding, Advertising and marketing, Sales and customers
MI	Venture capital, grant agencies, advertising, universities, Government entities, international markets	Self-funded, workshops, other SMEs, BIH	Markets and local institutions.	Opportunity/access, Skills development, funding, education, networks/collaborations
TN	Youth development Fund, CEDA, Government dept,	Self-funded, Forestry department, BIH, LEA	Access the Youth funds, link with Government dept.	Policy support, funding, collaborations/mentoring, markets, facilities

	BITRI and BIUST			
MH	BIH fund, Stanbic bank, University graduates, remote workers, BITC, Government Dept, International markets	Investors, Online learning skills, data policy, Parastatals		Funding, Open source, skilled workers, policy, Business opportunity
LBN	CEDA, NDB, transport, laboratory space,	Youth development fund, BIH, tutors	Space for laboratory work.	Skills development, funding, Transport, Office space.
CBH	Commercial banks, Mining companies, Radio, Youth development fund, BIH fund	Self-funded, Social media, Progressive Institute, BIH	Access the youth fund, BIH fund and explore markets through radio.	Social corporate responsibility, partnerships, markets, skills development, funding
SL	Government dept, International markets, BITC, Local institutions, Corporate firms,	Other SMEs, BIH space, social media	Finding international markets through BITC, look for markets in private firms	Influence, collaboration, markets, skills and knowledge, branding
PSHT	Local institutions, R&D funders, retail stores, salons	Self-funded, BIH space,	R&D partners and links with local retail stores	Mentoring & skills development, research and development, funding, distribution channels, suppliers

LH	Youth development fund, BIH fund, international funders	BIH space, Botswana television, radio and orange Botswana, Local institutions, social media	Access the youth fund, BIH fund	Products, partnerships, funding, team, marketing
RC	AGOA traders, Investors, Government grants, BIH, Government policy	Self-funded, Marketing partners, USAID, Botswana telecoms, coffee wholesalers, local industries, workshops, trade fairs	Access the youth fund, trade international.	Markets, funding, skills development, networks, industry establishment
OT	NDB, CEDA	Self-funded, Siemens, Mauritius suppliers, local raw materials, Sprint couriers, Gaborone private hospital, pharmacies, SADC	Access to funders	Reagents, funding, raw materials, transport, markets.
MOE	LEA, CEDA, youth development fund	Self-funded, Village development committees, business partners, technology X	Access the youth fund, BIH fund	Community partnerships, Incubation support/mentorship, funding, technologies, production
CAI	BIH, private firms	Tutors, local councils, youth development fund, iBranch	Access to BIH fund and links with local firms.	Skills development, partnerships, funding, scaling up, impact
SDS	Equipment, software	Self-funded, online	Access to	Funding,

	developers, websites and trade events	platforms, BIH, mobile tech, social media, TV	equipment partners, website developers.	technology/equipment, developer skills, communication channels, internal champions.
SPA	Government community trust, NGOs, LEA, BIH, youth development fund, CEDA, mining co, ministries, universities	Self-funded, Developer community, BIUST, Government projects,		Policy environment & adaptability, community impact & markets, funding & innovation, collaboration & experimentation, skills development & talent
GK	Did not do the session	Did not do the session	Did not do the session	Did not do the session

I

Groups Name	**Categories visualised**			
	Weak ties	Strong & medium ties	key roles	Sustain
II HUB	Government dept, BIH, CEDA, LEA, youth development	Self-funded, Local universities,	Government policy makers, investors,	Access to funding through partnerships, private sector

	fund, local investors, Universities, international exports.	mining co, research centres, private trainers, developer community	research partners, funding partners	engagements, partnering with local universities in R&D, external markets
Energy X	External funding, third party developers, procurement agents, big manufacturers, e-factory, Government funding	Internal Software development, labour office	Procurement partners, factory space, funding partners	Procuring as an ecosystem to reduce costs, applying for factory space as an ecosystem, explore e-manufacturing, digital manufacturing and AI technologies.
Innovation links	Accreditation bodies, universities, CEDA, innovation fund, youth funds, ministry of education, Radio, TV, Government.	Self-funded, Employees, training institutions, social media, Individual customers	Linking with institutions and accreditation bodies, funding partners, new markets	Partnering with universities and funders like CEDA. Linking with marketing partners like television and radio.
Innovation minds	BITC, BIH fund, BOBS, retail stores, local council, ministries	BIH, Trade fairs, suppliers, mentors, youth	Funding partners, retail partners, Botswana	BOBS certification, access funding through the new ecosystem

	development fund, TEF funds, CIPA, Google, radio, social media, mobile apps	bureau of standards (BOBS)

Appendix 12 Workshop evaluation

Workshop Evaluation Form

Date	
Workshop Location	
Presenter(s)	

