The Development of a Business Model Innovation Framework from a Value Network Perspective Applied to the Prospective Cemented Tungsten Carbide Additive Manufacturing Sector in South Africa

by

Ané van Heerden

Thesis presented in partial fulfilment of the requirements for the degree of Master of Engineering (Industrial Engineering) in the Faculty of Engineering at Stellenbosch University

The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the author and are not necessarily to be attributed to the NRF.

Supervisor: Prof S.S Grobbelaar

Co-supervisor: Prof N Sacks

April 2022

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: April 2022

Abstract

The adoption and implementation of Industry 4.0 technologies lead to numerous opportunities and challenges for small, medium, and micro enterprises (SMMEs), which form an important part of the manufacturing industry and the South African economy. One such technology is additive manufacturing (AM) that enables the production and delivery of new products and services. Since SMMEs are often characterised by a lack of finance, capacity, resources, and competencies, it is imperative to form part of value networks.

These intentionally formed value networks, referred to in this study as strategic business nets, aim to gain or sustain a competitive advantage through collaboration among competitors to increase capacity, co-operation with customers to develop focused competencies, and collaboration with partners that provide access to complementary competencies and resources. For SMMEs, the configuration of these strategic business nets remains challenging, as well as the ability to develop applicable networked business models to create, deliver, and capture value. Therefore, SMMEs require guidance to adopt new principles in transforming their business models from the firm-level to the network-level, referred to as *networked business model innovation.*

The aim of this study was to systematically develop a business model innovation framework from a value network perspective to support SMMEs to configure strategic business nets and develop appropriate networked business models. Furthermore, this study was focused on the application value of such a management framework and tool to the cemented tungsten carbide manufacturing industry of South Africa with a view to incorporate additive manufacturing into the sector via SMMEs. Although the use of AM techniques to produce tungsten carbide products is still an emerging research field, business related research is of utmost importance to support industry development and strengthening. Since SMMEs often cannot afford comprehensive external advisory services, lack guidance in business restructuring amidst disruptive change, and lack mature and systematic development procedures, it is imperative to focus research studies to develop self-explanatory methods and tools to guide the strategic development and growth of these SMMEs.

The management framework and tool were developed, refined, and evaluated through multiple design cycle iterations, as informed by the Design Science Research Framework. Various aspects, including frameworks, concepts, elements, and activities were obtained from the business model, business model innovation and value network literature domains. Furthermore, insights were obtained from various subject-matter experts within the business, manufacturing, and AM industries. As part of the management framework, a value network visualisation or mapping tool was developed, referred to as the *strategic business net configuration process*, to enable users to visualise the configuration of future strategic business nets.

To demonstrate the framework's applicability and capacity to support the prospective cemented tungsten AM industry of South Africa, a type of case study was conducted. The findings and insights obtained could provide potential support for future users and key role-players within the industry to build upon. Finally, the management framework was converted into a management tool using online, collaborative software that could be used by manufacturing SMMEs, or entrepreneurs that want to enter an emerging technology market.

Opsomming

Die aanvaarding en implementering van Industrie 4.0 tegnologieë lei tot talle geleenthede en uitdagings vir klein, medium en mikro-ondernemings (KMMO's), wat ‘n belagrike rol speel in die vervaardigingsbedryf en die Suid-Afrikaanse ekonomie ondersteun. Een van hierdie tegnologieë is *additive manufacturing* wat die produsering en lewering van nuwe produkte en dienste moontlik maak. Aangesien KMMO's soms gekniehalter word deur 'n gebrek aan finansiering, kapasiteit, hulpbronne en bevoegdhede, is dit noodsaaklik dat hulle deel vorm van waardenetwerke.

Hierdie doelbewus gevormde waardenetwerke, soos na verwys in hierdie studie as strategiese sakenette, het ten doel om 'n mededingende voordeel te verkry of te behou deur samewerking met mededingers om kapasiteit te verhoog, samewerking met kliënte om spesifieke bevoegdhede te ontwikkel, asook samewerking met vennote wat toegang bied tot aanvullende bevoegdhede en hulpbronne. Die ontwikkeling van hierdie strategiese sakenette bly vir KMMNO’s uitdagend, sowel as die vermoë om toepaslike netwerk-gebaseerde besigheidsmodelle te ontwikkel. Daarom benodig KMMO's leiding om nuwe besigheidsbeginsels aan te neem en om hulle besigheidsmodelle te omskep vanaf die besigheidsvlak na die netwerkvlak, waarna verwys word in hierdie studie as netwerk-gebaseerde besigheidsmodelinnovasie.

Die primêre doel van hierdie studie was om sistematies 'n besigheidsmodelinnovasieraamwerk te ontwikkel vanuit 'n waardenetwerk perspektief om KMMO's te ondersteun in die ontwikkeling van strategiese sakenette asook gepaste netwerk-gebaseerde besigheidsmodelle. Verder was hierdie studie spesifiek gefokus op die toepassingswaarde van so 'n bestuursraamwerk en hulpmiddel op die potensiële gebruik van *additive manufacturing* in die vervaardigingsindustrie van gesementeerde wolframkarbiede (*cemented tungsten carbide*) produkte in Suid-Afrika. Alhoewel die gebruik van *additive manufacturing* tegnieke vir die vervaardiging van wolframkarbiede produkte steeds 'n opkomende navorsingsveld is, is besigheidsverwante navorsing van uiterste belang ten einde die ontwikkeling van die bedryf te ondersteun. Aangesien KMMO's dikwels nie eksterne adviesdienste kan bekostig nie, sukkel met herstrukturering, en 'n tekort het aan ontwikkelingsprosedures, is dit noodsaaklik om navorsingstudies oor selfverduidelikende metodes en hulpmiddels te doen om by te dra tot die strategiese ontwikkeling en groei van hierdie KMMO's.

Die bestuursraamwerk en hulpmiddel is ontwikkel, verfyn en geëvalueer deur middel van verskeie ontwerpsiklusse, soos voorgestel deur die *Design Science Research* raamwerk. Verskeie aspekte, insluitende teoretiese raamwerke, konsepte, elemente en aktiwiteite, is verkry uit die besigheidsmodel, besigheidsmodelinnovasie en waardenetwerke literatuurdomeine. Verder is insig verkry vanaf verskillende vakdeskundiges in die besigheids-en-vervaardigings-bedrywe. 'n Waardevisualiseringshulpmiddel is ontwikkel as deel van die bestuursraamwerk, waarna verwys word in hierdie studie as die *strategic business model configuration process*, om gebruikers te help om strategiese sakenette te visualiseer op strategiese en taktiese vlakke.

‘n Gevallestudie is gedoen om die toepaslikheid van die raamwerk te demonstreer. Die fokus was op die potensiële gebruik van *additive manufacturing* om gesementeerde wolfraamprodukte in die gereedskap industrie in Suid-Afrika te vervaardig. Die bevindinge wat gemaak is en insigte wat verkry is, kan potensieël ondersteuning bied aan toekomstige gebruikers en belangrike rolspelers in die bedryf om op voort te bou. Uiteindelik is die bestuursraamwerk omskep in 'n bestuurshulpmiddel met behulp van aanlyn sagteware wat gebruik kan word deur KMMO's, of entrepreneurs wat 'n opkomende tegnologiemark wil betree.

Acknowledgements

The support of the DSI-NRF Centre of Excellence in Strong Materials (CoE-SM) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the author and are not necessarily to be attributed to the CoE-SM.

I want to thank my supervisors, Prof Saartjie Grobbelaar and Prof Natasha Sacks, for their guidance and contributions to this study. My deepest gratitude to my mom, dad and brother for their unconditional support, patience, input, brainstorming, help, prayers, and love throughout my years at university. Thank you for always believing in me, pushing me to go the extra mile, and encouraging me to give my best in everything I do. I also want to thank my boyfriend, for always listening to my frustrations and endless to-do lists, comforting me, loving me, supporting me, wiping off tears, and allowing me to follow my dreams.

Finally, I want to thank my Heavenly Father for His never-ending favour and grace upon my life. I want to thank Him for being my pillar, my stronghold, and my refuge. May whatever I continue to do with this degree, always honour and glorify His Name.

Table of contents

List of figures

List of tables

List of acronyms and abbreviations

3D	Three-dimensional
3DP	3D-Printing
AM	Additive Manufacturing
AMS	Advanced Manufacturing System
AMTS	Additive Manufacturing Strategy for South Africa
ARA	Actors-Resources-Activities
ASTM	American Society for Testing Materials
BEE	Black Economic Empowerment
BJ3DP	Binder Jet 3D Printing
BM	Business Model
BMC	Business Model Canvas
BMI	Business Model Innovation
BoL	Beginning of Life
CAD	Computer-aided Design
CoE-SM	Centre of Excellence in Strong Materials
CPS	Cyber-Physical System
DfAM	Design for Additive Manufacturing
DSI	Department of Science and Innovation
DSR	Design Science Research
EoL	End of Life
EU	European Union
FIR	Fourth Industrial Revolution
GDP	Gross Domestic Product
I4.0	Industry 4.0
ICT	Information and Communication Technology
IIoT	Industrial Internet of Things
IoT	Internet of Things
IP	Intellectual Property
IS	Information Systems
ISTMA	International Special Tooling & Machining Association
IT	Information Technology
LPBF	Laser Powder Bed Fusion
MNE	Multi-national Enterprise
MoL	Middle of Life
MRQ	Main Research Question
NGO	Non-Governmental Organisation
NRF	National Research Foundation
OEM	Original Equipment Manufacturer
PSS	Product-Service-System
R&D	Research and Development
ROI	Return on Investment
SA	South Africa
SBN	Strategic Business Net
SDL	Service Dominant Logic
SLM	Selective Laser Melting
SLS	Selective Laser Sintering
SME	Small to Medium Enterprise
SMME	Small, Medium and Micro Enterprise

SRQ	Sub-Research Question
TDM	Tool, Die and Mould-making
VCS	Value Creating System
VN	Value Network
VRIN	Valuable, Rare, Inimitable, and Non-substitutable

Chapter 1: Introduction

Chapter 1 presents the background which serves as motivation for the research and briefly explains several important concepts central to this thesis such as business model (BM), business model innovation (BMI), value network (VN), small, medium, and micro enterprises (SMMEs), additive manufacturing (AM), and cemented tungsten carbides (or hardmetals). The motivation for this study, the research gap, as well as the research problem, emerged from the research background and was translated into relevant research questions and objectives. This chapter also provides a brief overview of the research design and document outline.

Chapter 1 key objectives:

- Provide the background of the study (Section 1.1).
- Introduce the most important concepts (Section 1.2).
- Provide the rationale of the study (Section 1.3).
- Identify the research gap addressed by the study (Section 1.4).
- Define the research problem (Section 1.5).
- State the research questions and objectives (Sections 1.6 and 1.7).
- State the research scope of the study (Section 1.8).
- Present an overview of the research design (Section 1.9).
- Outline the structure of the document (Section 1.11).

1.1 Background

Small, medium, and micro enterprises are the driving force of many developing economies, including South Africa (SA), and form an important part of the manufacturing industry with a significant impact on the successful introduction of Industry 4.0 (I4.0) technologies, such as AM [103, 152]. The adoption of these I4.0 technologies enables new products and services to be introduced by SMMEs, as they can fulfil both the role of a user and/or a provider of I4.0 technologies [159]. However, financial, technological, capacity, human resource [64], innovation and other constraints prohibit SMMEs from adopting the required technologies associated with I4.0. Due to these constraints, and numerous other challenges faced by manufacturing SMMEs, competitiveness does not only depend on a single firm anymore but requires several firms in the VN to interact and collaborate—including SMMEs [144].

The interaction, collaboration, and co-operation among multiple organisations lead to the formation of intentional, closed VNs, referred to as strategic business nets [154], which can partially be managed and controlled to be efficient [154]. This allows for the integration of capabilities and resources from different organisations (including the customer) to enable value co-creation and the delivery of joint offerings or solutions to customers. There are various advantages for SMMEs if they are involved in such a collaborative effort, such as "*increasing companies' skills, capacities and capabilities by sharing resources and becoming suppliers of complete systems, learning and exchanging essential information, the possibility to develop more complex products, increased global market share and decreased production cost, etc."* [70]. These strategic business nets are often associated with new ways of creating, delivering and capturing value, i.e., BMI [255]. However, innovating BMs to become network-based is no easy task, but rather a complex venture that is critical for the survival of many organisations [136] in today's ever-changing and intricate business environment.

Evident in the literature, the advancement of Information and Communications Technology (ICT) (leading to I4.0) has a great impact on both BMs and VNs [111, 131, 243]. Osterwalder [170] stated that there is a particularly strong link between ICT and BMs since ICT has been a strong enabler for a variety of innovative BMs. Therefore, technology concepts, such as AM, is fundamentally intertwined with the BM concept [26]. This co-evolution implies, in line with Baden-Fuller and Haefliger [18] as well as Bogers *et al.* [26], that technological developments directly influence certain BM decisions [26]. Due to the wide use of traditional manufacturing technologies and the limited availability of different AM technologies, manufacturing companies need to explore or experiment with new BMs based on emerging technologies [33]. These exploratory processes imply the presence of important interactions between technology and BMI [18], as well as the link to the organisation of production, including supply chains [27] and consequently VNs.

Therefore, SMMEs cannot consider the introduction and adoption of I4.0 technologies without considering the formation of strategic business nets as well as the development of appropriate BMs for these nets. The aim of this collaborative effort towards configuring the strategic business net and innovating the BM, referred to as *networked BMI*, is to ultimately create a 'win-win' solution for all partners. New, untapped sources of value creation can be identified and implemented through the adoption of BMI [13]. Accordingly, Chesbrough [47] stated, *"technological innovations are of little value without appropriate business models",* he went further and said, *"a good business model can even make an inferior technology more successful than a superior technology".* The importance of these BMI efforts, in response to market disruptions, has also been highlighted by the Covid-19 pandemic that forced all companies to take steps to innovate and pilot their businesses in response to this new reality [116].

There are various I4.0 technologies, but this study focuses specifically on the introduction and adoption of AM by SMMEs in South Africa. These emerging, and sometimes disruptive technologies, lead to new value creation amidst I4.0 [98] that must be captured. Although it is acknowledged that AM will not replace mass production processes any time soon, as a supporting and complementary technology, it can improve businesses by enabling the introduction of additional products and services. As such, it is important to understand that AM is not a single technology or a single application [88]. Additive manufacturing rather consists of different processes associated with different technologies and different materials, used in several application areas (and they all continue to develop [88]). Some of these process-technology-material combinations are still emerging and some have already developed into mature, profitable and widely accepted applications [88]. The focus of this study is how to approach the development of adequate strategic business nets and networked BMs for these emerging AM technologies, as part of networked BMI, to ensure business and market soundness as soon as the emerging technology is commercially feasible.

1.2 Concept introduction

There is no widely agreed upon definitions for most of the concepts addressed throughout this study, therefore the aim of this section is to briefly introduce and clarify the conceptualisations or definitions adopted within this study (discussed in more detail in Chapter 3).

1.2.1 Business model

One of the most cited definitions for a BM is provided by Osterwalder and Pigneur [171], "*a business model describes the rationale of how an organisation creates, delivers and captures value*". Furthermore, according to Al-Debei and Avison [6], "*value proposition, value architecture, value finance, and value network articulate the primary constructs or dimensions of business models*" [6]. The crucial element is, however, the generation of value. If the customer does not perceive value in the product or service, it will not be used and certainly not be paid for, as it is indeed the concept of value that determines the product or service's worth [134].

Pieroni, McAloone and Pigosso [184] built on the activity system perspective of a BM proposed by Zott and Amit [254], and defined a company's BM as *"a system of interconnected and interdependent activities that determines the way the company 'does business' with its customers, partners and vendors".* In other words, a BM is a *"bundle of specific activities — an activity system — conducted* *to satisfy the perceived needs of the market, along with the specification of which parties (a company or its partners) conduct which activities, and how these activities are linked to each other"* [184].

Given the networked-nature of the current economy, the BM concept is being challenged from serving merely as "[a] *blueprint of how a single company does business"*, as suggested previously by Osterwalder and Pigneur [171], to transforming it more into *"a blueprint that explains how network partners do business together and a platform at which partners may compensate for their own weaknesses by exploiting other network partners' competences and skills and tune its own competences to the other network partners' core competences so as to achieve synergetic, network-level benefits"* [136]. In agreement with Laya, Markendahl and Lundberg [129], this study partially followed the proposition suggested by Palo and Tähtinen [177], that a network-level BM is, therefore, a collective BM which *"guides how a net of companies will create customer and network value by developing a collective understanding of the business opportunities and shaping the actions to exploit them".*

For this study, the view of the BM as a set of linked activities or functions, to explain value creation and value capture [255] (including strategic, market, and customer components [246]) but expanding it to value co-creation [161], where new customer value creation is co-shaped by organisations and other key players [236] to achieve a competitive advantage, is adopted. Using the scheme of analysis proposed by Bankvall, Dubois and Lind [20] and presented by Jocevski *et al.* [111], the focus of this study is on network-centered (centric) BMs, analysed from a network-level (or network perspective), meaning *"VN configuration to create and deliver a common value proposition"* [111]. It is argued that the BM elements are essentially the same as at the firm-level but need some additional elements to make it more comprehensive in order to stress the power of synergy and collaboration to enable innovation. Furthermore, this study, in line with Laya *et al.* [129], argues that the concepts of *"network business models"* [124], *"networked business models"* [176, 177] *"network-centric business models"* [20], *"network-embedded business models"* [20], and *"ecosystem business models"* [243] reflect the same viewpoint of developing and aligning the value creation process from a network perspective.

1.2.2 Business model innovation

Business model innovation refers to a more dynamic view of the BM and Foss and Saebi [75] provided the following frequently cited definition, "*BMIs are designed, novel, non-trivial changes to the key elements of a firm's business model and/or the architecture linking these elements*" as a response to internal and external incentives. Considering this commonly used definition, Weking, Stöcker, Kowalkiewicz, Böhm and Krcmar [242] argued that *"designed"* implies that BMI is a deliberate change to a current BM and *"novel, non-trivial changes"* excludes minor changes, such as a change in a supplier, to existing BMs. Foss and Saebi [75] also noted that BMI can be approached as static or dynamic. Where the dynamic view conceptualise it as an organisational change process requiring appropriate capabilities, leadership, and learning mechanisms whereas the static approach, view BMI as new types of innovative ventures that may affect firm performance [75].

For this study, the BMI endeavour is viewed from a dynamic perspective, and the definition provided by Foss and Saebi [75] is adopted, regarding BMI as a process, being a combination of BM design and BM reconfiguration, or in other words the process of developing the BM on a network-level.

1.2.3 Value network

Michael Porter popularised the value chain concept through his studies on competitive advantage [186]. The value chain framework aimed to enable strategic thinking about business activities in terms of costs and contribution [134]. While the early literature on value chain analysis focused on cost reduction and competitive positioning, and the literature on BMs focused on maximising profit, the need was recognised to extend the focus to address more complex value capture [134]. Consequently, the concept of VN emerged [134].

To clarify the difference between the concepts of value chain and VN, simply put, the term ‘chain’ refers to sequential flow while a ‘network’ implies multi-dimensional connectedness [224]. In broad terms, a VN can be regarded as a set of actors (called nodes) involved in the value creation with relationships (called connections or links) among them [164], aiming to achieve a common goal or central value proposition [22, 160]. Furthermore, the concept of business ecosystems has evolved from VNs [134]. Although the concepts are slightly different, a few parallels can be drawn between VNs and business ecosystems [134]. Business ecosystems can be defined as *“networks of firms that collectively produce a holistic, integrated technological system that creates value for customers”* [4].