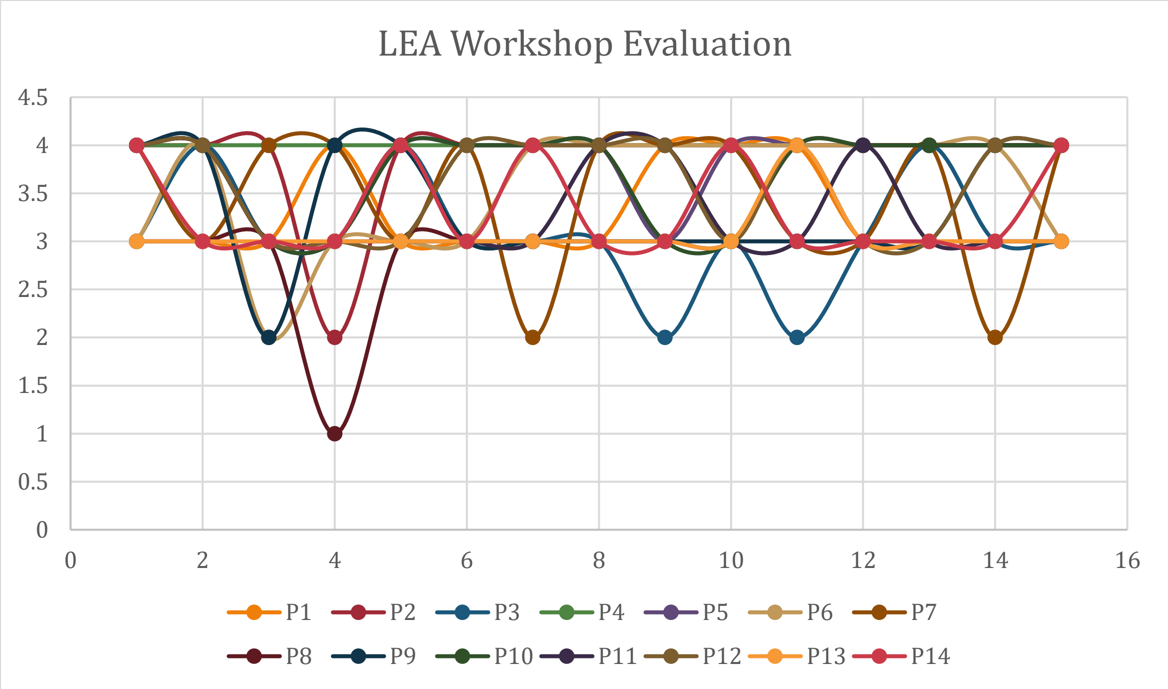
Please respond by using the 4-point rating scale to indicate the extent to which you agree of disagree with each statement. Circle the number that applies.

4-Strongly Agree **3**- Agree **2**- Disagree **1**- Strongly Disagree

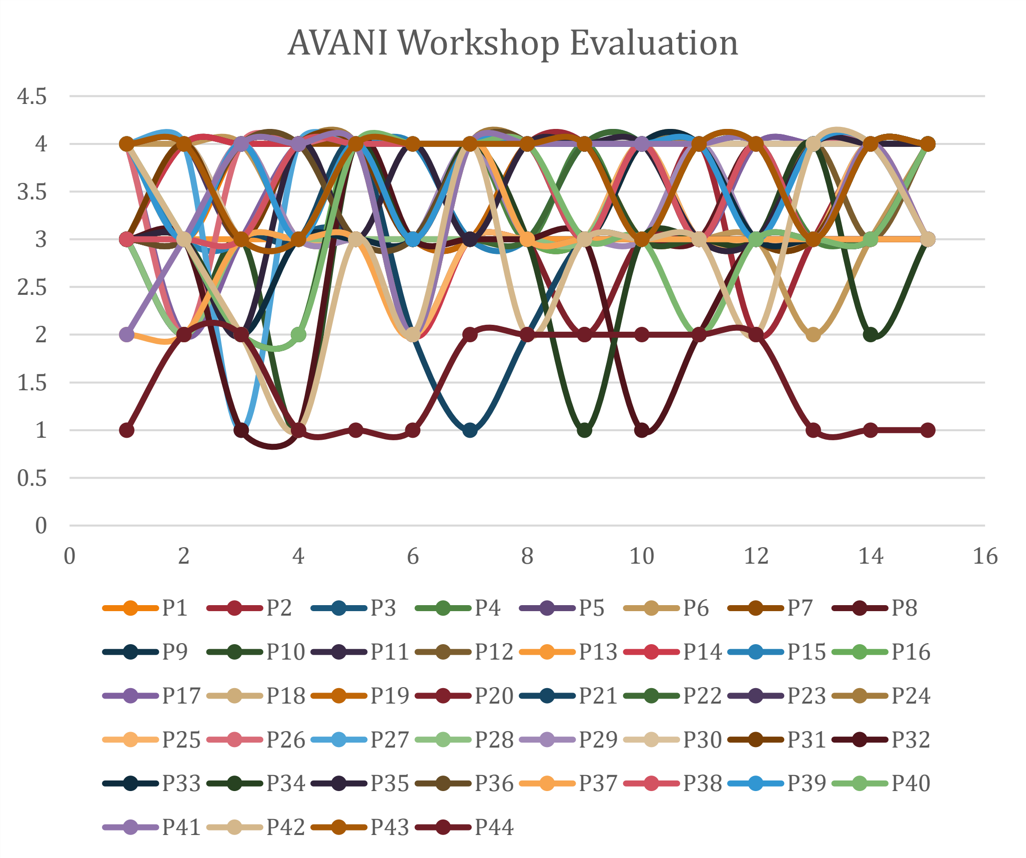
1. The workshop objectives were clearly stated and met	**4 3 2 1**
2. The questions and instructions were clear	4 3 2 1
3. The workshop helped me to connect with contacts that I knew before but didn't have a working relationship with.	4 3 2 1
4. The workshop helped me to make new contacts with people or organisations I didn't know.	4 3 2 1
5. The information presented was relevant and useful.	4 3 2 1
6. The presenter provided adequate time for questions and answered them satisfactorily.	4 3 2 1
7. The workshop introduced a new technique of developing	4 3 2 1

networks that I never used before.	
8. The workshop increased my knowledge and skills in the design of innovation ecosystems from scratch.	4 3 2 1
9. The workshop helped me to re-think my business model in terms of working with other organisations.	4 3 2 1
10. The connections developed from the workshop will be useful in my future innovation networks.	4 3 2 1
11. The opportunities identified during the workshop will be useful to my future business model development.	4 3 2 1
12. The physical arrangements were adequate	4 3 2 1
13. The workshop met my expectations	4 3 2 1
14. I would recommend the workshop to others.	4 3 2 1
15. The workshop was well organised.	4 3 2 1

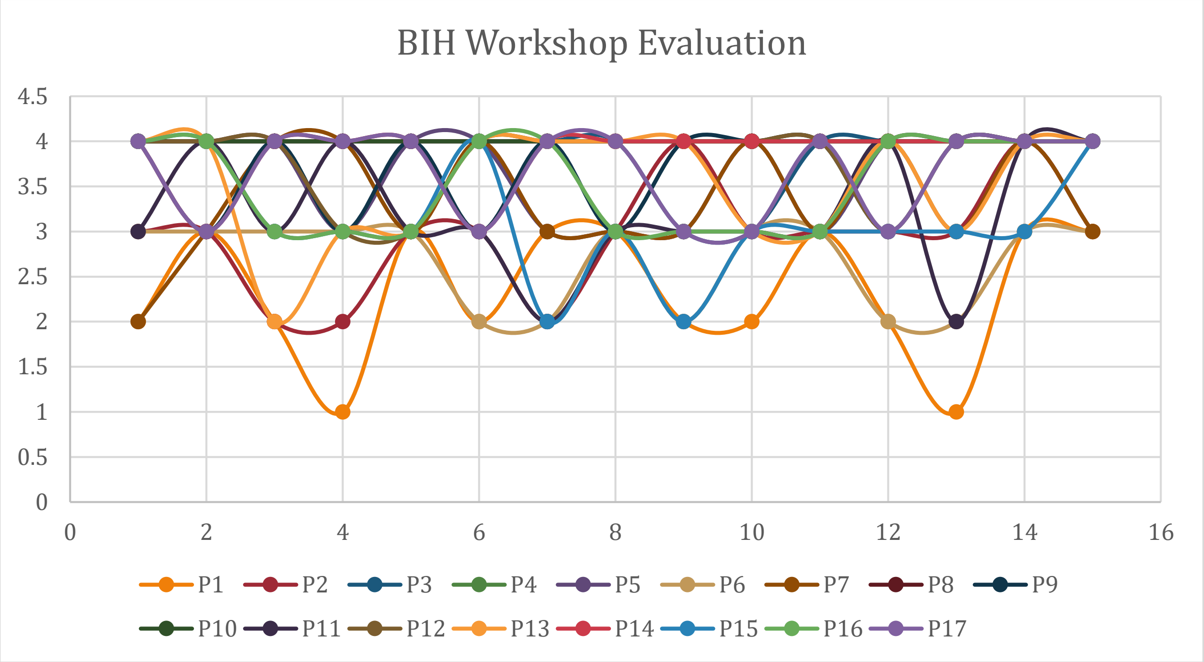
Others comments ____ ____ ______________



The Y-axis represents the measure of responses to the evaluation exercise. 4- strongly agree, 3-Agree, 2- Disagree, 1- strongly disagree. The X-axis represents the evaluation questions in appendix 1.



The Y-axis represents the measure of responses to the evaluation exercise. 4- strongly agree, 3-Agree, 2- Disagree, 1- strongly disagree. The X-axis represents the evaluation questions in appendix 1.



The Y-axis represents the measure of responses to the evaluation exercise. 4- strongly agree, 3-Agree, 2- Disagree, 1- strongly disagree. The X-axis represents the evaluation questions in appendix 1.

Appendix 13 Workshop schedule

'Building Innovation Ecosystems from Scratch'