According to Heikkilä and Kuivaniemi [100], the key difference between VNs and business ecosystems is the variety of actors included in the boundaries of the system. Value networks are generally regarded as organisations that collaborate to deliver value to a customer, while business ecosystems usually include additional actors such as competitors, suppliers, potential collaborators, public institutions, and investing firms [134]. Nevertheless, other scholars suggest that both concepts can indeed be the same object of study [129].

Within the VN literature, there are two views on networks, the ‘networks of organisations’ view and the ‘network organisation view’ [2]. This study however adopts the ‘network organisations view’, viewing network organisations with deliberately created structures, negotiated roles and goals which can indeed be partially managed to be efficient [154]. To distinguish between these two views on networks within the literature body, Möller and Rajala [154] refer to the ‘network organisations view’ as intentional business networks, called nets, value nets, or strategic nets.

Therefore, the focus of this study is on intentionally formed VNs with a finite set of parties that can be partially managed and controlled to be efficient [154], in this study referred to as *strategic business nets*, that aim to collaborate to achieve joint goals. This definition, therefore, excludes open, self-evolving, self-managed or unmanageable VNs. The strategic business net aims to gain or sustain a competitive advantage [154] through collaboration among competitors to increase capacity, co-operation with customers to develop focused competencies, and collaboration with partners that provide access to complementary competencies and resources [103]. The actors involved within these networks co-operate for business strategic development, and the companies involved remain legally and economically independent [103].

1.2.4 Small, medium, and micro enterprise

Although the terms SME (small to medium enterprise) and SMME are used interchangeably worldwide, there are no commonly used definitions for these terms [207]. However, in the South African manufacturing industry, SMMEs are classified as enterprises with less than 250 full-time employees and a total annual turnover of less than R170,0 million [38]. Although multi-national enterprises (MNEs) contribute significantly to the South African economy, it is estimated that the SMEs sector employs between 50 and 60 percent of the workforce across all sectors and contributes approximately 39% to the South African gross domestic product (GDP) (including some larger SMEs that have an annual turnover of less than R500,0 million) [116]. Therefore, the impact of SMEs or SMMEs is vital as they help to mitigate poverty, create jobs, and enable inclusive economic growth [116]. However, throughout this study, the term SMME is mostly used, aiming to include manufacturing SMMEs and SMEs, but specifically excluding the informal sector.

1.2.5 Additive manufacturing

Additive manufacturing technologies are also referred to as *"rapid prototyping, solid freeform manufacturing, layer manufacturing, digital manufacturing or 3D printing"* [50]. It refers to the process of manufacturing products layer-by-layer from three-dimensional (3D) model data instead of traditional manufacturing processes [17]. According to the American Society for Testing Materials (ASTM), there are primarily seven categories of AM technologies namely: *"binder jetting, directed energy deposition, powder bed fusion, sheet lamination, material extrusion, material jetting, and vat photo polymerisation"* [17]. Each of these consists of several distinct processes and are associated with different technologies and materials [17], therefore it is important to understand the process-technology-material relationship when identifying possible parts to be manufactured using AM. The focus of this study is, however, specifically on metal AM of which powder bed fusion, directed energy deposition, and binder jetting processes (the first two being the most dominant methods) are considered [17]. Furthermore, the metal material to which research findings are specifically applied is cemented tungsten carbide.

1.2.6 Cemented tungsten carbide

Cemented tungsten carbide, developed in 1925, is widely regarded as the hardest man-made metal-matrix composite material [67]. Tools for metal cutting and rock drilling are widely manufactured using cemented tungsten carbide [24] and comprises more than 65% of the material's usage [80]. Tungsten carbide cobalt composite materials are so-called hardmetals and is widely used in hard-facing applications such as cutting tools (turning, milling, drilling) for the machining of metal components [80]. Significant features of tungsten carbides include their wear resistance, high level of hardness, flexural strength, and fracture toughness properties [130]. Hardmetals have several superior properties compared to other materials, such as the ability to withstand deformation, impacts, heavy loads, high pressures, corrosion, and high temperatures. Due to its high wear resistance properties, this material has been used for products used in the medical, agricultural and several other industries [130].

The largest tungsten producer is China [130]. This places a huge burden on emerging manufacturing countries, including South Africa, because of the high importing costs due to tightening export restrictions in China [130]. Furthermore, the supply of tungsten is at risk as it is expected that worldwide tungsten reserves will be depleted in 40 years, leading to a decrease in production since 2012 [130].

Unlike other metal parts, tungsten carbide hardmetal parts are manufactured by the powder metallurgy technique which includes complex sintering processes [78]. This process technology has some limitations on geometrical freedom which poses a challenge due to the increasing demand for more complex shapes (including complex cooling structures) [78]. It is currently a time- and cost-intensive process to produce special interior contoured tools made of cemented carbide, only achievable to a limited extent on a large scale [78].

The increasing demand for individual, customised products leads to the need for alternative economic, flexible, and automated production, provided by AM [232]. Additive manufacturing has the potential to replace or complement traditional manufacturing methods, but for the case of tooling products, AM will most probably fulfil a complementary role, leading to potential hybrid manufacturing approaches. Such integrated approaches eliminate the limitations of individual processes while aggregating their advantages [139]. In the context of this study, a hybrid process refers to the combination of traditional manufacturing methods, together with AM process steps to produce the final part.

The production of tungsten carbide hardmetal parts using AM processes are associated with challenges regarding various control variables like temperature, pressure, time, atmosphere, and rate of heating and cooling which can alter the microstructure and mechanical properties of the final product [175]. Therefore, until recently, it was believed that it is either impossible to manufacture tungsten carbide parts using an AM process, or it is impossible for the manufactured parts to meet the prerequisites and fulfil the functional requirements [175]. However, according to the review conducted by Padmakumar [175], researchers have recently overcome the main challenges and succeeded in finding techniques to manufacture tungsten carbide parts with properties close to their conventional counterparts, but these parts are not able to replace their conventional counterparts yet [175], therefore it is still emerging and an ongoing research field.

1.3 Research rationale

Additive manufacturing technologies are used by various industries in South Africa. Since the 1980s, these technologies were developed and used primarily for prototyping applications to test ideas before going to market. The focus was on the manufacturing of polymer and resin parts that have limited applications and potential. However, over the past few years, the use of AM technologies to manufacture real production parts have increased. By 2014, final parts manufactured had grown from 3.9% to 42.6% of the total product and service revenues from AM. [60]

When it comes to new technology adoption, it is known that emerging economies have even more constraints and barriers than developed countries. When comparing South Africa to the rest of the world, the current adoption and impact of I4.0 are still relatively limited [102]. This is due to a variety of challenges related to: *"(i) the economic environment; (ii) the adoption of smart technology; (iii) the collaboration between industries, research institutions, and governments; (iv) education and awareness of I4.0; and (v) the high percentage of unskilled workforces being employed"* [102]. Therefore, the Department of Science and Innovation (DSI) commissioned the development of the National Advanced Manufacturing Technology Strategy for South Africa (AMTS) for the period 2014-2023 to speed the adoption rates up [60].

"AM for impact on traditional manufacturing sectors" is identified as one of the four key industrial focus areas of the strategy [60]. This focus area concerns the traditional manufacturing technology sector and the establishment of advanced AM technology within this sector [60]. There is a rising need in South Africa to find alternative solutions to manufacturing challenges concerning custom products and services, therefore it is imperative to explore the possibility of producing functional components using AM [232]. The introduction and establishment of AM within this sector will support the local industry to save on tooling costs, assist the industry to provide new products to the market more quickly, as well as to support the industry to reduce maintenance, repair and overhaul budgets through the development of AM-based refurbishment technologies [60].

As part of the implementation of the AMTS, the DSI-National Research Foundation (NRF) Centre of Excellence in Strong Materials (CoE-SM) launched several projects relating to AM of cemented tungsten carbide (hardmetal) products – this research study is one of them. In addition to the background presented, the researcher conducted a scoping review to inform the research gap and problem statement below. The results and findings of the scoping review were published as a conference paper in the proceedings of the IAMOT 2020 conference (see van Heerden, Grobbelaar and Sacks [230]).

1.4 Research gap

A key challenge for manufacturing SMME and other role-players in the transformation of their value offering (due to I4.0 technology adoption) is having the correct BM to create, deliver, and capture value. History has shown that technological evolution without adequate BM evolution is a pitfall for many organisations [192]. However, many SMMEs do not have sufficient resources to identify, assess, adapt, and incorporate new technologies and implement new business strategies and BMs. Unfortunately, given the economic situation of the country amidst the worldwide Covid-19 pandemic, many SMMEs in South Africa lack in-house skills or the ability to afford external business advisory services to advise them on structural business changes or to help them to reinvent their businesses at this time of change [116].

Due to the impact of AM on SMMEs in South Africa [60], together with the potential lack of strategic guidance on restructuring their businesses amidst disruptive change [116], as well as the lack of mature, systematic development procedures within SMMEs [144], it is important to focus research studies on the development of self-explanatory methods and tools to guide the strategic development and growth of these SMMEs. These methods and tools need to follow a structured approach to support SMMEs that cannot necessarily afford comprehensive external advisory services in their business transformation endeavours.

Within the BM literature, the elements of a BM are in general explored from a single firm's perspective, only a few employ the network perspective, whereas most adopt the perspective of a firm within the network [176]. Pieroni *et al.* [184] stated that the majority of methods and tools contained in BM frameworks still adopt organisational boundaries, and consequently they suggested that future research should explore how to take the inter-organisational or societal boundaries into account.

It is furthermore evident that attention is emerging towards the need to build a business from a perspective that involves all the firms that participate in the creation and delivering of an offering, as established theories and current BM frameworks are not comprehensive enough to describe network-based businesses [20, 111, 160, 243]. These existing theories and frameworks are inadequate to describe joint value architectures as they do not consider additional considerations such as a joint value proposition, different actors, roles, and value flows within a network [111]. Therefore, alternative views that are grounded in different theoretical foundations of firm interconnectedness (such as the actors-resources-activities framework [96] or VN analysis methodology [12]) , have been proposed by researchers as a more appropriate BM perspective for developing joint offers and understanding to pursue business opportunities in networks [111].

Laya, Jocevski, Ghezzi and Markendahl [128] argued that a network view is of particular interest for services that are based on ICT, in which a set of actors is actively involved in different stages of the development and delivery of the service. In a separate study, Jocevski *et al.* [111] however noted that there is potential in many other industries where the network-oriented view of BM would be useful, besides the ICT context. Therefore, this research study argues that the network-based view is of interest in the AM domain because of the involvement and participation of various firms to produce a single product and/or service.

The continuous increase in networked technologies and connections between different devices (also known as the Internet of Things (IoT)) lead to an increase in the interest of VNs in the form of industrial networks [20] or IoT networks and open (innovation) networks, which enable mobile BMs, e-business models [160], and network-centric BMs [131, 243]. These types of BMs are closely associated with platforms, or multi-sided BMs and collaborative platforms in open innovation or open business (market) environments, which has been trending in BM literature over the last few years [26, 205, 246].

Accordingly, Savolainen and Collan [200] identified two co-existing streams of academic literature on how AM-technologies will shape the business of manufacturing: *"1) The incremental change stream, where current industry players can enhance their earnings and position on the markets by utilising AM- technologies, and 2) The disruptive change stream, where AM is expected to have a radical effect on the current distribution of economic value in the manufacturing industry".* In response to these two scenarios, the authors investigated their effect in closed (focusing on internally developed innovations and intellectual property (IP) protection) and in open (focusing on open innovation and shared knowledge) market models. Savolainen and Collan [200] however concluded that due to the conceptual nature of AM technology, incremental AM adoption in closed business environments, leading to 3D printing service providers that operate via original equipment manufacturer (OEM)-controlled digital platforms to support spare parts service, will be most likely in the future [200]. The authors added that "*the open business models promoting the sharing of IP rights (acquired through paid efforts) and ignorance of quality requirements do not resonate with the common sense of either the manufacturers or the end-users" [200].* Therefore, this study is focused on networked BMI (including the configuration of strategic business nets and networked BMs) in closed business environments, whether the incremental or disruptive change stream is applicable.

Although AM technology has existed for almost three decades, academic research on it from a business or supply chain (including VN) perspective, has only begun recently and is still in an emerging, exploratory phase [169]. Öberg, Shams and Asnafi [165] aimed to clarify the current knowledge and missing perspectives on AM and BMs. Their study found that academic discussions on BMs focus on changes to the content (activities) of BMs, specifically related to production, and a few examples include changes in governance (who does what) in supply chain structures. Consequently, they concluded that it seems like the holistic BM influence due to AM are not described in previous research [165].

Furthermore, the use of AM to produce cemented tungsten carbide products (including tooling products) is still in the research and development (R&D) phase as the technology is not mature enough yet to be commercially feasible. The investigation of how to approach the introduction of this novel technology into the identified sector from a holistic, business and VN perspective is therefore of utmost importance to ensure alignment between the technology and BMs.

Based on the above section, it can be concluded that there is a gap in the identified literature to consider inter-organisational boundaries in the application of BM and BMI methods and tools [184] as current theories and frameworks are adequate on a firm-level, but not adequate and comprehensive enough to be applied to a network-level [111]. Therefore, there exists a gap in the literature on how to navigate networked BMI in a holistic and systemic approach. Addressing this gap in the literature firstly, will enable the researcher to address the second gap identified in the literature regarding the contextual application of this study, i.e. SMMEs need systematic development procedures [144] to guide them on how to innovate their BMs from a VN perspective to aid with the adoption of AM as part of restructuring their businesses in response to market disruptions.

1.5 Problem statement

The need exists to develop a framework for SMMEs, which contains appropriate processes, steps, activities, tools, and considerations, on how to holistically approach business model innovation from a VN perspective, in this study referred to as *networked BMI.* Such a networked BMI framework need to provide SMMEs guidance on the configuration of strategic business nets which are aligned with associated networked BMs and well as the emerging technology (in this case AM). The framework must ultimately be valuable and applicable to manufacturing SMMEs in South Africa that want to adopt AM, in this case, metal AM to produce cemented tungsten carbide (hardmetal) products.

1.6 Research questions

Based on the research gap and problem statement, the following main research question (MRQ) was formulated:

What main concepts, processes, steps, activities, tools, and considerations need to be included in a networked business model innovation framework and tool to support SMMEs in the development and configuration of their value networks and networked BMs, with application value to the adoption of AM within South African hardmetals sector?

To answer the above main research question, the following sub-research questions (SRQs) were formulated:

1. What relevant definitions, frameworks, elements, and concepts are available in each literature body (BM, BMI and VN) to support the framework development? (SRQ1)
2. What are the main influences of AM on SMMEs, the BM, BMI and the VN that could support the framework development? (SRQ2)
3. What is a possible hierarchical taxonomy for the networked BMI concept? (SRQ3)
4. What is a possible concept map of theory to visually illustrate the networked BMI concept? (SRQ4)
5. What are the key conceptual findings that need to be integrated into a conceptual framework? (SRQ5)
6. What aspects must be included in a potential management framework, based on the conceptual framework and external evaluations? (SRQ6)
7. What insights can be obtained through the demonstration of the management framework within the context of this study? (SRQ7)

1.7 Research objectives

This study aims to systematically develop a BMI framework (and converting it into a management tool) from a value network perspective to support SMMEs to configure strategic business nets and develop appropriate networked BMs, with application value to the prospective cemented tungsten carbide AM industry in South Africa.

To achieve the aim of this study and effectively answer the research questions, the following research objectives, described in Table 1.1, are pursued.

Table 1.1: Study objectives pursued in the study

Study objectives	Associated research question
1. To *conduct* a structured literature review on BMs, BMI, VNs, SMMEs, and AM, specifically: a. To *identify* the relevant definitions, frameworks, elements, and concepts (BM, BMI, VN). b. To *select* the most applicable existing theoretical frameworks as the study's theoretical foundation (BM, BMI, VN). c. To *identify* and *select* the fundamental concepts that form part of the networked BMI concept (BM, BMI, VN). d. To *identify* possible relationships between the fundamental concepts (BM, BMI, VN).	SRQ1
e. To *identify* the main influences of AM on each of the other concepts (BMs, BMI, VNs, SMMEs).	SRQ2
2. To *develop* a hierarchical taxonomy of the networked BMI concept, specifically: a. To *identify* possible facets and classes towards a taxonomy for the networked BMI concept. b. To *identify* possible relationships between the facets of the taxonomy.	SRQ3
3. To develop a concept map of theory, specifically: a. To *identify* key elements from the existing theoretical frameworks for a concept map of theory. b. To *design* a concept map of theory through the integration of the selected elements.	SRQ4
4. To develop a conceptual framework, specifically: a. To *analyse* and *integrate* the research results by *designing* a conceptual framework.	SRQ5
5. *To develop* a management framework, specifically: a. To *convert* the conceptual framework into a management framework. b. To iteratively *develop* and *evaluate* the management framework using appropriate methods.	SRQ6
6. To *demonstrate* the functionality of the framework to support SMMEs in the introduction and adoption of AM, specifically to produce cemented tungsten carbide products.	SRQ7

Study objectives	Associated research question
7. To *convert* the management framework into a management tool. 8. To *recommend* areas of future research related to this study that may be pursued in the future.	

1.8 Research design overview

The Design Science Research (DSR) framework was selected to guide the overall research process followed throughout this study. A summary of the research design, consisting of five phases, is depicted in Figure 1.1 below. During the first phase, the research was defined by providing an overview of the background of this study, establishing the research gaps, defining the questions and objectives (Chapter 1), and formulating the research design methodology (Chapter 2). Phase two identifies the theoretical building blocks of the framework through a structured literature review (Chapter 3) and includes the systematic development of the research artefacts on which the management framework is based (Chapter 4).

The third phase focuses on the final integration and synthesis of the theoretical findings through the development of the *strategic business net (SBN) configuration process* (Chapter 5) which forms an integral part of the management framework as a VN visualisation or mapping tool. The synthesis also includes the design and development of the conceptual framework. The phase is concluded by conducting preliminary evaluation of the SBN configuration process and the conceptual framework (Chapter 5). During phase four the conceptual framework is converted into a management framework (Chapter 6) and the framework is iteratively developed and evaluated, whereafter its value is demonstrated within the contextual application domain of this study (Chapter 7). Phase five consists of the conversion of the final management framework into a management tool (Chapter 8), as well as the conclusion of the study (Chapter 9).