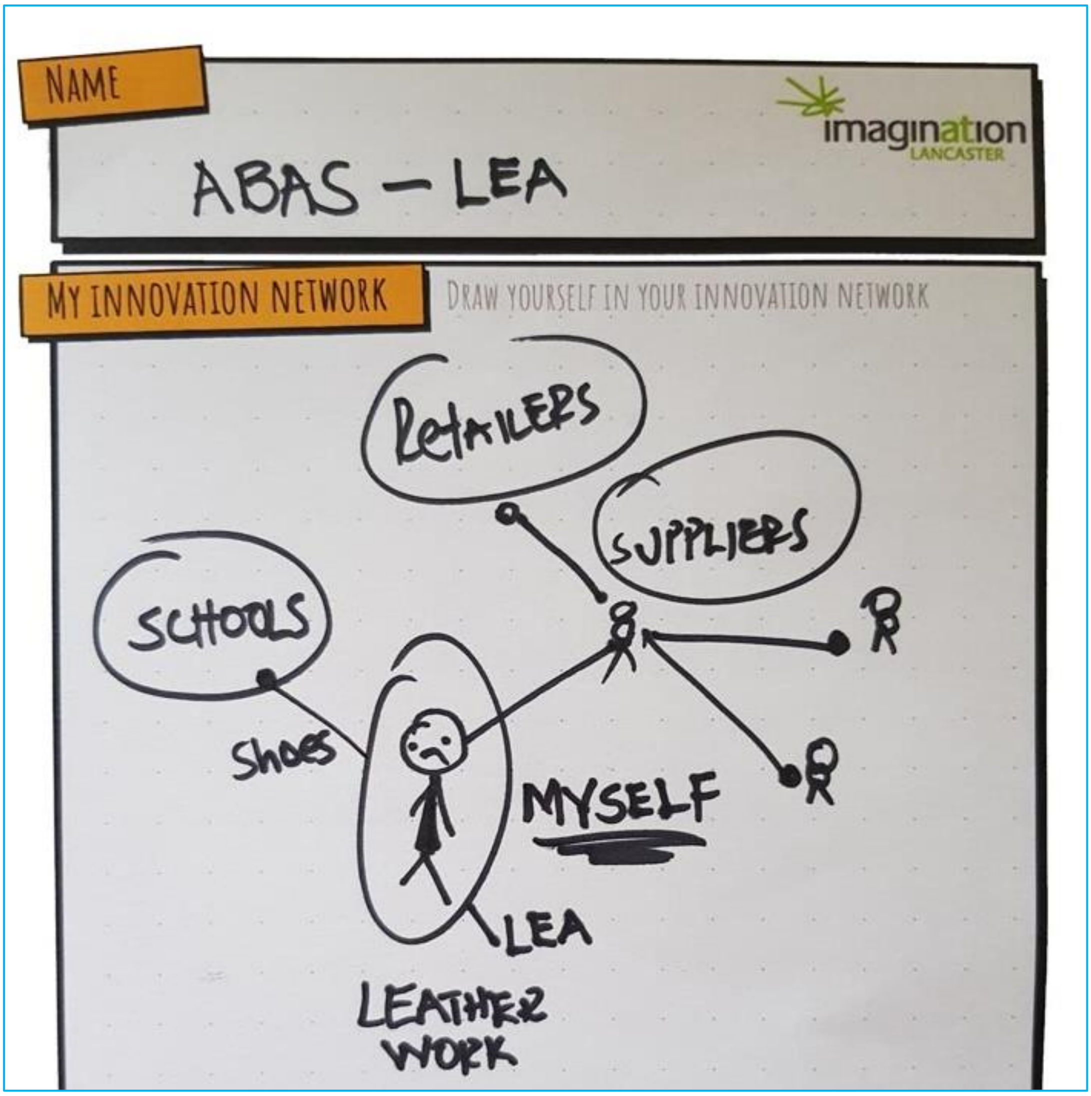
Workshop Program

Exchange: Identifying criteria for exchange of resources between key networks. Design: Visualising network connections and meaning. Develop: Connect the dots to explore structural holes, clusters, key stakeholders and niche services. Manage: Decide on potential roles and how each stakeholder may contribute value. Sustain: How will you maintain the connections to deliver innovations. OR-Death: Identify potential factors that may collapse the new connections.

No	Objective	Activity	Time
1	Having refreshments & getting ready	Arrival and coffee	5
2	Introduce the workshop aim	Facilitators brief	3
3	Getting to know people	5 Lines (5 secs to talk about yourself)	5
4	Making sense of innovation ecosystems.	Innovation ecosystem shared Value • PowerPoint presentation	15
5	***Individual organisations***	***Break into your respective organisations***	***5***
6	To explore what stakeholders' value most in their networks.	What criterion are important in your networks • List at least 10	10
7		Share the list with the group and select 5 most critical to use	10
8	Making decisions on key network contacts.	What actors are important in your networks • List at least 20 contacts in your project or business.	5
9	Designing interrelationships	Write 5 criterion on the spaces provided and Plot 20 actors on the tool segments. Plot according to the strength of the connection	10
10	Exploring opportunity for development of networks	Connect the nodes to reveal connections and gaps	5
11	Feedback	Share insights to the rest of the group	15
		Break	
12	***Mixing random organisations***	***Break away from your organisation into random groups***	***5***
13	Exploring stakeholder's preferred criterion	Preferably with people you don't know, list the important criterion that may connect you, and select 5 most critical to use	10
14	Exploring stakeholder's contacts	List at least 20 contacts that may be important in your new connections	10
15	Identify new links and roles	Write criterion and plot new stakeholders on the design tool	15
16	Develop and manage networks through new roles	Connect the nodes and assign new possible roles to nodes	10
17	Network sustainability	Assign sustainability roles to each node	10
18	Share new connections as new IE Designs.	Feedback- Group Presentations	30
19	Conclusions	Evaluation	5

**Designing Connections is Fun, Enjoy It*

Appendix 14 Example of visualisations produced during the first part of in-person workshops.



Appendix 15 Participant Information Sheet-for interviews and workshops.

Participant information sheet

Futures of Additive Manufacturing (AM) in Developing Nations: A Design Focused Ecosystem Thinking for Leveraging Value by SMEs.

I am a PhD student at Lancaster University, and I would like to invite you to take part

in a research study about the futures of AM in developing nations.

Please take time to read the following information carefully before you decide whether or not you wish to take part.

What is the study about?

This study aims to unravel the complexities of manufacturing ecologies in UK and Botswana. I am interested in understanding how UK AM SMEs and Botswana manufacturing SMEs design, implement, develop and evolve their complex ecologies. Then I hope to compare the cases and use insights to develop a guideline of how SMEs in developing nations can better leverage the technology of AM through an elaborate understanding of the dynamics of Innovations ecologies. Why have I been invited?

You have been identified as a possible participant in this study because you have an active role either as a keystone, niche player, hub landlord, dominator player or a neutral player in your manufacturing SME ecosystem.

I would be very grateful if you would agree to take part in this study.

What will I be asked to do if I take part?

If you decide to take part, nothing more than been interviewed (60 minutes) about your ecosystems and attending a workshop (1-hour) to discuss the research outcome will be asked of you. I will also ask your permission to take photos, audio and videos of workshop activities which will be anonymised to conceal your identity prior to transcription. If you do not agree to be recorded, I will take notes during the interview, and will anonymise those notes.

What are the possible benefits from taking part?

By taking part in this study you have the opportunity to contribute to the development

of AM ecologies in both UK and Botswana. Firms will extend their ecosystem networks towards the developing world and vice versa through the in-depth understanding of the varied local ecosystems, hence increasing their market access across the world and tapping on the emerging opportunities in both worlds.

Do I have to take part?

No. It's completely up to you to decide whether or not you take part.

What if I change my mind?

If you change your mind, you are free to withdraw your participation from the study at any time, and up to two weeks from the date of the interview and focus group If you want to withdraw, please let me know, and I will extract any ideas or information (data) you contributed to the study and destroy them. However, it is difficult and often impossible to take out data from one specific participant when this has already been anonymised or pooled together with other people's data.

What are the possible disadvantages and risks of taking part?

It is unlikely that you will experience any disadvantages or risks beyond those

encountered in normal life.

Will my data be identifiable?

After the data collection, only myself and my supervisors will have access to the ideas you share with me. I will keep all personal information about you (e.g. your name and other information about you that can identify you) confidential, that is I will not share it with others. I will remove any personal information from the written record of your contribution. I will anonymize any audio and video recordings and hard copies of any personal data, so that you will not be identified. All photos and videos will be concealed to hide the identifiable features of participants when used as output in my PhD thesis and conference publications.

How will we use the information you have shared with us and what will happen to the results of the research study?

I will use the data for research purposes only. This will include my PhD thesis and other publications, for example journal articles. I may also present the results of my study at academic conferences.

When writing up the findings from this study, I would like to reproduce some of the

views and ideas you shared with me. I will only use anonymized data, so that although I will use your exact words, you cannot be identified in my publications.

How my data will be stored

Your data will be stored in encrypted files (that is no-one other than me, the researcher will be able to access them) and on password-protected computers. I will store hard copies of any data securely in locked cabinets in my office. I will keep data that can identify you separately from non-personal information (e.g. your views on a specific topic) In accordance with University guidelines, I will keep the data securely for a minimum of ten years.

This study is funded by UK Commonwealth Scholarship Commission. The funder expects me to make my data available for future use by other researchers. I will exclude all personal data from archiving. I intend to archive/share the data via Lancaster University's institutional data repository and made freely available with an appropriate data license.

What if I have a question or concern?

If you have any queries or if you are unhappy with anything that happens concerning your participation in the study, please contact myself at b.nthubu@lancaster.ac.uk or by phone on +44 (0)1524 594395 or my supervisors Prof. Leon Cruickshank (l.cruickshank@lancaster.ac.uk) and DR. Daniel Richards (d.richards@lancaster.ac.uk)

If you have any concerns or complaints that you wish to discuss with a person who is not directly involved in the research, you can also contact:

Judith Mottram, Head of Department, Lancaster Institute for the Contemporary Arts, Lancaster University, Lancaster, LA1 4YW, Tel: +44 (0)1524 594395, email: judith.mottram@lancaster.ac.uk

This study has been reviewed and approved by the Faculty of Arts and Social Sciences and Lancaster Management School's Research Ethics Committee.

For further information about how Lancaster University processes personal data for research purposes and your data rights please visit our webpage: www.lancaster.ac.uk/research/data-protection

Thank you for considering your participation in this project.

Appendix 16 Consent form-for interviews and workshops.

CONSENT FORM

Project Title: Futures of Additive Manufacturing (AM) in Developing Nations: A Design Focused Ecosystem Thinking for Leveraging Value by SMEs

Name of Researchers: Badziili Nthubu

Email: b.nthubu@lancaster.ac.uk

Please tick each box

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily	..
2. I understand that my participation is voluntary and that I am free to withdraw at any time during my participation in this interview or workshop and within 2 weeks after I took part in the study, without giving any reason. If I withdraw within 2 weeks of taking part in the study, my interview data will be removed. But if I am involved in a workshop and then withdraw my data will remain part of the study.	..
3. I understand that as part the workshop I will take part in, my data is part of the ongoing conversation and cannot be destroyed. I understand that the researcher will try to disregard my views when analysing the workshop data, but I am aware that this will not always be possible.	..
4. If I am participating in the workshop, I understand that any	..

information disclosed within the workshop remains confidential to the group, and I will not discuss the workshop data with or in front of anyone who was not involved unless I have the relevant person's express permission	
5. I understand that any information given by me may be used in future reports, academic articles, publications or presentations by the researcher/s, but my personal information will not be included, and I will not be identifiable.	..
6. I understand that a fully anonymised data will be offered to Lancaster University's institutional data repository and will be made available to genuine researchers for re-use (secondary analysis) with an appropriate data license.	..
7. I understand that my name/my organisation's name will not appear in any reports, articles or presentation without my consent.	..
8. I understand that any interviews or workshops will be audio-recorded, or video recorded, and transcribed and workshop activities will be photographed, and that data will be protected on encrypted devices and kept secure.	..
9. I understand that photos, and videos of activities during the workshop that I attend will be captured and my personal identity will be concealed on the resulting output.	..
10. I understand that data will be kept according to University guidelines for a minimum of 10 years after the end of the study.	..
11. I agree to take part in the above study.	..

____________________ ________________ ________________

Name of Participant Date Signature

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

Signature of Researcher /person taking the consent___________________________ Date ___________ Day/month/year

One copy of this form will be given to the participant and the original kept in the files of the researcher at Lancaster University

Appendix 17 Demographic sheet.

Focus group: Demographic details questionnaire

Please answer the following questions in the spaces provided, circle or tick the most appropriate options.

1. Age:……………………………………………………………

2. Are you: (please tick as necessary) □ Male □ Female

3. What is your professional background?

□ Creative Artist

□ Designer

□ Manufacturer

□ Engineer

□ Scientist

□ Other: (please describe) ___________________________________

4. How many years of experience have you had in this current job?

□ <1 Year □ 1-2 Years

□ 2-5 Years □ 5-10 Years

□ >10 Years

6. Experience in additive manufacturing (optional):

□ <1 Year □ 1-2 Years

□ 2-5 Years □ 5-10 Years

□ >10 Years

Thank you for taking the time to complete this questionnaire

Appendix 18 Email Invitation to participant in the study.

Email of Invitation

Name of Researcher: Badziili Nthubu (PhD Candidate)
Supervisors: Prof. Leon Cruickshank and Dr Daniel Richards

Title of Project: Futures of additive manufacturing (AM) in developing nations: A design focused ecosystem thinking for leveraging value by SMEs.