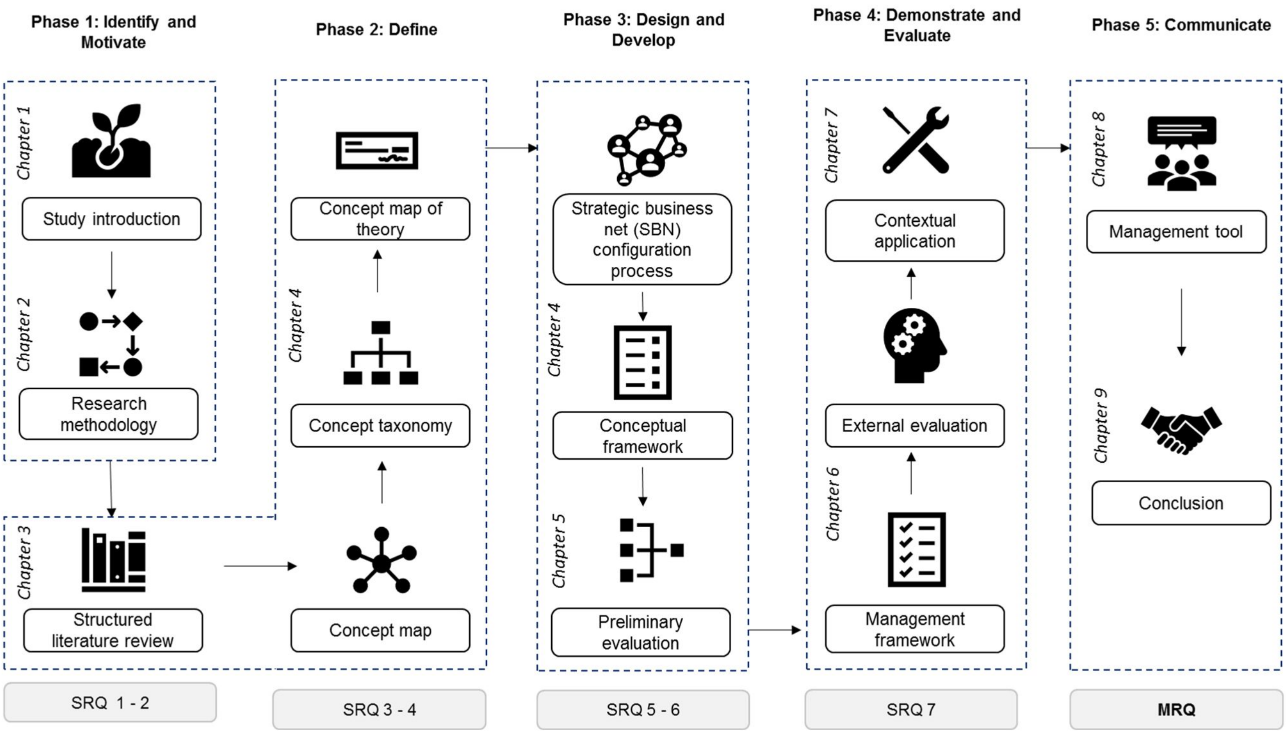


Figure 1.1: Summarised research design

A detailed discussion of the research design and methodology is presented in Chapter 2.

1.9 Research scope

This study considers three primary overlapping research domains for the development of the framework namely: business model, business model innovation, and value network. The environment (contextual application area) provides the context and scope of the problem that is addressed by the research and can be illustrated by the intersection between the research domains of additive manufacturing, SMMEs and South Africa. The relationship between these research domains and the primary project aim is depicted in Figure 1.2.

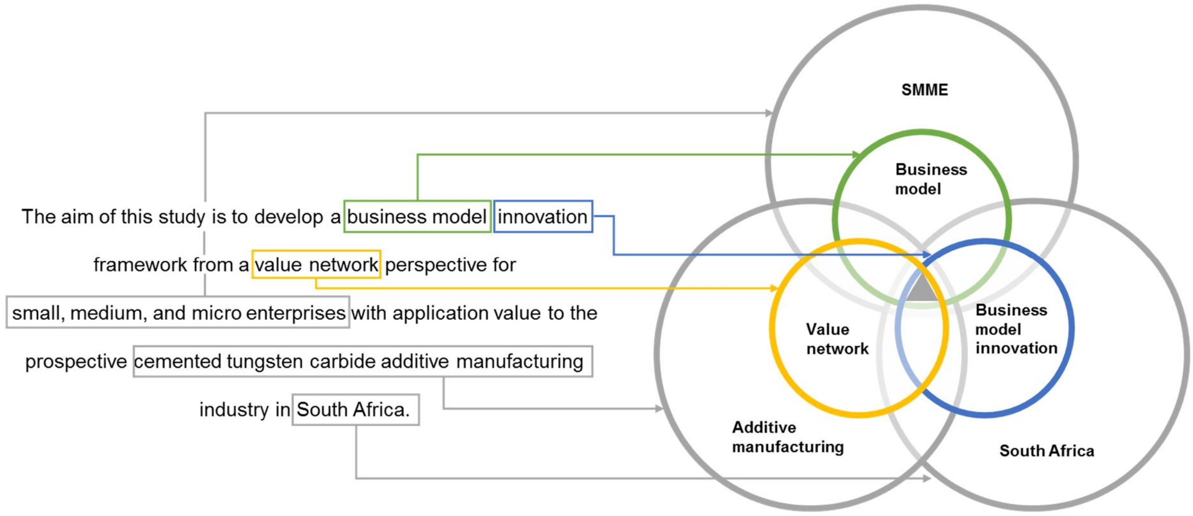


Figure 1.2: Relationship between the project aim and the primary domains of the study

Due to the complexity associated with each of the relevant domains as well as the various closely related literature bodies, this study's scope is limited to the following to ensure the most feasible outcome, given the time constraints of this study:

- **Business model:** Firm-level and network-level BMs are included. Other types of BMs such as e-BMs, mobile BMs, platform BMs, collaborative BMs, joint business models (co-BM) etc, are excluded.
- **Business model innovation:** BMI as a process (e.g., search, experimentation, transformation) [75], including BM design and configuration, or BMI as the BM development process are included. Business model innovation as just an outcome (i.e., the innovative BM) [75] and co-BMI frameworks, etc. are excluded.
- **Value networks:** Closed VNs, formed with intention, consisting of a finite set of actors that can be partially managed and controlled that aim to collaborate and achieve joint goals are included. Collaboration networks, responsive supply chains, distributed manufacturing, and collaborative manufacturing models, are all closely associated with VNs due to the degree of integration within these networks and models, however, these networks and search terms were not specifically included to remain within the boundaries of what the study wants to achieve. Open innovation networks, self-evolving, unmanageable etc. networks as well as smart supply chains are excluded.
- **Additive manufacturing:** SMMEs wanting to adopt AM, including possible entrepreneurs are included. Multi-national enterprises that want to adopt AM are excluded.

1.10 Ethical considerations

Human participation in the form of interviews were required in the evaluation phases of this study, therefore ethical clearance was obtained. To ensure the research results are applicable, relevant, and accurate, data from external parties were obtained.

It is acknowledged that some of the information might be confidential, in which case the researcher ensured that no confidential information or data was disclosed. All guidelines prescribed by Stellenbosch University were followed to ensure nobody was harmed in the execution of this project. Ethical clearance was granted for this study by the REC under SU project number **21714.** The researcher took note of the following:

1. The participation in this study was completely voluntary and any participant was free to withdraw at any time.
2. The researcher was responsible for obtaining consent from participants before data collection.
3. The participants were not forced to answer any questions they did not feel comfortable with.
4. All information disclosed during the study remained confidential and was stored in a secure location.
5. No personal information of any participant was disclosed.
6. The researcher obtained verbal consent from the participants to make a recording of the interview.

The interviews were conducted during the Covid-19 pandemic, thus the principle of *primum non nocere* or first, do no harm was adopted; therefore, all interviews were conducted electronically via the Zoom or Microsoft Teams platforms to avoid physical contact.

1.11 Document outline

Chapter 1: Introduction

The introductory chapter introduces the context of the project and gives an overview of the main concepts of this study. This chapter motivates the study and presents the research gap which leads to the problem identification, research questions and objectives. An overview of the research design is given followed by an overview of the outline of the document.

Chapter 2: Research design and methodology

The research design and methodology followed throughout this study is presented in Chapter 2. This chapter includes the discussion of the Design Science Research framework used as well as the details regarding the research design based thereon. In addition, the various research methods used to complete this study are also discussed.

Chapter 3: Structured literature review

A structured literature review is conducted in Chapter 3, based on the identified research scope. During the reporting of the review, SRQ1 and SRQ2 are answered. The findings and answers to the sub-research questions formed the basis of the theoretical concept maps and frameworks designed in the following chapters. The thorough review of literature ensured the framework is rigorous and based on adequate theories and theoretical frameworks.

Chapter 4: Theoretical integration and synthesis

Chapter 4 extends the foundational work done in Chapter 3, through the integration and synthesis of the theoretical findings into a concept map, hierarchical taxonomy (SRQ3) and concept map of theory (SRQ4). As part of the design of the conceptual framework, the SBN configuration process is developed as a VN visualisation tool to address the need for a value mapping tool on both the strategic and tactical levels of the network. The chapter is concluded by providing the initial design of the conceptual framework, answering SRQ5.

Chapter 5: Preliminary evaluation

The SBN configuration process is evaluated using a real-life example (scenario) in Chapter 5 to ensure the application feasibility thereof. The internal evaluation of the conceptual framework, using the hierarchical taxonomy designed in Chapter 4 as a set of requirements, is also presented in this chapter.

Chapter 6: Management framework

In Chapter 6, the management framework is iteratively developed and evaluated (SRQ6) using different categories of subject-matter experts. The external evaluation is conducted using semi-structured interviews and questionnaires. A selected group of experts from the business category evaluated the hierarchical taxonomy, the concept map of theory, the SBN configuration process, as well as the management framework. After the framework was evaluated from a business perspective, it was evaluated from a manufacturing (including AM) perspective. Whereafter subject-matter experts from both categories completed a questionnaire to rate the effort and importance of the networked BM elements, strategic business net features, and activities included in the framework. The chapter concludes with a discussion of the results obtained from these ratings.

Chapter 7: Contextual application

In Chapter 7 the context of the study is investigated and a selection of applicable steps within the management framework is executed to demonstrate the functionality of the framework (SRQ7). The aim is to provide insights, as well as business and management guidance for potential manufacturing SMMEs regarding the development of strategic business nets and an adequate networked BM within the identified industry to adopt the emerging technology under investigation.

Chapter 8: Management tool

In Chapter 8, the motivation and purpose for the development of a management framework and management tool are reflected on, and an overview of the overall development process is provided. Thereafter, the final management framework is presented followed by the presentation of certain aspects of the management tool. The facilitation and use of the management tool are also discussed.

Chapter 9: Conclusion and future work

Chapter 9 concludes the research study presented in this document. A summary of the research process is presented, followed by a discussion on the realisation of the project's research questions and objectives. The study's contributions and limitations are discussed and finally, a few suggestions for future work based on this study are provided.

1.12 Conclusion: Chapter 1

Developing a BMI framework from a VN perspective to support SMMEs to configure strategic business nets and develop appropriate networked BMs, with application value to AM within the cemented tungsten carbide industry in South Africa, will lead to possible industry development and strengthening if research findings are leveraged by the correct industry players.

In this chapter, the background and overview of the study and key concepts were provided. The research gap and rationale were discussed, followed by the research problem, questions, and objectives the study aims to address. A brief overview of the research design was included, and the ethical considerations were given. This chapter concluded with an overview of each of the chapters contained within this document. The following chapter discusses and presents the research design and methodology.

Chapter 2: Research design and methodology

Chapter 1 clarified the need for the development of a BMI framework from a VN perspective (networked BMI) for SMMEs with potential application value to the prospective cemented tungsten carbide AM sector of South Africa. Chapter 2 aims to discuss the research design and methodology that guided the researcher in addressing the research questions and achieving the research objectives in more detail. The management framework was developed in a stepwise manner using Design Science Research, and the evaluation thereof adopted a similar approach.

Chapter 2 key objectives:

- Provide an overview of the research paradigms (Section 2.1).
- Provide an overview of the different research approaches (Section 2.2)
- Introduce Design Science Research (Section 2.3).
- Present the research design and methodology for this study (Section 2.4).
- Provide an overview of the research methods applied (Section 2.4).

2.1 Research paradigms

Kuhn [126] defined a research paradigm as *"the set of common beliefs and agreements shared between scientists about how problems should be understood and addressed".* Gliner, Morgan and Leech [89] described the scientific research paradigm as *"the approach or thinking about the research, the accomplishing process, and the method of implementation".* Therefore, the research paradigm provides direction for the research process and is more a philosophy than a methodology. A research paradigm or philosophical position comprises of the entire set of theoretical and methodological (ontological and epistemological) assumptions the specific research is based on [179]. Each research paradigm can be described according to its ontology, epistemology, methodology, methods [179] and axiology [228]. The selection of an appropriate research paradigm is, therefore, essential [34] as it guides the researcher's approach and the perspective taken.

Ontology and epistemology ensure the researcher creates a holistic view of how knowledge is viewed and how one can see oneself in relation to this knowledge, as well as the methodological strategies used to un/(dis)cover it [179]. Ontology is concerned with the nature of reality or issues that pertain to what exists [23] while epistemology questions what the conditions (nature, limitations and justification) should be for acceptable knowledge in a discipline [34]. The awareness of philosophical assumptions will assist the researcher with creativity and will ultimately improve the research quality [179]. Finally, axiology describes what is regarded as valuable [228]. Figure 2.1 below explains the difference and relationship between the terms associated with the scientific research paradigm.

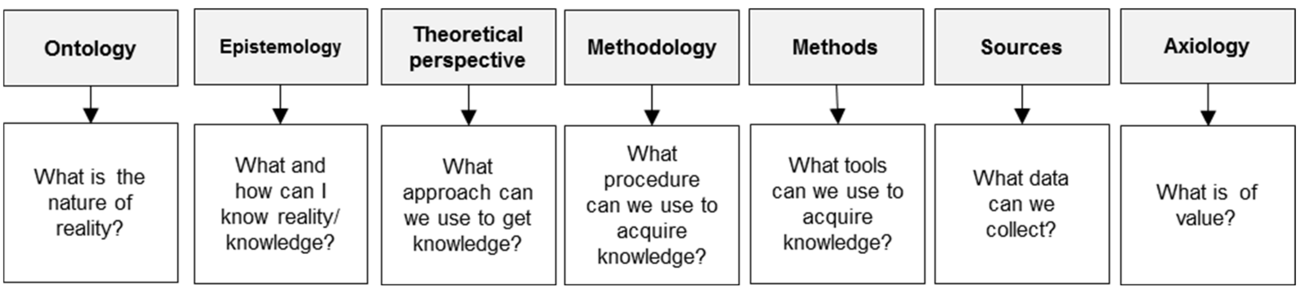


Figure 2.1: Relationship between terms associated with the scientific research paradigm (adapted from [179])

Positivism, interpretivism, and design are three of the major research paradigms which were considered for this study. However, Hevner, March and Park [107] as well as March and Smith [140], associate design science with a pragmatic philosophy. Accordingly, Hevner [105] added that design science research is essentially pragmatic in nature due to its emphasis on relevance; making a clear contribution to the application environment. The three paradigms, as described by Vaishnavi and Kuechler [228], are summarised in Table 2.1 below.

Table 2.1: Philosophical assumptions of the three research perspectives [228]

Basic belief	Research perspective		
	Positivist	Interpretive	Design
Ontology	Single reality that is knowable, probabilistic.	Multiple realities that are socially constructed.	Multiple, contextually situated alternative world-stated which are socio-technologically enabled.
Epistemology	Objective; dispassionate.	Subjective, i.e. values and knowledge emerge from the researcher-participant interaction.	Knowing through making: objectively constrained construction within a context. Iterative circumscription reveals meaning.
Methodology	Observation; quantitative, statistical.	Participation; qualitative. Hermeneutical, dialectical.	Developmental. Measure artefactual impacts on the composite system.
Axiology	Truth: universal and beautiful; prediction.	Understanding: situated and description.	Control; creation; progress (i.e. improvement); understanding.

The positivist and interpretive research paradigms are generally described within the natural science domain since both are concerned with knowledge about objects and phenomena in nature or society [206], cited by Vaishnavi and Kuechler [229]. Whereas the design paradigm can be described as *"science of the artificial"* since it is concerned with the construction of objects and phenomena, referred to as artefacts, which aim to meet specific desired goals [229]. Consequently, it is concluded that this study is grounded in the design paradigm as it aims to develop artefacts to meet specific goals.

Within the design paradigm, knowledge lies in the utility of the artefact, i.e., to guide and support SMMEs in the process of developing feasible business opportunities with adequate networked BMs and strategic business nets. Furthermore, the development process is objectively constrained within a context. For this study, the context is defined as SMMEs located within South Africa that want to introduce and adopt emerging technologies such as AM.

2.2 Qualitative and quantitative research approaches

There are primarily two reasoning methods that describe the relationship between theory and research, namely inductive and deductive. In short, when following a deductive approach, theory guides the research, and when following an inductive approach theory is the outcome of the research [34]. Furthermore, the research could be approached using the qualitative, quantitative, or mixed-methods approach. The quantitative research approach is commonly associated with the deductive reasoning method as it involves a theory or hypothesis to be tested and revised based on the findings [34]. Whereas the qualitative approach is often associated with the inductive reasoning method as it refers to the development of a theoretical understanding of a phenomenon based on data such as interviews and focus groups [34].

Qualitative research is primarily exploratory and aims to understand the underlying motivation of social problems encountered by individuals and groups [56]. This research method aims to develop and refine concepts throughout the research process by collecting and analysing non-numerical data from research participants [34]. Data collection is often focused on a limited number of respondents who have carefully been selected to participate because of their specific knowledge base [34]. The data can be collected through various methods, such as individual interviews, group discussions, or multi-case studies [34]. After the data is collected, the researcher focuses on analysing the data from individuals or groups, together with their interactions, communications, and experiences, and aim to provide possible explanations to it [34, 90].

Quantitative research involves the collection of numerical data where researchers focus on measurement, causality [90], generalisation, and replication [34]. Where measurement refers to the *"ability to reliably measure concepts",* and causality refers to *"thinking about both the cause and effect"* [34]. Generalisation aims to *"generalise the findings beyond the research context"* and replicability refers to *"requiring explicit methods in order to enable other researchers to precisely replicate the study conditions*" [34]. To identify inherent patterns within data, measurable data is required. To verify or test a theory, quantitative research investigates the relationships among variables [56]. In conclusion, qualitative and quantitative research studies differ in purpose, approach, data collection, and independence of the researcher [34, 56].

The mixed-method research approach is not a replacement but rather a combination of the quantitative and qualitative research methods [244]. The mixed-method approach makes use of numerical and non-numerical data when trying to answer a research question. Furthermore, the researcher can utilise the advantages of both research methods throughout the study. Table 2.2 summarises the key differences between the two primary research approaches.

Table 2.2: : Key differences between the two research approaches (adapted from [34])

	Qualitative	**Quantitative**
Ontological orientation	Constructionism	Objectivism
Epistemological orientation	Interpretivism	Positivism
Reasoning method	Inductive	Deductive
Nature of study	Exploratory	Descriptive and casual
Type of data	Non-numerical data; words; pictures; actions	Numerical data
Purpose	Discover ideas, in-dept understanding of phenomenon	Test hypothesis or specific research questions
Approach	Observe and interpret	Measure and test
Data collection	Unstructured Rich, thick, and deep data	Structured Hard, reliable data
General approach	Words and description	Numbers and measurement

This research study is primarily a qualitative study, following an inductive approach, therefore various qualitative research methodologies were investigated which falls into the design research paradigm. However, as part of the evaluation process, a structured questionnaire is used to collect quantitative data to identify patterns and compare results, therefore it is concluded that this study ultimately follows a mixed-method approach.

In the following section, an overview of Design Science Research is provided, followed by a discussion of its relevance to and implementation within this study.

2.3 Design Science Research

Design Science Research, based on design research, is a growing and evolving research field. Design research covers all design fields and is concerned with research into or about design itself [229]. This includes the methods used, designers involved, and the education required [229]. In contrast, DSR is research that uses design as a research method [229]. Based on the grounding of this study in the design paradigm, this research study pursues a DSR approach [105], which is also in line with existing discussions in design science and BM research [170, 233].

The aim of DSR is to contribute design heuristics and multiple types of knowledge to solve real-world problems. An *artefact* is used to present the knowledge, which is a broad term that includes various categories, some of which are described in Table 2.3 below [229].

Table 2.3: Outputs or artefacts of DSR [229]

Artefact	Description
Constructs	The conceptual vocabulary of a domain.
Models	Sets of propositions or statements expressing relationships between constructs.
Frameworks	Real or conceptual guides to serve as support or guide.
Architectures	High level structures of systems.
Design principles	Core principles and concepts to guide design.
Methods	Sets of steps used to perform tasks—how-to knowledge.
Instantiations	A realisation of constructs, models, methods, and other abstract artefacts within the application environment such as software products or implemented processes.
Design theory	A prescriptive set of statements on how to do something to achieve a certain objective. A theory usually includes other abstract artefacts such as constructs, models, frameworks, architectures, design principles and methods.

To better understand the execution of DSR, Hevner [105] defined a conceptual framework, depicted in Figure 2.2. The framework consists of three cycles of activities that form part of the DSR cycle: 1) the relevance cycle, 2) the design cycle, and 3) the rigour cycle. Each of these cycles is briefly described below.

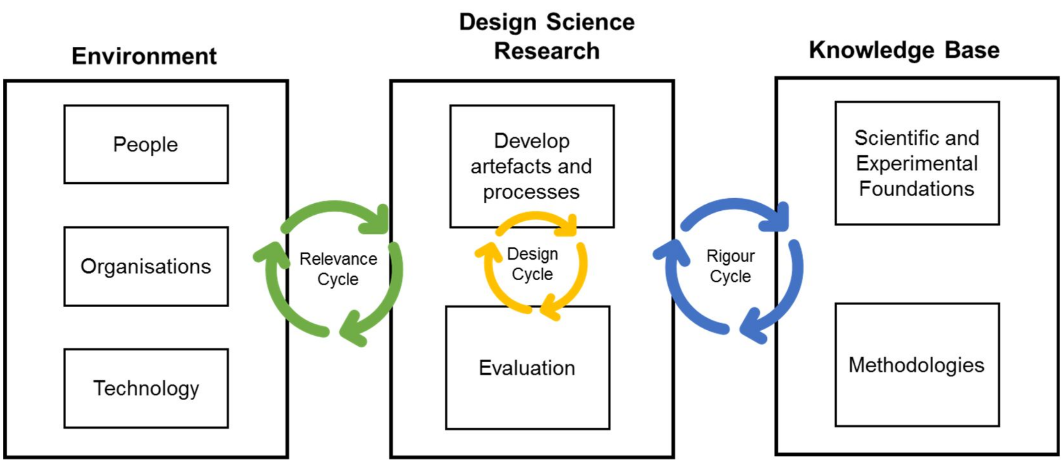


Figure 2.2: Design Science Research framework [105]

2.3.1 The relevance cycle

The relevance cycle initiates or triggers DSR through the identification and representation of opportunities and problems in an actual application environment [105]. The aim is to ensure that the artefact developed throughout the research study, is appropriate, applicable, and implementable within the environment, thus linking the environment and the artefact [105]. The environment provides the context and scope of the problem that is addressed by the research study. As illustrated in Figure 2.2 above, it consists of the respective people, organisations and technology that is either currently used, or planned to be used. This cycle also provides the requirements for the research as input into the study [105]. The *goals, tasks, problems, and opportunities* that are identified within the environment assist to define the research [106].

Ultimately, the output of the DSR must be returned to the environment for study and evaluation in the application domain. Field testing will determine the correctness and completeness of the research requirements, indicate any deficiencies in the artefact's functionality or its inherent qualities, and will indicate if any corrections need to be made before another iteration of the relevance cycle is performed [105].

2.3.2 The rigour cycle

The rigour cycle provides the foundation for DSR through the inclusion of existing knowledge, referred to as the knowledge base. In addition to the knowledge base of scientific theories and engineering methods, is the knowledge from state-of-the-art experiences and expertise [105]. The inclusion of past knowledge ensures research contributions are not purely routine designs based on the application of well-known processes [107]. Research contributions to the knowledge base are key to selling the research to the academic audience just as useful contributions to the environment are the key selling points to the practitioner audience [105].

2.3.3 The design cycle

The design cycle involves the rapid, iterative development, evaluation, and subsequent feedback of the artefact which draws from both the environment and knowledge bases [105, 107]. As discussed above, the requirements are input from the relevance cycle and the design and evaluation theories, and methods are drawn from the rigour cycle. Artefacts must be rigorously and thoroughly tested in laboratory and experimental situations before releasing the artefact into field testing along the relevance cycle. This calls for multiple iterations of the design cycle in DSR [105].

2.3.4 DSR guidelines

To aid scholars in conducting and evaluating good DSR, Hevner and Chatterjee [106] prescribed a set of guidelines. Table 2.4 contains a description of the guidelines, together with a brief overview on how it was implemented throughout the study.

Table 2.4: DSR guidelines and application [106]

Guideline	Description	Application in this study
Guideline 1: ***Design as an Artefact***	Design science research must produce a viable artefact in the form of a construct, a model, a method, or an instantiation.	This study aimed to develop a management framework (converted into a tool), which may be described as a method and is presented in Chapter 8.
Guideline 2: ***Problem Relevance***	The objective of design science research is to develop technology-based solutions to important and relevant business problems.	The study aimed to address real business problems in the South African AM sector (which is technology-based); therefore, it repeatedly draws from the application environment in the development process to ensure the relevance of the process and research artefacts. Furthermore, in Chapter 7 the framework is applied in the real-word context of this study.
Guideline 3: ***Design Evaluation***	The utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods.	During the iterative development of the management framework in Chapter 6, multiple semi-structured interviews were conducted with business, manufacturing, and AM subject-matter experts to ensure the relevance and rigour of the framework (as well as some of the other research artefacts). The activities within the framework were evaluated using a structured questionnaire. Various of the steps

Guideline	Description	Application in this study
		contained in the framework was also evaluated through the theoretical contextual application (a type of case study) in Chapter 7. These evaluation methods are described in this chapter.
Guideline 4: ***Research Contributions***	Effective design science research must provide clear and verifiable contributions in the areas of the design artefact, design foundations, and/or design methodologies.	The final management framework and its utility are discussed in Chapter 8. The positioning of the framework's contribution is discussed in this chapter, and the overall contribution of this study is discussed in Chapter 9.
Guideline 5: ***Research Rigour***	Design science research relies upon the application of rigorous methods in both the construction and evaluation of the design artefact.	The various research methods that were applied in the development, design and evaluation of the framework and tool are discussed in this chapter.
Guideline 6: ***Design as a Search Process***	The search for an effective artefact requires utilising available means to reach desired ends while satisfying laws in the problem environment.	The framework developed in this study leverages existing knowledge from the BM, BMI and VN domains as well as incorporating information from the AM, SA and SMME knowledge bodies to meet the needs in the problem environment. Furthermore, valuable insights were also obtained from the subject-matter experts.
Guideline 7: ***Communication of Research***	Design science research must be presented effectively both to technology-oriented as well as management-oriented audiences.	The research process discusses the various components of the framework in sufficient detail for technology-orientated audiences. Careful attention is also given to the discussions, particularly the presentation of the final tool (Chapter 8) to ensure its relevance to management-orientated audiences, including SMME owners or entrepreneurs.

Based on the overview provided of the DSR framework to rigorously guide the research process and to facilitate the effective development of the management framework and tool, the formulation of the research design and methodology for this study is discussed in the following section.

2.4 Research design and methodology

The execution of DSR is guided by the DSR conceptual framework which consists of iterative design cycles. To ensure the developed framework is relevant and rigorous, the design cycles are informed and guided by requirements and considerations from the environment and knowledge bases. In the DSR framework, the environment provides context and scope, whereas the knowledge base consists of the range of existing knowledge and information which are relevant to the artefact and development process.

The intersection between the domains of AM, SMME and South Africa, is the environment of relevance, see the green circles in Figure 2.3. Since the focus is on the intersection of the three domains, each individual domain may also be drawn from to provide greater insight. The study aimed to develop a BMI framework from a VN perspective to support SMMEs, therefore the established domains of BM, BMI and VNs provided a solid knowledge base to guide and inform the development of the framework, see the blue circles in Figure 2.3.

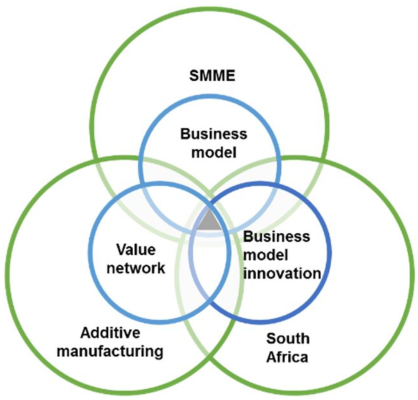


Figure 2.3: Research rigour and relevance domains

The DSR framework as well as the research questions (discussed in Section 1.7) were used to guide the formulation of the overall development approach of the framework and consequently the management tool. Therefore, the management tool was developed using six design cycle iterations. These design cycles consisted of a development component, in which specific framework aspects were designed, and/or an evaluation component, in which specific aspects were reviewed and evaluated to ensure utility. The rigour and relevance cycles, characteristics of DSR, were not considered as separate cycles but were rather incorporated within the design cycles by drawing from the knowledge base and environment, as illustrated in Figure 2.4.

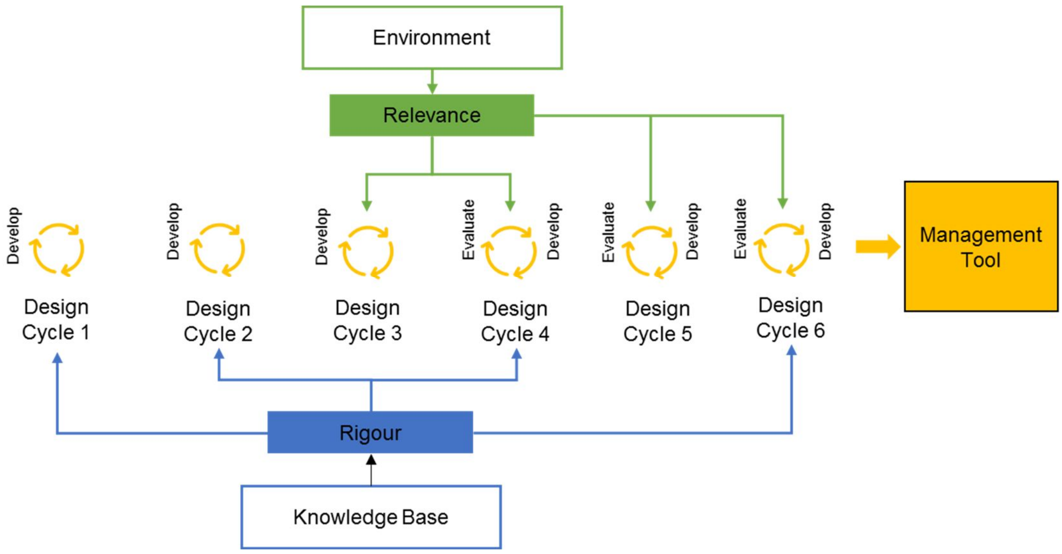


Figure 2.4: Overall approach of the development of the final management tool

The detail of the six design cycles as well as the corresponding relevance and rigour cycles are described within the context of this study's research design. The research design is *based on* the DSR framework (Section 2.2), *influenced by* the design paradigm (Section 2.1), *informed by* three primary overlapping literature domains (Section 1.8), and *guided* by three overlapping contextual domains (Section 1.8).

The methodological process suggested by Vaishnavi and Kuechler [229] and the process model applied by Peffers, Tuunanen, Rothenberger and Chatterjee [180] were used to develop the research design and methodology, see Figure 2.5 below for an overview. The research design is structured into five phases, with associated steps in each phase. The overview also includes the applicable chapters within this document, how the research process is related to the design cycles, as well as the various research methods incorporated to conduct some of the steps. Lastly, Figure 2.5 highlights where the research questions discussed in Section 1.6 are answered.

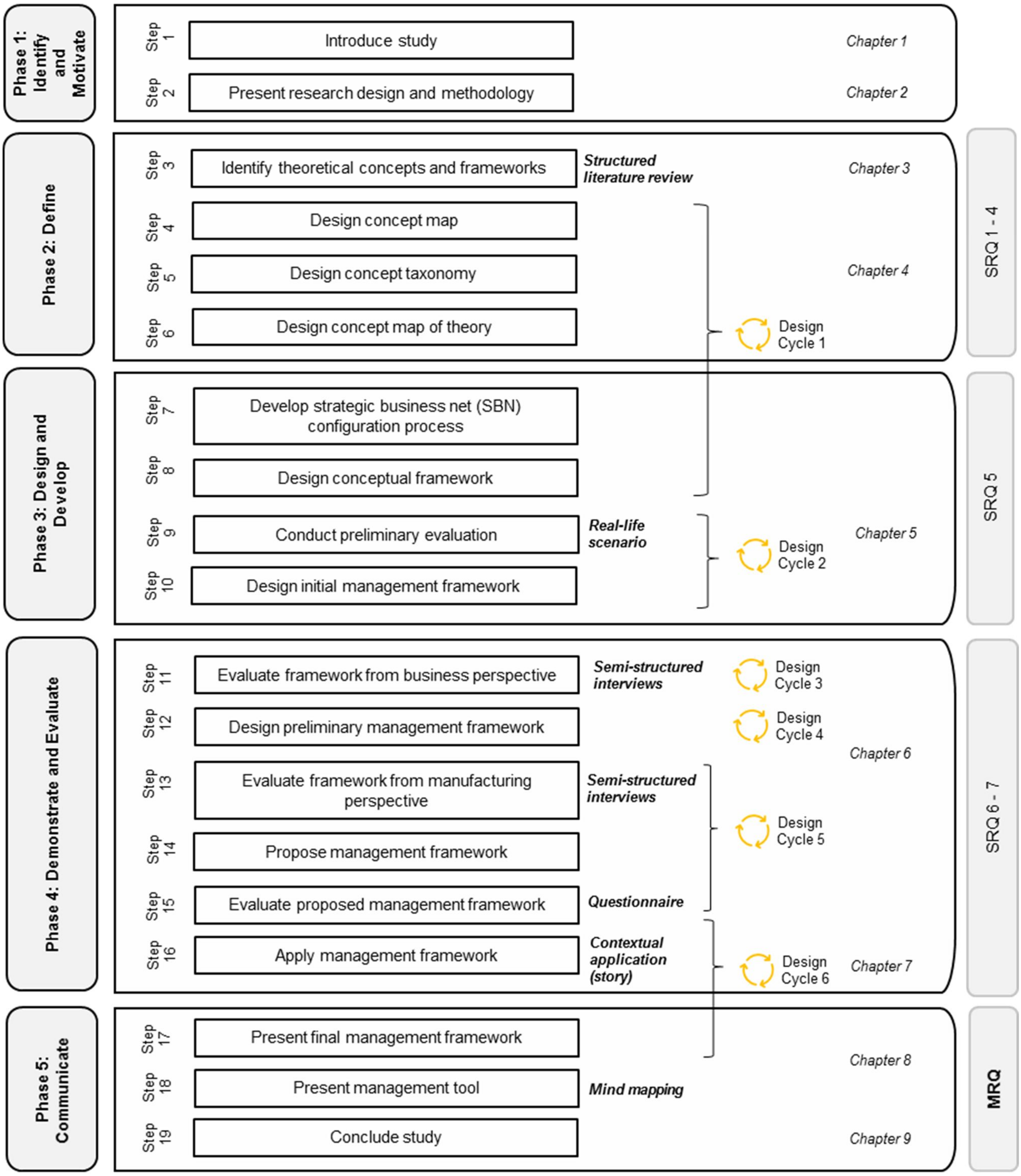


Figure 2.5: Detailed research design overview

In the following sections, the execution of the five major research phases is discussed along with an explanation of the corresponding design cycles and research methods.

2.4.1 Phase 1: Identify and Motivate

Phase 1 aimed to introduce the study and to provide adequate motivation for the study within the application environment (forming part of the relevance cycle). In **step 1**, the study was introduced by giving a brief background on the need for a BMI framework (including steps, activities, and tools) from a VN perspective with application value in the development of the prospective cemented tungsten carbide AM sector in South Africa. The background, together with the identified research gaps, led to the formulation of the research problem, research questions, and objectives (Chapter 1).

In **step 2**, the researcher formulated the research design and methodology that would effectively and efficiently answer the research questions, and meet the objectives set out in this study. The research methodology guided the overall research process followed throughout this study to develop the management tool. The DSR framework was selected to guide the research design, consisting of multiple design cycle iterations, and was supplemented with various research methods (Chapter 2). Figure 2.6 below demonstrates the outputs from Phase 1.

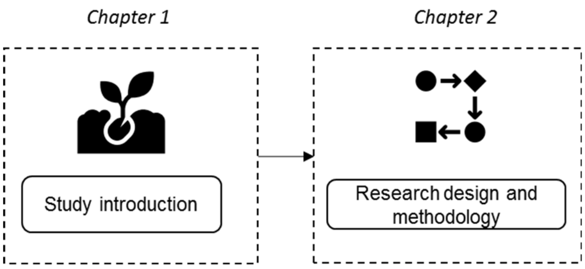


Figure 2.6: Phase 1 outputs

2.4.2 Phase 2: Define

Phase 2 aimed to answer the first set of sub-research questions of this study, which primarily consisted of the identification, review, analysis, as well as synthesis and integration of the relevant literature bodies. In **step 3**, SRQ1 was answered after a structured literature review was conducted that led to the identification of the most relevant definitions, frameworks, elements, and concepts available in each literature body (BM, BMI, and VN). As part of step 3, relevant literature from the contextual domain (AM, SMME, SA) were also reviewed to identify the influence of AM on the other concepts that could potentially be included in the management framework, answering SRQ2. The overview and outcomes of the structured literature review are depicted in Figure 2.7.

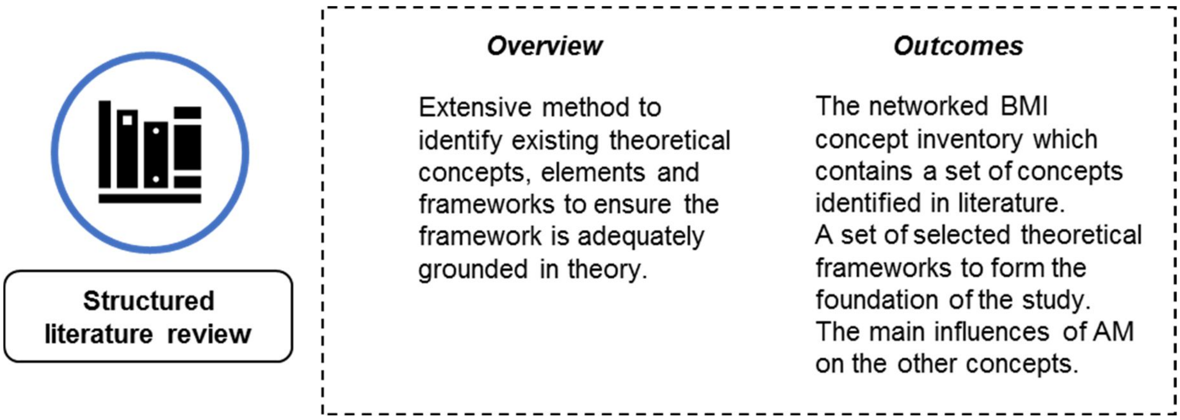


Figure 2.7: Overview and outcomes of the structured literature review

The method and process steps suggested for the systematic review process was used to conduct the structured literature review presented in Chapter 3. A systematic review can be described as an *"appraisal of and systematic search into primary research papers using a rigorous and documented methodology to search and select studies to minimise bias in the results"* [92]. The systematic review guides the researcher to gather data, discard the unwanted data and then to summarise the remaining data to successfully answer the identified research question [92]. However, the accuracy and reliability of a systematic review are dependent on the available literature body [120].