Sponsor: UK Commonwealth Scholarship Council

Dear Participant,

I am a PhD student at Lancaster Institute for the Contemporary Arts (LICA), Lancaster University, United Kingdom. I would like to invite you to participate in the interview and later in a workshop for my study which aims to investigate AM SMEs ecologies in UK and local manufacturing SMEs ecologies in Botswana. The comparative output of the research is expected to provide theories of what is happening between UK AM SMEs innovation ecosystems and Botswana SMEs local manufacturing innovation ecosystems. It will be interesting for firms to participate in this research to understand the dynamics of their ecosystems, and how they can improve on the existing local ecologies to create and extract more value through leveraging other emerging ecosystem opportunities. The future making of things will be largely driven by evolving innovation ecosystems, where AM as a disruptive innovation will play a bigger role in how we co-produce things.

The information sheet and a consent form has been attached to this email in order to give you more detail about the interview and workshops. Please take the time to read the information to decide whether or not to participate in the research. The study is supervised by Prof. Leon Cruickshank and Dr Daniel Richards based in Lancaster University.

Once you have confirmed your participation in this research, please return the consent form to me, I will contact you shortly to arrange a suitable date and time for the interview and workshop. I look forward to your response.

With best wishes

Appendix 19 Visualisation results for chapter 5 case study project.

	Artist ecosystem	**FabLab ecosystem**	**3D printing Bureau ecosystem**
Main clusters	Seven tools reveal the Artist and gallery as the main clusters [Gephi, Cytoscape, Sankeymatic, GraphCommons, Zingsoft, OmicsNet, NetworkX]	**Three main clusters are revealed: FabLab Staff** [Gephi, Cytoscape, Sankeymatic, GraphCommons, Zingsoft, OmicsNet, NetworkX] **Design & prototyping** [Cytoscape, Sankeymatic, GraphCommons, Zingsoft, OmicsNet, NetworkX] **Equipment booking** [Gephi, Cytoscape, GraphCommons, Zingsoft, OmicsNet, NetworkX]	Two tools reveal clusters as 3D bureau service and UK manufacturer [Gephi and NetworkX]

Main bridges	Seven tools reveal the gallery and Artist as the main bridges. [Gephi, Cytoscape, Sankeymatic, GraphCommons, Zingsoft, OmicsNet, NetworkX]	One main bridge: FabLab staff [Gephi, Cytoscape, Sankeymatic, GraphCommons, Zingsoft, OmicsNet, NetworkX]	Three main bridges: 3D bureau service, resellers and niche clients [Gephi, Cytoscape]
Node size	Six tools show the gallery having higher degree followed by the artist node [Gephi, RAWGraphs, SocNetV, HighCharts, Zingsoft, Tableau] Three tools show the Artist having a high degree than the	Eight tools show FabLab staff with high degree followed by equipment booking [Gephi, Chord Snip, Cytoscape, Sankeymatic, SocNetV, HighCharts, Zingsoft, Tableau]	Nine tools show a high degree of connections in Equipment manufacturers, 3D printing Bureaus services and equipment resellers [Gephi, Chord Snip, Cytoscape, RAWGraphs, Sankeymatic, SocNetV, HighCharts, Zingsoft, Tableau]

	gallery. [Chord Snip, Cytoscape, Sankeymatic]		
Structural holes	Holes between: Gallery & 3d firms [Gephi, Cytoscape] Int markets & Gallery collectors *[Gephi, NetworkX, Zingsoft]* Chemical Co & 3d firms *[Gephi]* Gallery & creative Industry *[Cytoscape, Zingsoft]* **Artist & Int markets** [Cytoscape, OmicsNet] Artist & other galleries *[Sankeymatic]*	Holes between: Equipment booking & Universities, Co-working & Universities, Community users & FabLab staff, Community users & Design *[Gephi]* Equipment booking & Co-working, Bespoke service & equipment booking *[Cytoscape, Zingsoft]* Design & Universities *[Cytoscape]* FabLab staff & Hack//burn *[Sankeymatic]* Design & Hack//burn *[Zingsoft]*	Holes between: **UK manufacturers & Aerospace clients** [Gephi, Cytoscape, Sankeymatic, OmicsNet] **Manufacturers & resellers** [Gephi, Zingsoft, NetworkX] 3D printing bureau & resellers, Foreign Manufacturers & UK markets *[Gephi]* Motorsport clients & foreign manufacturers *[Cytoscape, Zingsoft, OmicsNet, NetworkX]* Manufacturers & resellers *[Cytoscape]* Resellers and UK markets *[Sankeymatic]* Motorsport clients & 3D printing bureaus *[Zingsoft]* Manufacturers &

	Int markets & Chemical Co *[Zingsoft]* 3d firms & Int markets *[OmicsNet]* Chemical Co & Int markets *[Zingsoft]*	Co-working & Markets *[Zingsoft]* Design & Markets, Design & Equipment booking *[OmicsNet]* Equipment booking & community users *[NetworkX]*	bureaus *[OmicsNet]*
Weak ties	Weak ties between: Gallery & Chemical Co *[Gephi]* Gallery collectors & 3d firms *[Gephi, D3]* **Artist & Int markets** [Gephi, Chord Snip, RAWGraphs, D3] **Gallery & 3d firms** [Gephi,	Weak ties between: FabLab staff & universities, Hack//burn & Bespoke service *[Gephi]* FabLab staff & Hack//burn *[Chord Snip]* Community users & Equipment booking *[Chord Snip]* Markets & design *[RAWGraphs,*	Weak ties between: Aerospace & motorsport clients, 3D printing bureau & resellers, 3D printing bureau & equipment manufacturers *[Gephi, D3]* UK equipment manufacturers & 3D printing bureaus *[Chord Snip, D3]* UK manufacturers & resellers *[Chord Snip]* Aerospace clients & manufacturers