During the systematic review, a transparent and orderly process is followed to ensure a thorough and fair review of the literature [122]. The systematic literature review synthesises existing research studies to: (1) understand the overall picture created by the evidence presented in existing research [183]; (2) identify gaps for further research [122, 183]; and (3) provide context to position new research appropriately [122]. The major steps in a systematic literature review include the definition of a research question, searching for and selecting studies for review, analysing the selected studies, and finally presenting the results of the review [137]. These steps, suggested by MacGill [137], were followed to conduct the structured literature review used to answer the research questions of the current study, see Table 2.5.

The structured review method was selected as numerous systematic literature reviews have already been conducted in the respective fields. The aim of this literature review was to generate a holistic picture of how the respective research fields are structured and what existing definitions, frameworks and tools are contained in each body. The value of this study lies in the integration and synthesis of the relevant theoretical knowledge bodies to develop a useful and informative framework.

Table 2.5: Systematic review procedure used to conduct the structured literature review (adapted from [137])

Steps	Description of application in this study	Section reported
1. Define the research question	SRQ1 and SRQ2 were identified as the research questions to be answered in the review that aims to support answering the MRQ.	Section 3.1.1
2. Decide which studies to include in the review	A detailed protocol that describes in advance the process that will be applied was formulated. The review protocol included a search strategy and the selection criteria based on the research questions and context of this study.	Section 3.1.2 – 3.1.3
3. Search for the studies	The search strategy was followed by searching for peer-reviewed literature using several appropriate electronic databases and a predetermined search string, containing the required search terms from each literature body.	Section 3.1.4
4. Select the studies and collect the data	The primary literature body was selected following the selection criteria that included (in addition to the databases and search string) the type of record, the title and abstract, accessibility, language, and lastly the inclusion and exclusion criteria. As part of the selection process, snowballing was used to include the most referenced and relevant records from each literature body. The process was documented to indicate the basis on which articles were included or excluded.	Section 3.1.4
5. Assess and address the risk of bias in the included studies	Due to the use of snowballing, the risk of bias needed to be assessed and addressed as the researcher specifically chose some additional studies to be included. Although it is not recommended, the risk is minimal for this study as articles were added in addition to the records selected following the selection criteria. Furthermore, the research body is however not misrepresented as most recent systematic literature reviews from each body were included to minimise bias.	Section 3.1.5
6. Analyse the data	The selected records were analysed, and data were extracted in a structured approach to answer SRQ1 as well as SRQ2.	Section 3.2 – 3.6
7. Present the final results of the review	The findings from the literature review were summarised, and the answers to SRQ1 and SRQ2 provide a sound theoretical (rigour) basis for the framework. The main findings and concepts were synthesised and presented using theoretical maps and frameworks. These theoretical-based artefacts formed the basis of the conceptual framework and furthermore enabled the systematic development of the management framework and tool.	Section 4.2 – 4.6

Steps 4 to 6 present the results of the review in a systematic manner, ensuring the management framework and tool are rigorous and grounded using applicable theories and theoretical frameworks. Developing a BMI framework from a VN perspective led to the identification of the need to understand what the concept of *networked BMI* entails, and how to holistically approach it, through the integration of the three primary research bodies (BM, BMI, VN).

In **step 4**, the concepts forming part of the concept inventory were structured and presented in a concept map, divided into four value dimensions (value network, value proposition, value finance, and value architecture) with applicable relationships between these concepts. The concept map aimed to create a holistic and overall picture of the selected primary dataset, with a focus on the core concepts contained within the BM, BMI, and VN records that can be used as elements to describe the networked BMI concept. These elements were used as a checklist for the conceptual framework, to ensure no key element is overlooked (Chapter 4).

To make more sense of the complex concept map containing all the elements, a hierarchical concept taxonomy was developed in **step 5** to provide a better understanding of what the networked BMI concept entails and how to approach it, answering SRQ3. This hierarchical taxonomy served as a set of theoretical 'requirements' for the conceptual and management frameworks which were used during the internal evaluation process (Chapter 5).

In **step 6** a concept map of theory was designed to depict the networked BMI concept, described in the hierarchical taxonomy, answering SRQ4. This concept map aimed to integrate existing theoretical frameworks from each literature body (BM, BMI, and VN) to illustrate the networked BMI concept and to visually present what the proposed management framework aims to achieve. These three research artefacts formed part of the first design cycle, ensuring the rigour of the framework, as it demonstrates the fact that it is based on existing knowledge, theories, and frameworks. Figure 2.8 below demonstrates the outputs from Phase 2.

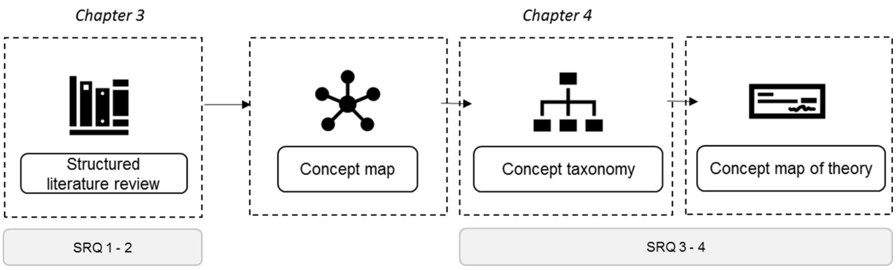


Figure 2.8: Phase 2 outputs

2.4.3 Phase 3: Design and Develop

As part of the development of the conceptual framework, it was observed that there was no single practical process to map a strategic business net on the strategic and tactical level. Therefore, in **step 7**, a strategic business net (SBN) configuration process was developed to be incorporated into the conceptual and management frameworks that will enable users to systematically develop and visually map their strategic business nets. This visualisation tool also aimed to enable users to easily link the concepts of the networked BM and the strategic business net, as the configurations directly influence each other. In **step 8** the initial conceptual framework was designed, consisting of phases, sub-phases, steps, and the concepts addressed in each step, answering SRQ5. The phases, sub-phases and steps are based on the theoretical frameworks and findings from the literature review. To identify the concepts that must be addressed in each step, the concept map (based on the concept inventory) was used. The conceptual framework aimed to propose a more high-level practical application of the concept map of theory, through the integration of the framework elements and the core concepts. The conceptual framework provided the theoretical foundation for the management framework and concluded the second design cycle.

In **step 9** the relevance and applicability of the SBN configuration process were evaluated from a business perspective using a real-life scenario as an example of an SMME within South Africa that want to participate in a VN and want to transform their BM from the firm-level to the network-level. Although the selected SMME was not within the entire contextual landscape of this study (i.e., not considering the adoption of AM), valuable insights were gathered during the application of the process that led to the addition of two steps to the process. The findings and insights obtained regarding the research artefacts, as well as the operating environment of SMMEs, guided the completion of the fourth design cycle. The overview and the outcome of the real-life application to evaluate the process are depicted in Figure 2.9.

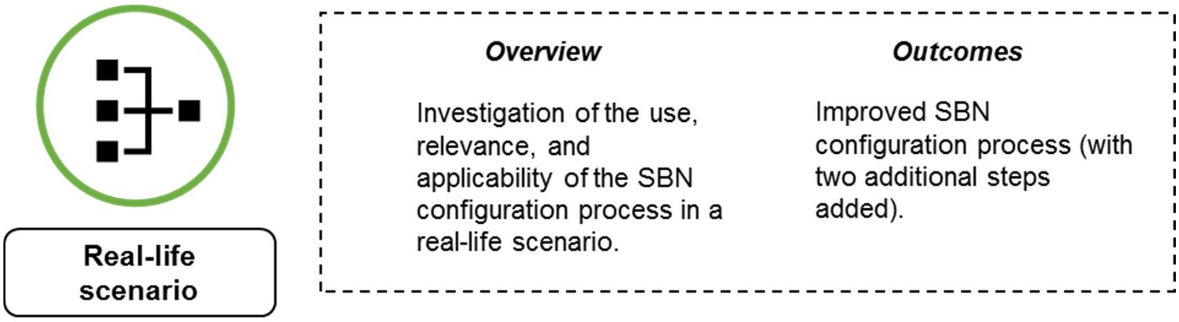


Figure 2.9: Overview and outcomes of the real-life scenario

A real-life scenario is closely associated with a case study as both are conducted in a real-life context and setting, but a scenario does not follow a strict and formal process with facts, figures, and data as in the instance of conducting a case study [109]. It is furthermore usually shorter than a case study and may contain fictionalised elements of a situation set in realistic settings [109].

Furthermore, as part of the preliminary evaluation conducted in step 9, the initial conceptual framework was internally evaluated using the hierarchical taxonomy designed in step 5. In step **10** the initial management framework was designed as part of the second design cycle, building on the conceptual framework. Additional steps, activities, tools, considerations, guiding questions, and concept definitions were added to the initial conceptual framework. Since the potential user of the management tool may not necessarily be a business expert, the additions to the framework needed to be comprehensive to lead the user in the correct direction. Figure 2.10 below demonstrates the outputs from Phase 3.

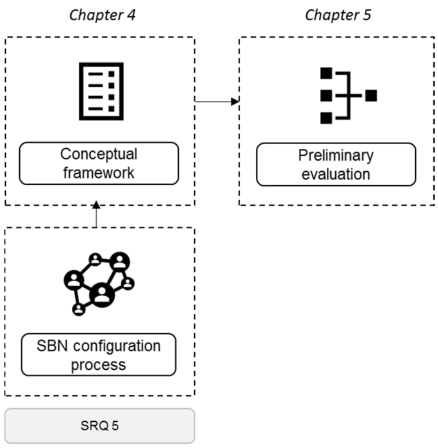


Figure 2.10: Phase 3 outputs

2.4.4 Phase 4: Demonstrate and Evaluate

Four design cycles iterations were completed during Phase 4. In **step 11** the initial management framework and some of the other research artefacts (hierarchical taxonomy, concept map of theory and SBN configuration process) were evaluated through semi-structured interviews with business subject-matter experts from different backgrounds. During **step 12** the preliminary management framework was designed, incorporating contextual considerations and influences identified in step 3 to ensure the framework adequately address aspects related to the adoption and implementation of AM. In **step 13** the preliminary management framework was evaluated through semi-structured interviews with manufacturing and AM subject-matter experts from diverse backgrounds. After the necessary adjustments and modifications were made, the proposed management framework was presented as part of **step 14**. Conducting multiple interviews with a wide range of subject-matter experts with different backgrounds and different expertise contributed to the overall rigour and relevance of the management framework and other research artefacts. An overview of the interviews and the outcomes are depicted in Figure 2.11.

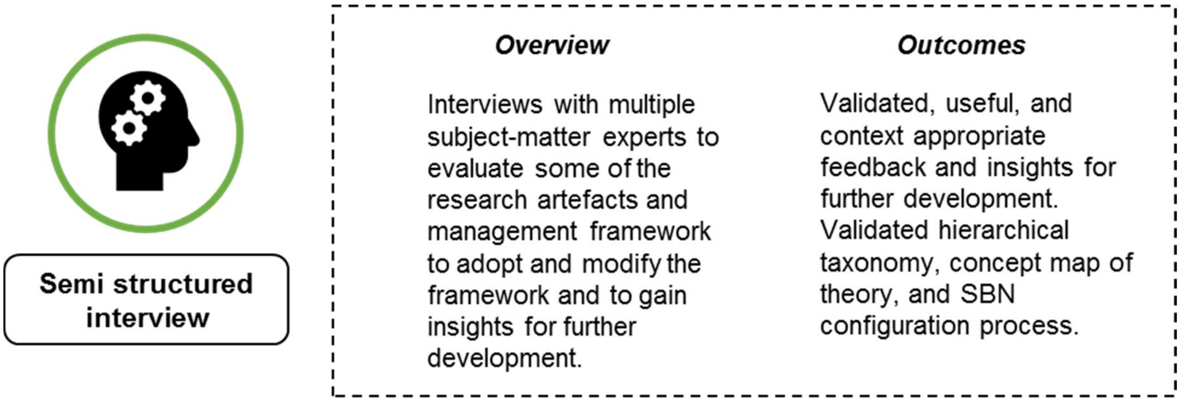


Figure 2.11: Overview and outcomes of the semi-structured interview

Interviews are commonly used as it is a powerful way to build understanding in research [72]. It is used when personalised data is needed, a good return rate is required, or where probing might be necessary [115]. Qualitative research studies frequently make use of semi-structured interviews as it provides more flexibility for both the interviewer and interviewee, compared to structured interviews used in quantitative research [34].

Semi-structured interviews are more open than structured interviews as they only provide discussion guidelines, allowing ideas to be explored based on the interviewee's responses to predetermined questions, themes or topics [115, 188]. Consequently, during these interviews, the researcher is able to probe the interviewee to gain more understanding into specific themes or topics, or to explain unclear questions [115]. However, a disadvantage of semi-structured interviews is the possibility that inexperienced researchers may inadequately prompt the interviewee in order to collect relevant data [115]. The interview is usually recorded and subsequently transcribed to implement coding strategies on the raw data [115].

Many procedures for conducting qualitative interviews exist [57]. The approach suggested by Creswell [57] focuses on the data collection in an interview. The procedure for qualitative interviews may be described by seven stages according to Creswell [57], see Table 2.6.

Table 2.6: Qualitative interview procedure and implementation (adapted from [57])

Stage	Description and implementation in this study
1. Define the purpose of the interview.	Clearly formulate what wants to be achieved with the interview. This should be aligned with the overall research questions and what the interview aims to evaluate. (Section 6.4.1 and 6.6.1)
2. Identify appropriate participants.	Identify potential participants that will be best suited to achieve the defined aims. (Section 6.4.2 and 6.6.2)
3. Decide on the interview type.	Choose between telephone interview, Skype, Teams, or any other online platform (due to the Covid-19 pandemic all interviews were conducted electronically).

Stage	Description and implementation in this study
4. Design an interview protocol/guideline.	An interview protocol or guide includes information about the interview, general instructions for conducting the interviews, the research artefacts to be evaluated, and the specific questions to be asked. The questions must be developed to achieve the aims. (Section 6.4.3 and 6.6.3)
5. Obtain consent from participant.	The participants were informed about the ethical implications related to their participation and informed consent were obtained from the participants before starting the interview.
6. Use adequate recording procedures.	The interviews were recorded, and supplementary notes were made that were used to analyse the interview.
7. Use good interview procedures.	The interviewer gave attention to listen more than to speak, engage with the interviewee, and politely probe for further insights in the interviews. The participants were thanked for their time.

In **step 15**, the activities contained within the proposed management framework (as well as the selected networked BM elements and strategic business net features) were evaluated by business management and manufacturing subject-matter experts using a structured questionnaire. An overview of the questionnaire and the outcomes are depicted in Figure 2.12.

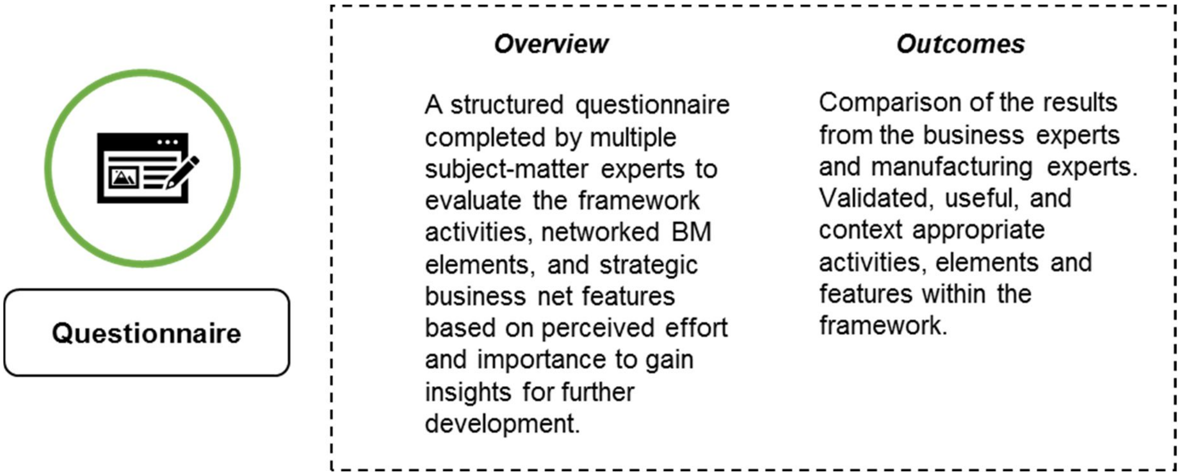


Figure 2.12: Overview and outcomes of the questionnaire

A questionnaire or survey involves directly collecting information from people (or sometimes organisations). The type of information collected by questionnaire considers the person's or organisation's level of knowledge, personality, attitude, beliefs, or preferences. Well-designed questionnaires are highly structured to allow the same types of information to be collected from a number of people in the same way and for data to be analysed quantitatively and systematically. [133]

As part of the evaluation of the management framework, structured questionnaires were used to gather evaluation information from subject-matter experts. For this study, self-completion (or self-administered questionnaires) were used where respondents answered questions by completing the questionnaire by themselves. This type of questionnaire can come in several forms and may be sent by mail or post. The respondent is then usually asked to return the completed questionnaire to the researcher. [34]

In **step 16** certain steps within the management framework were applied to the contextual application domain of this study (AM, SMME, SA), as part of the final design cycle and answering SRQ7. This application domain initiated the research project, as described in Chapter 1. To make the application domain more practical and applicable, the tooling industry, also referred to as the Tool, Die, and Mould (TDM) industry, was selected as it has great potential for the adoption of AM technology using cemented tungsten carbide as a manufacturing material. The important role the industry plays in innovation and the introduction of products into the market, stresses the importance to develop this industry specifically. During this step, the SBN configuration process was also evaluated from a manufacturing perspective. An overview of the contextual application and the outcomes are depicted in Figure 2.13.

Contextual application (story)

Overview

Investigate the use of the management framework within the real-life context of this study to evaluate the relevance and to gain insights for further development into a management tool.

Outcomes

Refined management framework with application value to the context of the study. Prototype scenarios for the design and configuration of certain elements with real-life application potential for the tooling industry.

Figure 2.13: Overview and outcomes of the contextual application

Case studies, scenarios and stories are all closely related, but they do differ [109]. The difference between a story and a case study is that a story can be based on a real or fictional context, whereas a case study is based on a real context and setting [109]. Stories may furthermore be short or long, do not need to contain facts, figures, and data, and may contain fictionalised elements, which are not typically characteristics of case studies [109].

Therefore, the contextual application conducted in this study is rather classified as a story instead of a case study. However, based on some of the similarities between the two approaches, it was decided to follow a case study approach which is commonly used in qualitative research to guide the application process [57]. The case study methodology proposed by Yin [249] was thus used to inform the contextual application methodology followed in this study, depicted in Figure 2.14. The step regarding the identification of cases is excluded, as a relevant industry has already been selected due to the nature of the context of this study. This methodology provides the high-level process, and a brief overview of the is given below, but the detail of how it was applied is discussed in Chapter 8. Furthermore, using a type of case study as part of the DSR paradigm is of particular value as the case study, or contextual application in this case, aids to establish relevance by drawing from the direct application environment. It is, however, important to note, that because it is a story, created for an emerging technology, some fictionalised elements, not supported by the literature, may be included to demonstrate the framework's functionality and applicability.