	RAWGraphs] Galley collectors & Other galleries *[Chord Snip, D3]* Int shows & Creative industry *[R-chie]*	*D3]* FabLab staff & Community users *[RAWGraphs, D3]*, Markets & FabLab staff *[R-Chie]*	*[RAWGraphs]* Foreign manufacturers & UK markets *[R-Chie]*
Roles structures	Five tools show the gallery as the keystone actor and Artist as a niche actor. [Gephi, RAWGraphs, SocNetV, Zingsoft, Tableau] Two tools show the Artist as the keystone actor and gallery as the niche actor *[Chord Snip, Cytoscape]* No dominators are shown in all tools	Six tools show FabLab staff as keystone actor and equipment booking, hack//burn and design prototyping services as niche actors. [Gephi, Chord Snip, SocNetV, Zingsoft, Tableau, Cytoscape]	Six tools show equipment manufacturers, 3D printing bureaus and equipment resellers as dominators [Gephi, SocNetV, Chord Snip, Cytoscape, Zingsoft, Tableau]

Appendix 20 Ethics approval letter.

Reply Reply all Forward Archive Delete ...

Ethics approval (reference FL18034) please quote this reference in all correspondence about this project

FE **FASS and LUMS Research Ethics <fass.lumsethics@lancaster.ac.uk>**
20/12/2018 15:03

To: Nthubu, Badziili Cc: Cruickshank, Leon; Richards, Daniel

Dear Badziili

Thank you for submitting your application and additional information for *Futures of Additive Manufacturing (AM) in Developing Nations: A Design Focused Ecosystem Thinking for Leveraging Value by SMEs.* The information you provided has been reviewed by members of the Faculty of Arts and Social Sciences and Lancaster Management School Research Ethics Committee and I can confirm that approval has been granted for this project.

As principal investigator your responsibilities include:

- ensuring that (where applicable) all the necessary legal and regulatory requirements in order to conduct the research are met, and the necessary licenses and approvals have been obtained;
- reporting any ethics-related issues that occur during the course of the research or arising from the research (e.g. unforeseen ethical issues, complaints about the conduct of the research, adverse reactions such as extreme distress) to the Research Ethics Officer;
- submitting details of proposed substantive amendments to the protocol to the Research Ethics Officer for approval.

Please do not hesitate to contact me if you require further information about this.

Kind regards,

Debbie

Debbie Knight
Secretary, FASS-LUMS Research Ethics Committee fass.lumsethics@lancaster.ac.uk
Phone (01524) 592605| D22 FASS Building, Lancaster University, LA1 4YT
Web: FASS & LUMS Research Ethics Guidance & Application form

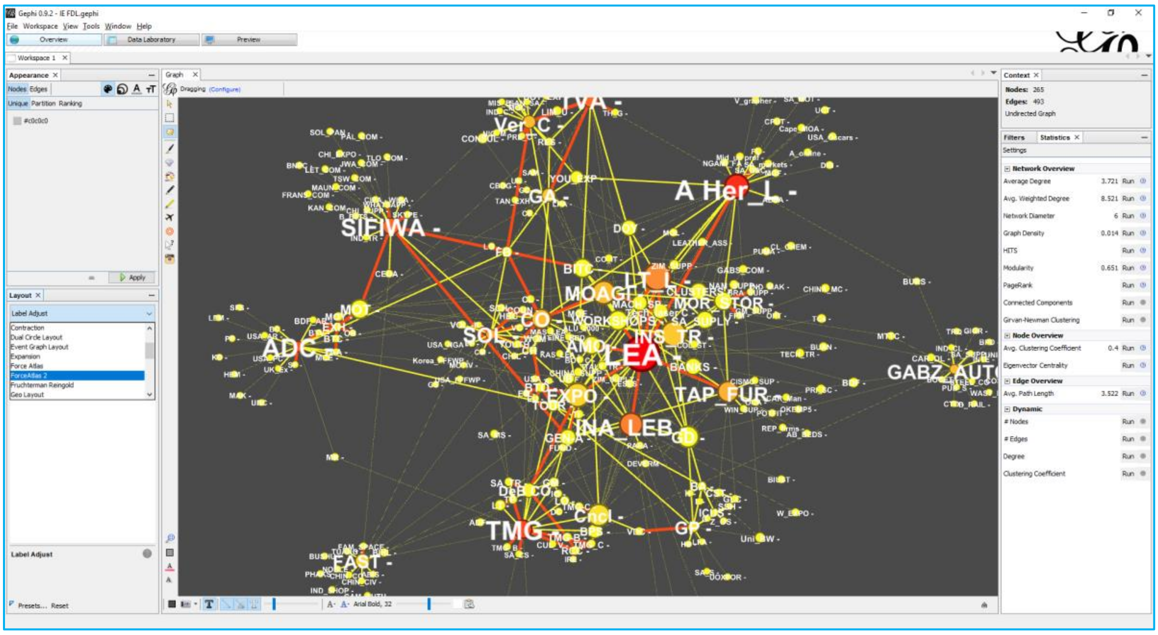
Lancaster University
www.lancaster.ac.uk/50

Appendix 21 How visualisations were produced in Gephi 0.9.2, Googlesheets and OmicsNet tools.

1. Gephi 0.9.2

Step	Task
1.	Format data into CSV files (defining source, target, type, weight)
2.	Open New project in Gephi
3.	Open Data laboratory tab
4.	On the Data table, import node spreadsheet (node data sheet produced earlier)
5.	Choose Graph type- undirected graph
6.	Import edge spreadsheet (CSV data sheet produced earlier)
7.	Switch from laboratory tab to overview tab
8.	Before running the algorithm, set network statistics by running the following; Average degree Network diameter Graph density Modularity Eigenvector centrality- 10,000 iterations
9.	Go to layout algorithms, select ForceAtlas2 algorithm
10.	Set behaviour alternatives as follows; Scaling = 3 Gravity = 1 Check Dissuade hub Linlog mode Prevent overlap Edge weight influence = 1
11.	Run the algorithm
12.	Set & run node size by using a degree ranking as follows; Min = 15 Max = 80 Set & run node colour by using degree ranking as follows; Yellow, Orange, Red
13.	Set & run node label size by degree ranking as follows; Min = 1 Max = 2
14.	Run the Label adjust the algorithm to avoid label overlaps
15.	Set & run edge colour by edge weight using the node colour scheme Yellow, Orange, Red
16.	Set & run label size by weight ranking as follows; Min = 1 Max = 2
17.	Go to the Preview tab, refresh to see the results
18.	Perform visual network analysis

Gephi 0.9.2 view



2. Google Sheets

Step Task

1. Format data into CSV file, (defining source, target & weight)

2. Open New project in Google sheets

3. Go to file, import file as CSV.

4. On the toolbar, open Add-on and select create Chordsnip

5. A pop-up window will appear seeking permission to run script

6. Click continue

7. A visualisation interface will appear on the right of the sheet containing the following tabs;

   a. Chart

   b. Settings

   c. About

8. Under the chart tab, a chord snip dynamic visualisation appears, which allows the following;

   a. Isolation of nodes and ties using a mouse function

b. Viewing of detailed node and edge labels using a mouse hovering function.

9. To customise visual attributes, go to the settings tab, you will see the following;

a. Chart settings

b. Source data settings

c. Image embed code

10. To customise visualisations, select chart settings

11. Click appearance and set the visualisation diameter to 270

12. Under the links, set colour mode to ramp value and set variables as follows;

a. Colour ramp start = R (230) G (250) B (30)

b. Colour ramp end = R (250) G (65) B (10)

c. Opacity = 0.9

d. Border width = 2

13. Run the algorithm by clicking apply

14. Select chart to view the changes

15. Then click the back tab to adjust the nodes

16. Select nodes and set the following variables;

a. Pad and angle between nodes = 0.05

b. Thickness of arc = 20

c. Sort diagram = none

d. Label padding = 1

e. Font size = 8

f. Font colour = R (33) G (33) B (33)

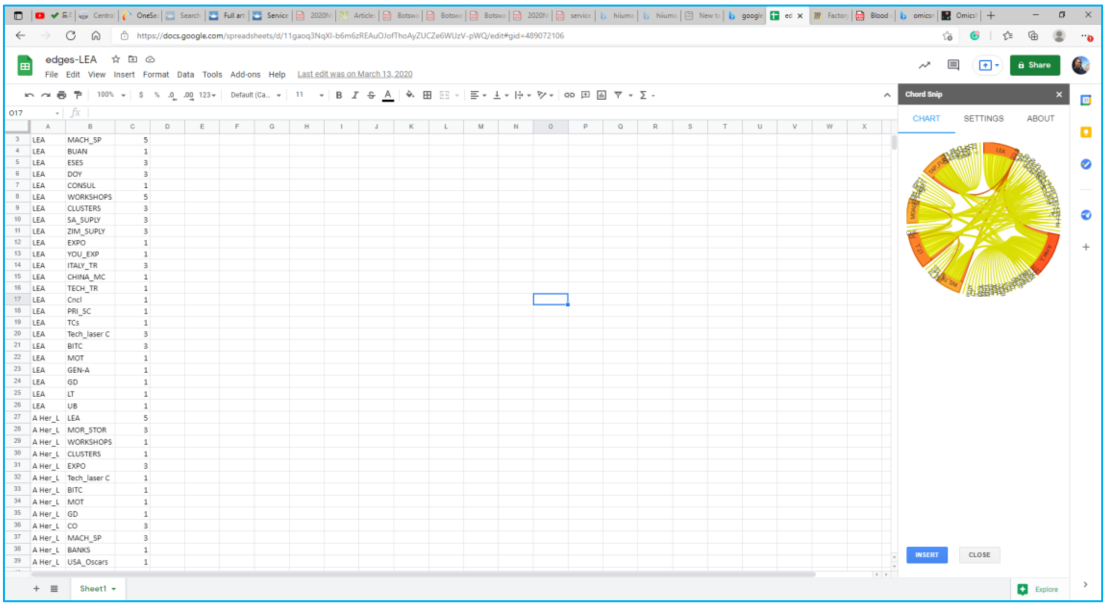
G. Font name = Roboto

17. Run the algorithm by clicking apply

18. Click chart to view the visualisation

19. Perform visual network analysis

Google sheets view



3. OmicsNet

Step Task

1. Format data into a graph file, i.e. sif, graphml, JSON or txt(edge list)

2. Go to [OmicsNet]

3. Click graph file

4. A dialogue box will pop up, click choose file to locate your graph file.

5. Upload and submit the file and click proceed.

6. Omicsnet will be loaded, showing the network view.

7. Under network attributes, change network background colour to white

8. Select the standard layout algorithm

9. To customise visualisations, select styling and set the following parameters;

a. Node Label customisation

Threshold

-Display options = Global

-Topology = Betweenness

-Threshold = 5

Click submit

Label colour = #020202

Click choose

Display option = set to show

Label type = set to HTML based

Click submit

b. Node colour customisation

Node attribute = degree

Sequential = yellow, orange & red

Click submit

c. Node size customisation

Node scope = All nodes

Node size = Increase++

Node attributes = Degree

Node shading = Standard

Click submit

d. Edge opacity = 1 click submit

e. Edge width = 5 click submit

f. Edge colour = #d6a04a click choose

G. Edge bundling = Confirm

H. Colour scheme

Node attribute = Degree

Sequential = Yellow, orange & red

Click submit

10. Under the drag scope set to the current mode

11. Perform visual network analysis using the 3D tools from the toolbar.

OmicsNet View