Define objectives → Identify resources → Analyse resources → Apply information → Leverage findings

Figure 2.14: Contextual application methodology followed (adapted from [249])

The first stage of the methodology is to define the objectives (Section 7.2). To achieve these objectives, relevant resources, in the form of existing theoretical literature studies need to be identified (Section 7.3). The relevant resources are then analysed to identify the required information that can be used to inform the framework steps (Section 7.4). After the information is analysed, it is applied to complete the identified framework steps and templates to demonstrate the applicability of the framework in the study's context (Section 7.5). In the final stage of the methodology, the findings are leveraged through the adaptions made to the management framework. Figure 2.15 below demonstrates the outputs from Phase 4.

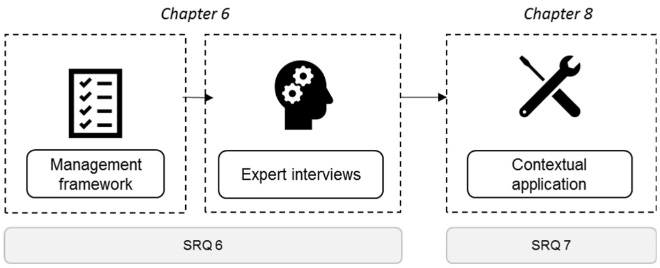


Figure 2.15: Phase 4 outputs

2.4.5 Phase 5: Communicate

During the final phase of this study, the framework was finalised and the results, including the management tool, were presented. In **step 17** the management framework was finalised through the integration of all the findings and insights obtained from the different evaluations, completing the final design cycle iteration. During this step, some final versions of other research artefacts designed throughout this study were also presented.

In **step 18** the management framework was converted into a management tool using the mind mapping method. The facilitation and use of the tool were also explained. An overview of the mind mapping process and the outcomes are depicted in Figure 2.16.

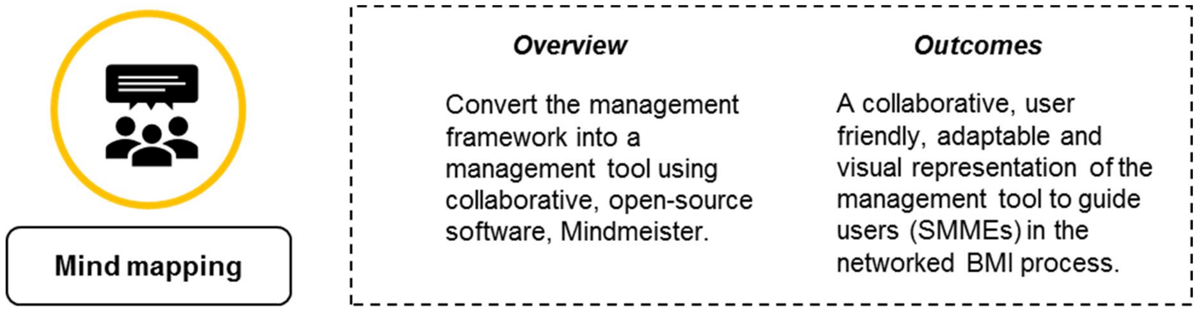


Figure 2.16: Overview and outcomes of mind mapping

The University of Adelaide's writing centre provided the following definition of what mind mapping is: "*Mind mapping was developed as an effective method for generating ideas by association. In order to create a mind map, you usually start in the middle of the page with the central theme/main idea and from that point, you work outward in all directions to create a growing diagram composed of keywords, phrases, concepts, facts and figures*" [14]. Furthermore, they provided the following benefits of using mind mapping: it provides an overview of a large subject/broad topic and allows it to be represented in a more concise fashion, encourages the ability to see the bigger picture and creative pathways, enables planning and decision-making, and providing a more attractive and enjoyable format to look at [14].

To enable a visual presentation of the management framework in a format that can be used by potential users, mind mapping was selected. An open-source software package, Mindmeister, was selected to create the framework blueprint. The software enables easy modifications, making the tool adaptable to enable users to personalise the framework to the business requirements. It furthermore provides the opportunity to enable collaboration among various people. The use of a mind map to understand and guide the execution of the networked BMI effort will enable users to document findings or answers informally for future reference. The mind map furthermore aims to improve brainstorming among employees (or network partners) that could lead to creative ideas and business opportunities. The completed mind map can also help to provide a holistic overview of what is going on and can later be used to create formal documents of decisions and plans.

Figure 2.17 below illustrates the systematic approach (Part A-F) followed throughout this study to ultimately create the management framework and tool, answering the MRQ.

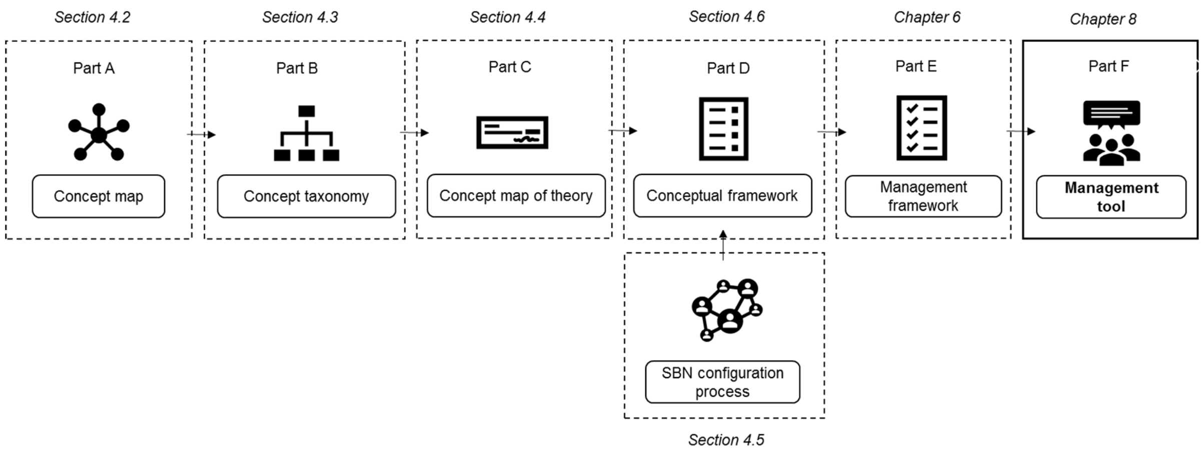


Figure 2.17: Systemic approach followed throughout this study

The management framework (and tool) is an output from the other research artefacts designed and developed as part of this study. Figure 2.18 below illustrates the proposed relationships between all the artefacts. The concept map designed in Section 4.2 *informed* the concept taxonomy designed in Section 4.3. The concept taxonomy proposed a more structured and hierarchical approach to the networked BMI concept, based on the concepts contained in the concept map. The concept map was also used as a *checklist* during the design of the conceptual framework (Section 4.5), to ensure all fundamental concepts were addressed within the framework.

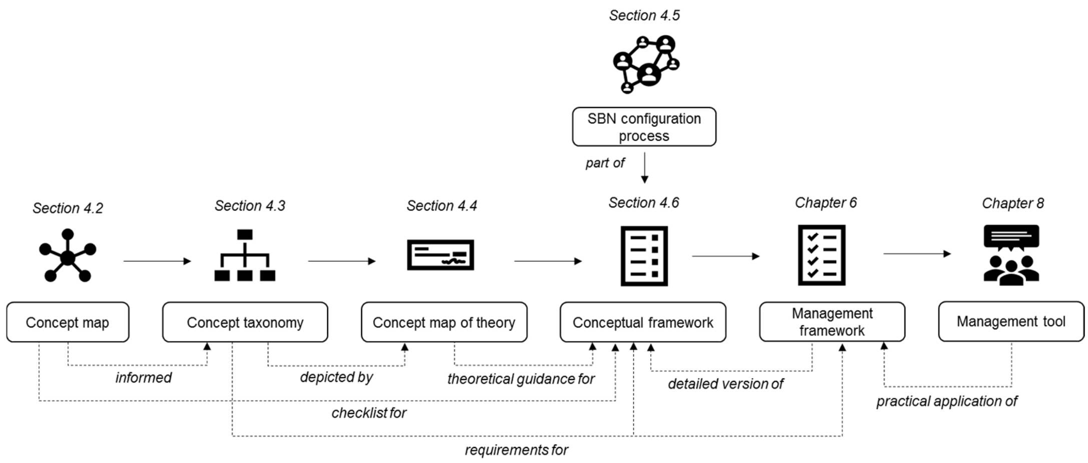


Figure 2.18: Relationships between the research artefacts

Furthermore, the concept map of theory, designed in Section 4.4, provided a more holistic approach to the networked BMI concept, and was thus regarded as a set of *requirements for* both the conceptual framework and the management framework. Due to the conceptual nature of the conceptual hierarchy, a concept map of theory was designed to *depict* the information contained in the taxonomy in a more visual way. The concept map of theory, therefore, provided *theoretical guidance for* the design and development of the conceptual framework that aimed to provide more logical steps on how to practically approach the networked BMI concept.

As *part of* the development of the conceptual framework, the SBN configuration process was designed to enable visualisation of the strategic business net on a strategic and tactical level. The management tool presented in Chapter 8 is the *practical application of* the management framework, enabling potential users to conduct the activities in the framework in an easy to use, understandable, and customise manner.

In the final step, **step 19**, the study was concluded. The research process was reviewed to show how the research questions were answered throughout this study. The research contributions, limitations and suggestions for future research were finally discussed. Figure 2.19 below demonstrates the outputs from Phase 5.

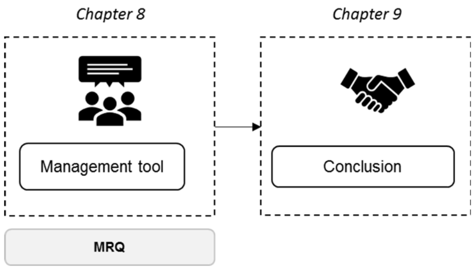


Figure 2.19: Phase 5 outputs

2.5 Conclusion: Chapter 2

The research design followed in this study was developed *based on* the DSR framework, *influenced by* the design paradigm, *informed by* three primary overlapping literature domains, *guided* by three overlapping contextual domains, and *supplemented by* various research methods to best answer the research questions.

The research design incorporates six design cycle iterations in which the management framework (and tool) is iteratively developed and evaluated, establishing the relevance and rigour of the framework by drawing from the application environment and knowledge base. These iterations are supported by various research methods, namely: a structured literature review, a real-life scenario, multiple semi-structured interviews, a questionnaire, contextual application of the framework, as well as mind mapping to convert the framework into a management tool.

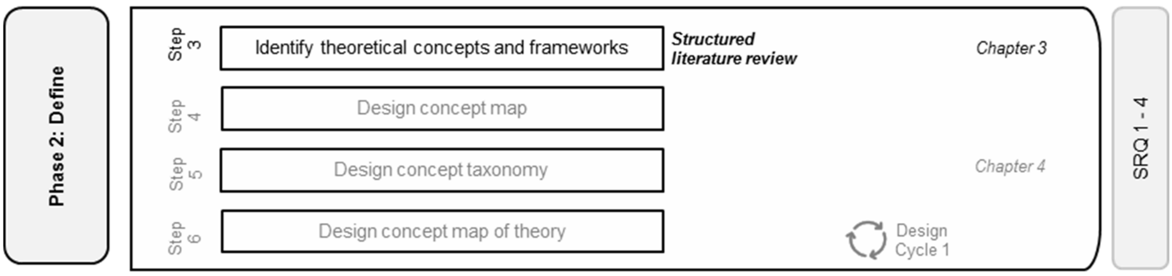
This chapter concluded the first phase of the research design, illustrated in Figure 2.5. In the following chapter, the structured literature review is discussed. This commences the second phase of the study which aims to identify the fundamental concepts and theoretical frameworks to build the framework upon.

Chapter 3: Structured literature review

A structured literature review is conducted in Chapter 3 to answer SRQ1 and SRQ2. The findings from the chapter informed Design Cycle 1 and Design Cycle 4 through the identification and analysis of the relevant literature or knowledge bases of the study's scope. Within this chapter, each of the three primary literature domains is analysed and the most important findings are presented, together with the fundamental concepts contained in each body. The most relevant frameworks were selected from each body to form the foundation of the other research artefacts developed in Chapter 4 during the synthesis and integration of the literature findings.

Chapter 3 key objectives:

- Initiate the structured literature review (Section 3.1).
- Present descriptive analysis of the primary dataset results (Section 3.2).
- Present the business model conceptual analysis (Section 3.3).
- Present the business model innovation conceptual analysis (Section 3.4).
- Present the value network conceptual analysis (Section 3.5).
- Present the main influences of AM on the identified concepts (Section 3.6).



3.1 Structured literature review initialisation

The literature review is conducted as part of the DSR approach's rigour cycle. The aim is to gain relevant knowledge regarding the concept of the business model, business model innovation, and the value network. To ensure a proper understanding and consideration of the context (relevance), knowledge was also obtained from the AM and SME/SMME literature bodies.

The literature gap has already been identified in Section 1.4, describing the departure point of this study. Figure 3.1 below illustrates the framework used to inform the literature review on the identified concepts (rigour) within the required contexts (relevance). For the structured literature review, it was important to consider the total research scope and therefore aspects regarding both the rigour and relevance cycles were included.

Please note that some of the findings reported within this structured literature review were also included in the scoping review which was published as a conference paper in the proceedings of the IAMOT 2020 conference, see van Heerden *et al.* [230].

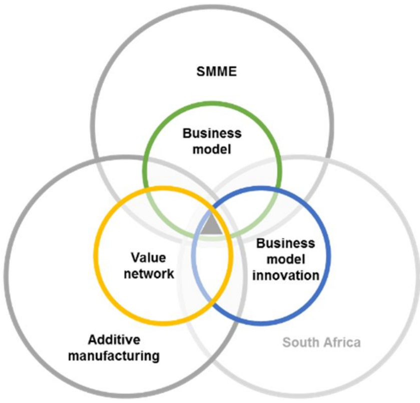


Figure 3.1: Research scope

The major steps in a systematic literature review include the definition of a research question, searching for and selecting studies for review, analysing the selected studies, and finally to present the results of the review [137]. These steps are also applicable to the structured literature review used to answer the research questions of the current study.

The structured review method was selected as numerous systematic literature reviews have already been conducted in the respective fields. The literature review aimed to generate a holistic picture of how the respective research fields are structured and what are existing definitions, frameworks and tools contained in each body. The value of this study lies in the integration and synthesis of the relevant theoretical knowledge bodies to develop a useful and informative framework. Reviewing existing literature was of immense importance to ensure the management framework has a sound theoretical grounding.

The overarching phases and corresponding steps presented in Table 3.1 were followed by the researcher to conduct the structured literature review.

Table 3.1: Phases and steps for the structured literature review

Step	Section
1. Define the research question	3.1.1
2. Decide which studies to include in the review	3.1.2 – 3.1.3
3. Search for the studies	3.1.4
4. Select the studies and collect the data	3.1.4
5. Assess and address the risk of bias in the included studies	3.1.5
6. Analyse the data	3.2 – 3.6
7. Present the final results of the review	4.2 - 4.6

The first phase in the review process was to thoroughly plan the review. The review planning included substantiating the gap in the literature, defining the questions to be answered by the literature review, and writing a detailed protocol that describes in advance the process and methods that will be applied. The protocol included the search strategy and study selection criteria (inclusion and exclusion).

3.1.1 Research questions

The study aimed to link and synthesise different aspects of the identified focus areas or concepts towards a networked BMI framework that are applicable to be used by SMEs/SMMEs in the AM context of South Africa. Consequently, the structured literature review aimed to answer the following research questions, forming part of the study's SRQs:

1. Which relevant definitions, frameworks, elements, and concepts are available in each literature body (BM, BMI and VN) to support the framework development? (SRQ1)
2. What are the main influences of AM on SMMEs, the BM, BMI and the VN that could support the framework development? (SRQ2)

3.1.2 Search strategy

The next necessary element in planning the review was defining the search strategy. Therefore, the following section describes the predefined search strategy followed to conduct the structured literature review.

The primary literature sources considered useful for this literature study were peer-reviewed literature, including journal articles, conference papers, and masters' or doctoral theses. To identify the peer-reviewed literature, the web-based search engines that were consulted included Scopus, Google Scholar, Research Gate, ScienceDirect and SpringerLink. These databases consist of large collections of business- and science-related proceedings and articles.

The main objective of the literature review was to gain a holistic understanding of the literature bodies within the research scope, refer to Figure 3.1, to enable the identification of the most relevant concepts. To identify the primary data set, relevant search terms from each focus area were identified and included. The respective terms in the search string were joined using the appropriate Boolean operator 'OR' to link terms of the same category, and the Boolean operator 'AND' to link different categories. Therefore, the following search string was used to identify the primary literature studies: *("business model" OR "business model innovation") AND ("value" OR "value chain" OR "value network") AND "additive manufacturing" AND ("SME" OR "SMME")*

The research bodies of BM and BMI are closely related; therefore, the 'OR' operator was used and not the 'AND' operator. To ensure the concept of value, the most common theme from all focus areas, was properly considered the search term 'value' was also included. No term specifying the developing country context, or rather South Africa, was included, as most of the research regarding AM is conducted in developed countries and therefore the inclusion would have disregarded most of the articles (please note that the context was included later in Chapter 6 and 7). However, the inclusion of the terms 'SME' or 'SMME' considered the South African context as most enterprises (including manufacturers) within South Africa are SMMEs.

As part of the study selection process, the most frequently cited articles were identified and included through the process of snowballing, thereby enabling the inclusion of the foundational studies in each literature body or focus area. The vastness and complexity of the three primary literature bodies led to the careful selection of articles that included the most recent publications on systematic literature reviews on the topics as well as fundamental work conducted in each area. Although the focus was on the intersections of the literature bodies, studies from individual literature bodies were also included. The inclusion and use of the systematic literature reviews on each focused concept reduced the size of the included relevant literature tremendously.

3.1.3 Selection criteria

Following the formulation of the search strategy, a more detailed selection criterion was defined as part of planning the review. Accordingly, the identified literature was screened and excluded according to the following criteria:

- Type: exclude papers that are not journal articles, research reviews, conference papers or master's or doctorate theses.
- Full text availability: exclude papers where the full text is not available.
- Language: exclude papers that are not published in English.
- Duplication: exclude papers that are repeated in the search results.
- Relevance: exclude papers that appear to be irrelevant to the project scope.

Initially, relevance was established by reading the title of the article. Whereafter the abstract, and sometimes the introduction and conclusion of each identified paper, was read to further exclude some irrelevant papers. In cases where the relevance of the content was not clear, the entire document was read extensively. The remaining documents were tested against the inclusion criteria to identify the appropriate data sources.

The final step in selecting the data sources was to test the remaining papers against the contextual (relevance) inclusion criteria. Any papers that did not meet any of the required inclusion criteria, were excluded. The following inclusion criteria were applicable:

- Discussion or application of BMs, BMI, VNs, or a combination.
- Discussion or application of BMs, BMI, VNs in the manufacturing or AM sector.
- Discussion of the adoption of advanced manufacturing technologies for SMEs/SMMEs.
- Discussion of the introduction of services in the manufacturing industry.

3.1.4 Study search and selection

To illustrate the process of searching the selected databases and identifying the most relevant literature studies to be included in the study, the following flow chart is used, see Figure 3.2 on the following page.

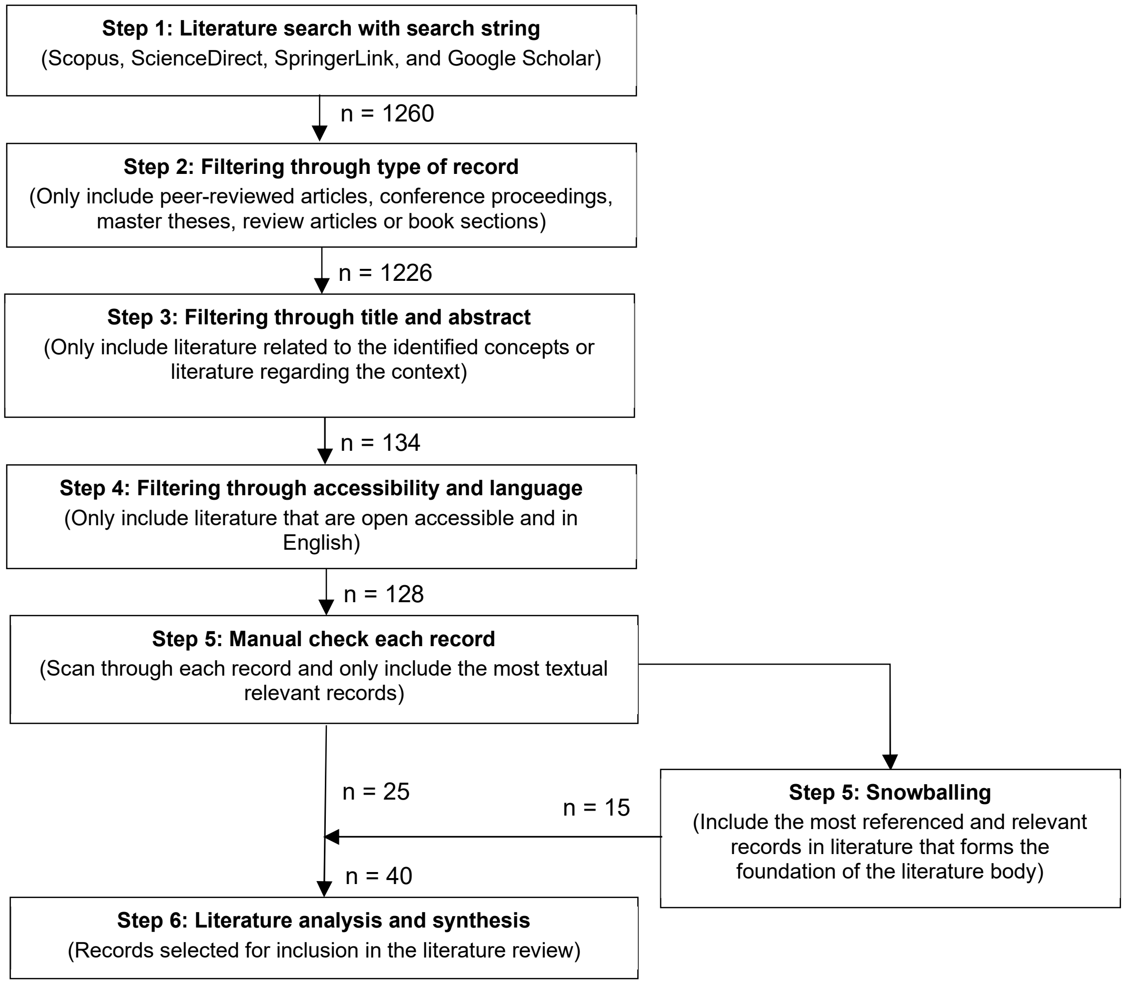


Figure 3.2: Process followed to select the primary data set

3.1.5 Bias assessment

Due to the inclusion of the snowballing technique in selecting some of the studies which were included in the primary data set, it was necessary to assess and address possible bias from the researcher.

During the bias assessment, it was concluded that potential bias had no real influence on the quality of the study since a few hand-picked articles were included and none were hand-picked to be excluded. Furthermore, the inclusion of relevant and recent systematic reviews regarding the primary literature domains also reduced the possible bias. To ensure all the relevant literature is considered to inform the integration of the concepts towards the development of the framework, classification was done to identify articles with a focus on a concept or a context, and those articles that integrate the concepts within the contexts, see Table 3.2. Table A.1 in Appendix A contains the articles' names included in the primary data set. Figure 3.3 below illustrates the distribution of articles in the various identified categories.

Table 3.2: Primary data set article categorisation

Category		Description of Category	References
Concepts (Rigour)	Business models	Articles in this category investigated different aspects regarding BMs such as development approaches, frameworks, and the origin and evolution of the BM concept.	[6], [7], [19], [246]*, [242]
	Business model innovation	Articles in this category investigated different aspects regarding BMI such as the different theoretical approaches, the development of the BMI concept, different frameworks, and the different applications thereof.	[220], [127], [75]*, [245]*, [184]
	Value networks	Articles in this category focused on aspects relating to value, the value chain, value transformation, the evolution from value chain to value network, or the design and development approaches of value networks.	[22], [231], [59], [194]*
Context (Relevance)	SMEs or SMMEs	Articles in this category investigated different aspects regarding potential challenges, benefits, and obstacles for SMEs or SMMEs.	[152], [223], [145]
	Additive manufacturing	Articles in this category reviewed the effects, advantages, and challenges associated with the adoption of smart manufacturing, advanced manufacturing, or specifically additive manufacturing.	[74], [76]*
Integration (Rigour and relevance)	Conceptual integration	Articles in this category focused on business aspects and business models in combination with value chains or value networks and the relationship between business models and value networks, value chains or the concept of value.	[154], [161], [136], [176], [177], [160], [114], [128], [201], [111]*
	Contextual integration	Articles in this category studied the integration between the selected concepts in the identified contexts.	[97], [251], [192], [26], [205], [159], [144], [125], [185], [225], [200]

*Systematic literature reviews

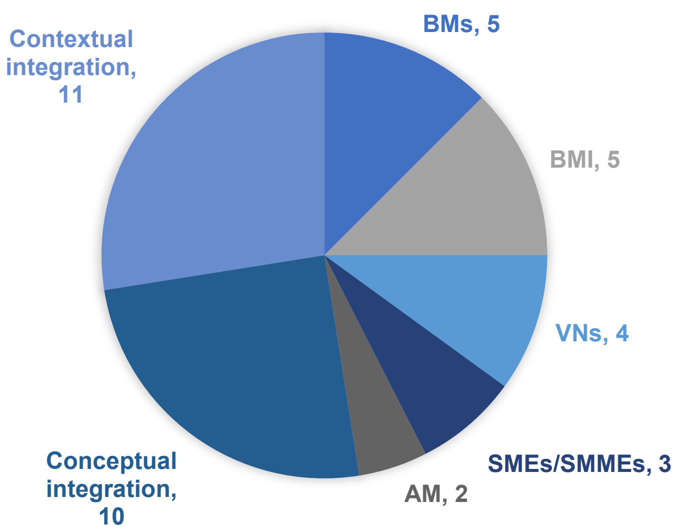


Figure 3.3: Primary data set categorisation distribution

3.2 Descriptive data analysis

The descriptive statistics provide a holistic view of the selected studies in the primary dataset. The first part of the descriptive statistics relates to the paper characteristics.

The graph below, Figure 3.4, shows the results of the first descriptive statistic, namely the publication timeline of the primary literature body. The light blue fraction at the top represents the articles categorised in the *Integration* category. As illustrated, most of the articles are from 2016 onwards, ensuring the literature is timely and relevant.

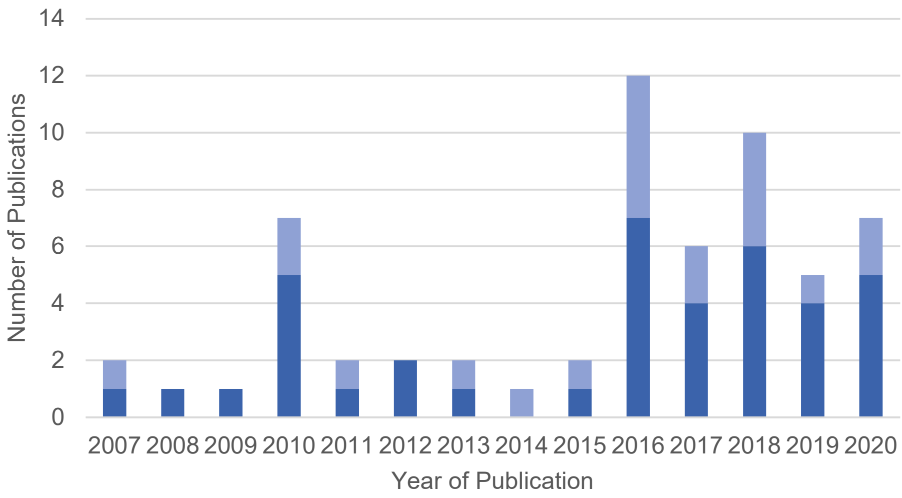


Figure 3.4: Timeline of the primary studies

The next descriptive statistic that was considered was the type of publications, see Figure 3.5. Almost all the selected literature were peer-reviewed journal articles. A few conference papers were included, as well as three theses. Therefore, the primary literature body consists of 82% journal articles, 8% conference proceedings, 8% theses and 2% book sections.

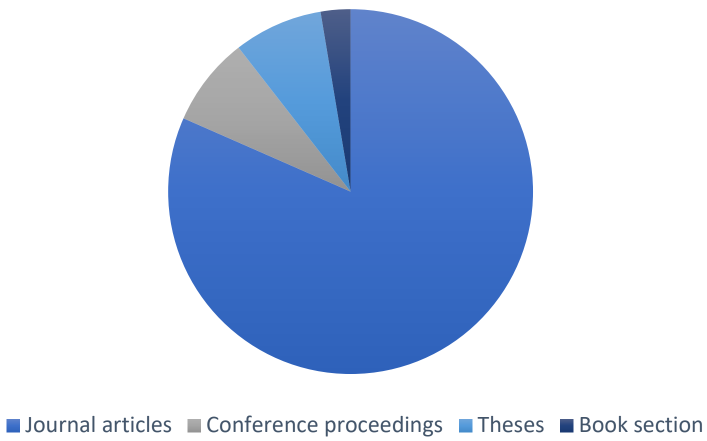


Figure 3.5: Type of publications of the primary studies

For the rest of the descriptive statistics, only articles categorised in the *Integration* categories were considered to ensure relevance. The inclusion of only these articles resulted in the highest probability of providing a better understanding of the applicable integrated literature body.

The research approach (theoretical, empirical, or consolidated) used in the papers was examined. By analysing the selected studies from the *Integration* category, it was determined that 60% of the studies were theoretically approached, 15% empirically, and only 25% were approached in a consolidated manner, meaning that theory was tested with an empirical method such as a case study.

The papers that contained case studies in the empirical or consolidated approach, were further examined to determine the geographical application area of the case study. It was found that all the case studies focused on developed economies in Europe (e.g., Finland, Sweden, UK, Germany). This emphasises the need for the application of case studies in developing economies such as South Africa.

When looking at the application areas of the selected studies, it was noted that the studies were scattered along different areas. However, the study conducted by Kritzinger *et al.* [125] was the only study that considered the AM aspects in tooling applications.

The final descriptive statistic that was studied for this structured literature review, was the theoretical focus and application of findings on the company size (see Figure 3.6). 25% of the studies were conducted on only theoretical, illustrative types of case studies, 30% focused on MNEs, and 15% focused on SMEs. 20% of the studies had no specific focus but were conducted more in general with a 'global' focus or focussing on both SMEs and MNEs.

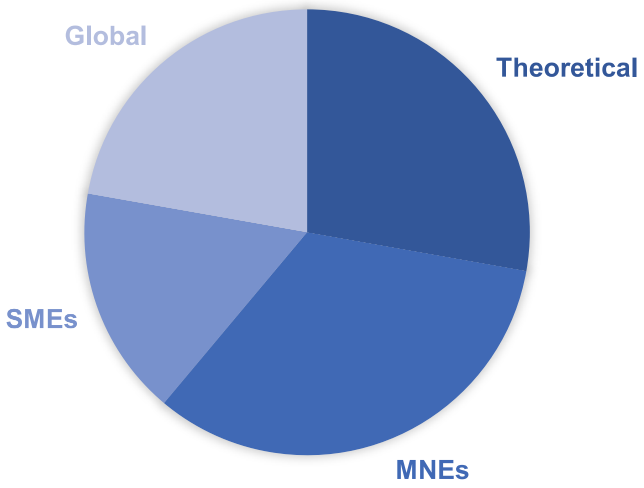


Figure 3.6: Application areas of the primary studies

From these findings, it is evident that little research is focused on the manufacturing and introduction of advanced manufacturing technologies in the TDM industry, and no research is conducted focusing on developing countries per se. Therefore, there is an evident gap in the literature to give attention to this industry focusing on SMEs in developing countries in the research community.

The following section aims to answer the following research-sub question: *Which relevant definitions, frameworks, elements, and concepts are available in each literature body (BM, BMI, and VN) to support the framework development? (SRQ1).* Figure 3.7 below illustrates the logic and approach followed in the section below to answer the question.

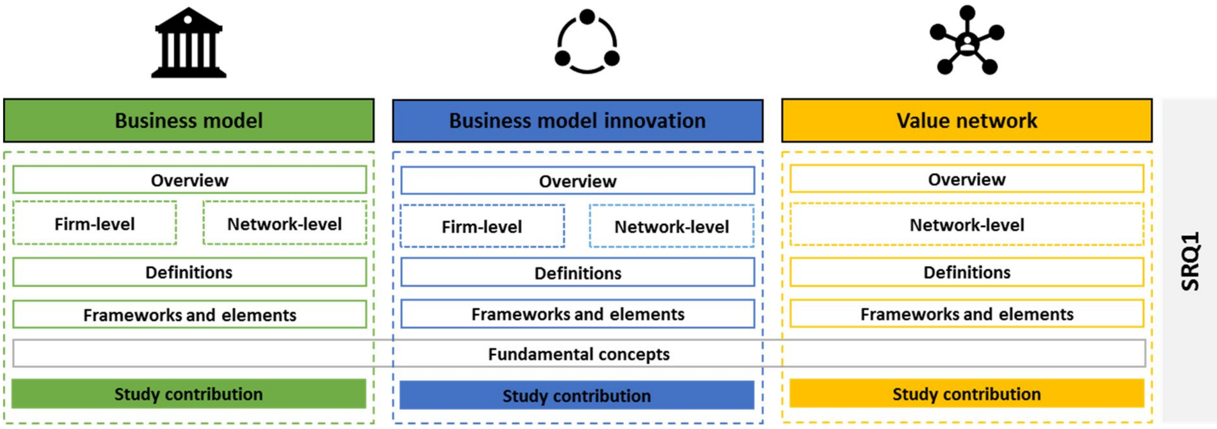


Figure 3.7: SRQ1 approach and structure

3.3 Business model

3.3.1 Overview

The BM construct emerged in the 1970s and was originally associated with system modelling in information technology (IT) [246]. Business model constructs are imprecise and are understood and interpreted in different ways by different people [82]. Since the 1990s, the concept has been maturing, with contributions from various disciplines and diverse application areas, causing it to have a global impact [246]. The literature review confirmed that although there is a broad range of BM definitions or conceptualisations, researchers and practitioners are still trying to analyse and broaden their understanding of this concept [20, 160, 161, 176, 246]. Despite the different conceptualisations, definitions, understandings, and applications, it is a valuable concept used within theory and in the industry since the BM concept helps to explain how strategy is applied to real-world business activities [220].

Business model frameworks consist of different elements or components that refer to the notion of value creation or the business logic of a reference system (unit of analysis), such as an organisation, VN, ecosystem, or industrial sector [246], often referred to as lenses or perspectives. Consequently, within the literature body, the focus of the BM range from a very detailed product level, the business level and the company level to the much aggregated industry level [246], which are referred to as the level of abstraction of representing the reference system. Although Laya *et al.* [128] argue that the VN and ecosystem are essentially the same, the distinction between the perspectives can perhaps be made based on the inclusion and exclusion of certain stakeholders [134]. Despite the difference in reference systems, there is no clear or commonly accepted definition of what a BM is nor its different constituent elements [246].

Although the concepts of BM, strategy, and business processes are used interchangeably by scholars and practitioners, they are not the same but closely related [6]. Each concept addresses similar problems but on different business layers, namely the planning level, architectural level, and implementation level [170]. Business models can therefore be regarded as an intermediary between an organisation’s strategy and its business processes [233], see Figure 3.8. The strategy focuses on how to create a competitive advantage, the BM depicts the logic of value creation and the effective coordination of business resources, and business processes describe the production of a specific output through the use of several inputs [233].

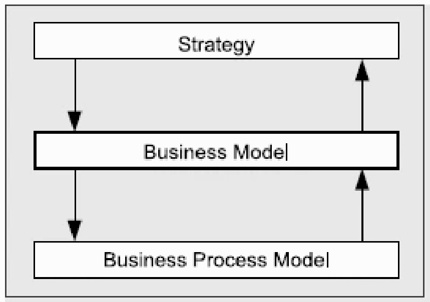


Figure 3.8: BM as intermediary between strategy and business processes [3]

Business model alignment is considered from different perspectives within the academic literature [59]. The first perspective concerns the internal alignment of BMs. According to Sosna, Trevinyo-Rodríguez and Velamuri [211], cited by Dara [59], newly developed BMs require organisational alignment as managers need to mobilise resources and develop competencies to implement the BM. Indeed, according to Al-Debei and Avison [6], the BM function as an alignment instrument that improves *"harmonisation and consistency among strategy and business process"*. As illustrated in Figure 3.9, strategy, BMs, business processes, and information systems (IS) or IT need to be treated as a harmonised package [6]. For this study, this type of alignment is referred to as internal firm-level alignment.

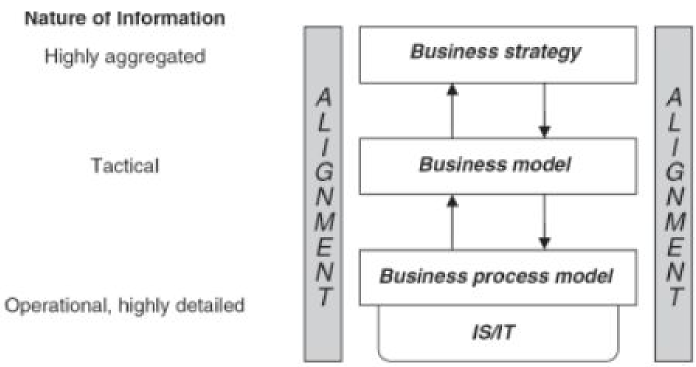


Figure 3.9: Alignment of business layers [6]

The next internal perspective towards alignment concerns the alignment or configurational fit on the network-level. This refers to the alignment that must be accomplished between the network-level BM and firm-level BMs, as well as between all the firm-level BMs. Such alignment can only be achieved when executives and managers pay considerate attention to building the right collaborative BM [62]. Network actors must have aligned BMs that are complementary in terms of resources and capabilities. The BMs of VN actors need to be aligned in order to achieve coherency, complementarity and consistency for the successful performance of the entire VN [59].

While BM alignment is highlighted from an internal perspective by some authors, others approach BM alignment from an external perspective [59]. Smith, Binns and Tushman [209] argued that organisations analyse the external environment and develop strategies accordingly, consequently, BMs need to be aligned with the external environment. In a similar vein, Svejenova, Planellas and Vives [216] noted that BMs need to be aligned with changes in customer needs, stakeholder priorities, and the external environment the business operates within. Furthermore, from the strategic management perspective, designing and aligning BMs is considered to be a dynamic capability [219], referring to organisational routines by which organisations gain, reconfigure, integrate, and dismiss their resources [66].

Osterwalder [170] suggested that a BM can function as a conceptual link, forming a triangle between strategy, business organisation, and ICT, see Figure 3.10. Thus, using strategy, business organisation, and ICT, the firm can be approached from different angles and on different business layers. Building on this suggestion, Wirtz *et al.* [246] categorised the BM research field into three categories: technology-oriented, organisation-theory oriented and strategy-oriented. The authors stated that the classification of BMs in these three categories was easy, up until 2000, then the classification becomes increasingly difficult due to the blurring of the boundaries between these basic theories [246]. They furthermore concluded that recently authors refer to the fundamental works and aspects of all three basic perspectives on the BM, leading to the development of an increasingly uniform BM understanding [246].

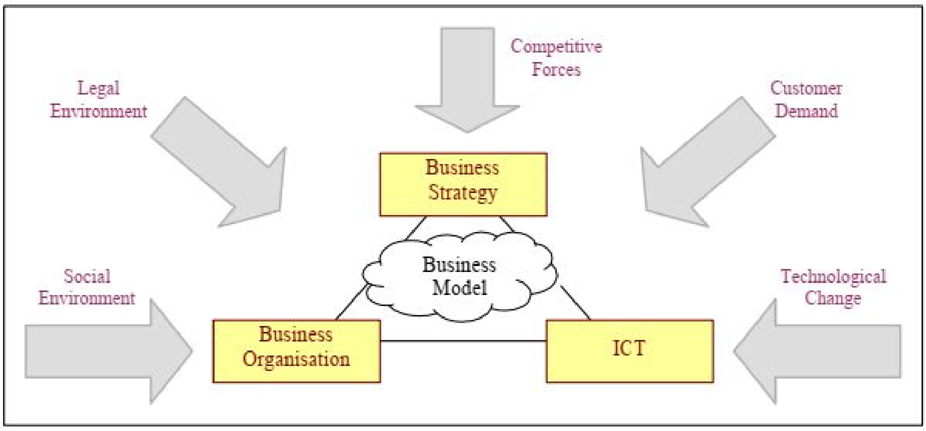


Figure 3.10: Environment, BMs, strategy, processes, and ICT [17]

The BM has been called many things throughout literature and in practice, such as a statement, a representation, an architecture, a conceptual tool or model, a structural template, a pattern, a framework etc, mostly centered around a focal firm, where sometimes its boundaries or reach are wider, referred to as boundary spanning [128]. Within the BM literature, the elements of a BM are in general explored from a single firm's perspective, a few employs the network perspective, whereas most adopt the perspective of a firm within the network (or between firm and network) [59, 176].

When analysing BM papers, a primary distinction can therefore be made between firm-centered and network-centered BMs [20]. Firm-centered BMs refers to the application of BM frameworks to a single firm, and network-centered BMs refers to the application of BM frameworks to a network of firms [111]. Furthermore, two different levels of analysis can be applied to these BM applications, namely firm-level and network-level analysis [111]. Firm-centered analysis takes the firm and its business exchanges as the starting point, whereas network-centered analysis starts with an understanding of the business logic at the network-level [20]. Hence, from a firm perspective, analysis of the firm-centric BM is carried out inside-out, while for the network-centric BM the analysis requires an outside-in approach [20]. Additionally, this network-level is considered by some authors as a system of interrelated BMs [254]. Table 3.3 below provides a brief description of the differences in analyses, proposed by Bankvall *et al.* [20] and presented by Jocevski *et al.* [111].

Table 3.3: Scheme of analysis for firm-centric and network-embedded BMs [20]

	Firm-level analysis	**Network-level analysis**
Firm-centric business model	Value proposition and exploitation considering a focal firm.	Firm's relationship with suppliers, customers, and other external actors.
Network-centric business model	The role and position of a specific firm within a network.	Value network configuration to create and deliver a common value proposition.

According to Wirtz *et al.* [246], several authors are recognising the need to understand the BM concept from a perspective that relies on network-level value creation processes [20], where such BMs provide a wider conceptualisation of networked value creations and business exchange patterns [246]. Therefore, expanding the boundaries of the reference system from a firm-level to a network-level and thereby going to a much higher level of abstraction. For this study, the network perspective is of particular concern, but the importance and fundamental contributions of the firm-level perspective are not disregarded. Therefore, the BM literature discussion contained in this section is divided based on these two perspectives.

3.3.2 Firm-level: definitions

The different definitions and components of the BM are closely related in describing what the BM consists of [69]. The elements of BMs are also referred to as building blocks and are sometimes presented as part of the definition or described as separate lists, frameworks or ontologies [172]. Despite all these conceptualisations, definitions, frameworks and BM elements contained in the literature (see a few selected definitions in Table A.2 in Appendix A), Wirtz *et al.* [246], as well as Foss and Saebi [75], agree that an increasingly uniform BM understanding seems to be developing in recent years. Most current definitions are close to or consistent with the following definition provided by Teece [220]: BM is the *"design or architecture of the value creation, delivery, and capture mechanisms"* of a firm. Furthermore, Corallo, Errico, Latino and Menegoli [54] identified five different approaches to the BM definition:

- *"Elements-based approach underlines the relationships among several elements of the company (internal and external) and how this will respond to the business context.*
- *Value proposition-based approach underlines the capacity of the business model to create value for the company's customers.*
- *Work-based approach: underlines how the company works.*
- *Networked-based approach underlines the relationships among firms, suppliers, customers, stakeholders, etc.*
- *Revenues-based approach underlines the capacity of the BM to generate revenues and give sustainability to the company."* [54]

Although there is no clear definition of what BM is, Zott *et al.* [255] identified the following four views on BM within the literature: *"1) BM as a unit of analysis, 2) BM as a holistic approach on how firms 'do business', 3) BM conceptualised through firm's activities, 4) BM as an explanation of value creation (as well as value capture)."*

Of these four views, two are of particular concern for this study, the conceptualisation of activities, and the explanation of value creation [255]. An activity system design framework, see Table 3.4, suggested by Zott and Amit [254], forms part of the conceptualisation of activities view on the BM. Zott and Amit [254] addressed three design elements within their BM framework, namely; *content* (referring to activities that are performed), *structure* (describing how activities are linked), and *governance* (describing who performs the activities) [254]. The inclusion of these design elements in their BM definition makes their definition a bit more comprehensive than the definition provided by Teece [220]. Their approach furthermore also includes analysis of BM dynamics in terms of activity design themes; indicating that the main drivers for change are the following: *novelty*, *lock-in*, *complementarities*, and *efficiency* [254]. These design themes properly acknowledge the need for change and the importance of BMI which can easily be adapted to fit a VN instead of only a single firm. The activity system perspective also encourages the firm to systemic and holistic thinking when designing its BM, instead of concentrating on isolated, individual choices [254]. This is important as the systemic perspective and systemic thinking play a vital role throughout this study.

Table 3.4: An activity system design framework [254]

Framework provides insight by: Giving business model design a language, concepts, and tools. Highlight business model design as a key managerial/entrepreneurial task. Emphasising system-level design over partial optimisation.	
Design Elements	
Content	What activities should be performed?
Structure	How should they be linked and sequenced?
Governance	Who should do them, and where?
Design Themes	
Novelty	Adopt innovative content, structure, or governance.
Lock-In	Build in elements to retain business model stakeholders.
Complementaries	Bundle activities to generate more value.
Efficiency	Reorganise activities to reduce transaction costs.

Building on the activity system view of a BM, Wirtz *et al.* [246] argued that in addition to the architecture of value creation, a BM must take strategic, market, and customer components into consideration, to achieve the ultimate goal of securing the competitive advantage. Pieroni *et al.* [184] also elaborated on the work conducted by Zott and Amit [254] and defined a company's BM as *"a system of interconnected and interdependent activities that determines the way the company "does business" with its customers, partners and vendors"* [184]. In other words, a BM is a *"bundle of specific activities — an activity system — conducted to satisfy the perceived needs of the market, along with the specification of which parties (a company or its partners) conduct which activities, and how these activities are linked to each other"* [184].

Using the BM to explain value creation and value capture is the second important view. This view in essence builds upon the definition of the BM based on the activity system perspective, with the focus on the architecture of value creation [255] instead of only on the activities and how they are linked. According to Nenonen and Storbacka [161], the purpose of the BM construct is to *"depict the managerial opportunities for a focal firm to influence value co-creation".* For this study, the view of the BM as a set of linked activities, to explain value creation and value capture [255] (including strategic, market, and customer components [246]) but expanding it to value co-creation [161], where new customer value creation is co-shaped by organisations and other key players [236] to achieve a competitive advantage, is adopted.

3.3.3 Firm-level: frameworks and elements

Since there is a diverse range of perspectives on the definition of the BM concept, there are various BM frameworks, containing various BM elements or components. Table A.3 in Appendix A presents a few selected BM frameworks and their elements. Considering the different interpretations, the models or frameworks in literature can be divided into canvas and non-canvas models [165, 230]. The canvas models refer to illustrative descriptions of a company's different processes while non-canvas models refer to textual descriptions of the content, structure, and governance of activities [165, 230].

Although the selected BM frameworks consist of different aspects, components, or elements, they also have similarities. An important similarity is that all frameworks describe how firms create and capture value [69], hence focusing on the concept of 'value'. Because if the customer does not perceive value in the product or service, it will not be used and certainly not be paid for, as it is indeed the concept of value that determines the product or service's worth [134]. When looking at the function of a BM framework, Fielt [69] stated that all BM frameworks address what a BM is made-off, defined either as BM elements, or components, questions [156], building blocks [172], functions [48] or partial models [246]. The BM frameworks furthermore highlight the importance of the relations between the elements or components and show a hierarchical structure [69].

To identify which of the selected firm-level BM frameworks will be built on throughout this study, a comparison between the frameworks was done, see Table 3.5. The comparison aimed to select the frameworks that will be most suitable in the context of this study, thus explicitly focusing on the concept of 'value' as well as having the VN as a central component. Despite the wide use of the Osterwalder Business Model Canvas (BMC) [172] throughout existing studies and in industry, the primary framework selected to guide this study is the V4 BM structure from Al-Debei and Fitzgerald [7], because both contextual requirements of this study are met. However, the framework is not completely comprehensive, therefore the 360° Business Model Framework from Rayna and Striukova [191] was selected as the second primary framework because it also focuses on the concept of 'value'. These two frameworks are presented and discussed in more detail below.

Table 3.5: Comparison of BM frameworks

Framework	Advantages	Disadvantages
Technology-Market Mediation [48]	Focus on technology introduction, value network as an element.	Does not focus on value, not comprehensive.
Business Model Canvas [170]	Well established, comprehensive	Does not focus on value.
Entrepreneur's Business Model [156]	Focus on an entrepreneur or focal actor, focus on value.	Does not consider the value network.
Four-Box Business Model [113]	Comprehensive.	Does not focus on value.
The V4 Business Model Structure [7]	Focus on value, value network is a main dimension with associated elements.	Not comprehensive.
St Gallen Business Model Navigator [81]	Simple and easy to use.	Does not focus on value, does not consider the value network, not comprehensive.
360° Business Model Framework [191]	Focus on value, comprehensive.	Value network is not a main dimension.
The Integrated Business Model [246]	Comprehensive.	Does not focus on value.

Al-Debei and Fitzgerald [7] developed the V4 BM structure after examining the dimensions, elements, properties, and semantics of mobile services in key academic papers published during 1998 – 2008. Using a bottom-up approach through the categorisation of thematic indicators, the authors developed a framework and conceptualised their findings as V4. The 'V4' stands for the four overarching dimensions of BMs which are: Value-proposition, Value-network, Value-architecture, and Value-finance. Each dimension consists of three to seven complementary concepts. Figure 3.11 illustrates the V4 model, consisting of the four value dimensions in the middle circle and the sub-dimensions of each value dimension in the outer boxes. [7]

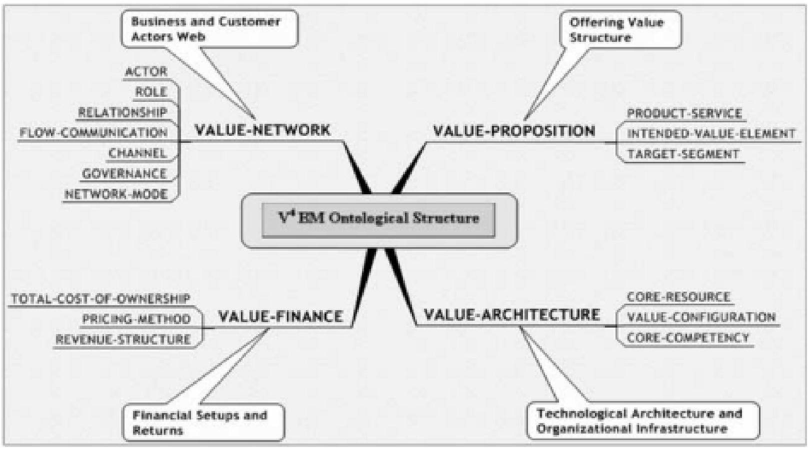


Figure 3.11: V4 BM ontological structure [7]

Rayna and Striukova [191] stated that the literature body has two lacks, firstly the lack of tools that allows BMs to be examined in their entirety, and secondly the lack of the inclusion of the complex relationships between BM changes and market outcomes. To address these two issues, they proposed the 360° Business Model Framework, see Figure 3.12. According to the authors, it is an integrated and value-focused view on all the value dimensions that make up the foundation of every BM. [191]

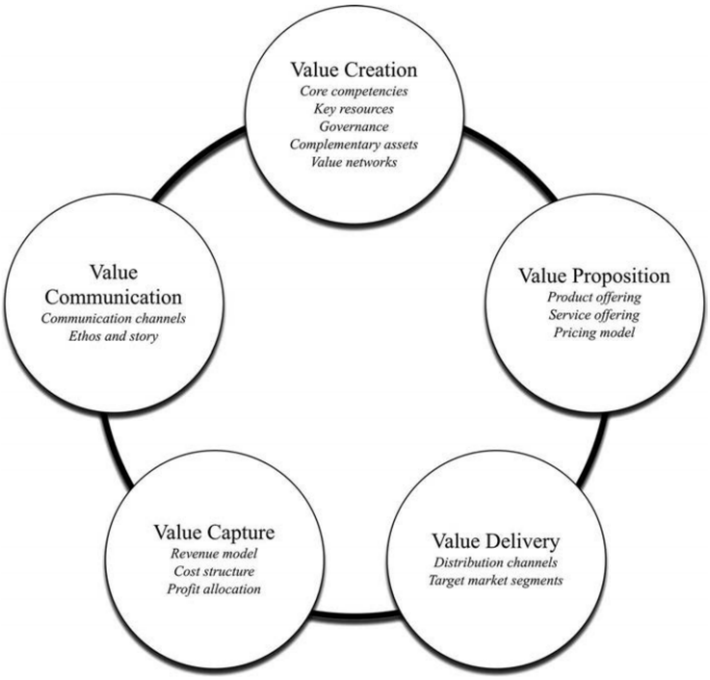


Figure 3.12: 360° Business Model Framework [191]

Given that we are amidst I4.0, additional up-to-date BM elements must perhaps also be considered to ensure the relevance and timeliness of the concept maps proposed in Chapter 4. Therefore, the taxonomy proposed by Weking *et al.* [242] was also selected to be included as a guiding framework in this study. They developed a taxonomy to characterise I4.0 BMs through analysing 32 case studies of I4.0 BM innovators, see Figure 3.13. From this, they derived 13 patterns which could be divided into three super-patterns namely, integration, servitization, and expertisation, see Figure 3.14. *Integration* refers to innovating a BM with new processes and integrating parts of the supply chain. New combined products and services are the basis for *servitization*. *Expertization* refers to a hybrid of product- and process-focused BMs, which includes consulting services and multi-sided platforms. [242]

Marked characteristics (*) based on Remané, Hanelt, Tesch, et al. (2017)

Meta-Dim.	Dimensions	Question	Characteristics					
Target Customers (Who)	Market	To which market does the firm sell?	B2B only (22)	B2C only (6)	B2B & B2C (4)	Multi-sided market * (8)		
	Segments	Does the firm target new customer segments due to the I4.0 transformation?	Existing customer segment only (13)	New customer segment only (8)	New and existing customer segment (11)			
	Contact	How does the firm interact with its customers?	Hybrid (intermediary and direct) (4)	Direct selling * (28)				
	Channel	Which channel is used for interacting with customers?	Offline (7)	Bricks & clicks * (20)	Online * (5)			
Value Proposition (What)	Strategy	Which general value proposition strategy does the firm use?	Add-on * (10)	Lock-in * (15)	Aikido * (5)	Make more of it * (12)		
	Product	What is the good the firm produces and makes money with?	Physical only (10)	Physical, digitally charged * (19)	Digital only (10)			
	Service	What is the content of the service offering?	Repair & maintenance (2)	Monitoring & predictive maintenance * (17)	Product (9)	Production (3)	IT (9)	Advice & consulting * (8)
Value Chain (How)	Development & Design	Who develops and designs the products that the firm sells?	Hired or employed experts (16)	Customer/ user designed * (3)	Development community/ crowdsourcing * (4)			
	Customization	How individualized is the product?	Mass production (7)	Mass customization * (14)	Mass individualization (5)			
	Push/Pull	What kind of production paradigm is used?	Pull/ on-demand * (8)	Push and Pull (1)				
	Factory	What is the size of the operating factories?	Mega-factory (4)	Micro-factory (5)				
	Role	Which role of the value chain does a firm focus on?	Integrator * (9)	Service and support * (20)	Intermediary * (6)			
Key Elements (How)	Key Partners	Which partnerships are essential to delivering the proposed value?	Inside-sector partners (6)	Outside-sector partners (5)	Customer or community including customization * (14)			
	Data Analytics	Where does the high-value data come from?	Internal data (4)	Customer's data * (21)				
	Key Employees	Which is the most characteristic job of the value creation and delivery process?	Operator & maintainer (15)	Remote monitoring (19)	Software developer & IT (10)	Consultant or trainer * (8)		
	Platform	What kind of digital platform is an essential part of the BM, if any?	IoT (21)	Merchant only (3)	Innovation * only (2)	Merchant & innovation (3)		
Value Capture (Why)	Revenue Model	How does the firm generate and manage revenues?	Sales * (24)	Revenue sharing * (2)	Freemium * (4)	Rent/ lease * (4)	Subscription * (18)	
	Continuity	How continuous are the revenues?	Once (10)	Mixed (16)	Continuous (12)			
	Sales Model	What does the customer pay for?	Ownership/ service delivery (24)	Use/ availability (11)	Result (3)			

The number in brackets indicates the number of cases that apply this characteristic.

Figure 3.13: Taxonomy of I4.0 BMs [33]

Super-patterns	Sub-patterns			
Integration (9)	Crowdsourced innovation (2)	Production as a service (3)	Mass customization (6)	
Servitization (18)	Life-long partnerships (12)	Product as a service (6)	Result as a service (3)	
Expertization (13)	Product-related consulting (5)	Process-related consulting (3)	Product-related platformization (5)	Process-related platformization (5)

The number in brackets indicates the number of cases that apply this business model pattern.

Figure 3.14: BM patterns for I4.0 [33]

In their paper, Al-Debei and Avison [6] stated that despite the recognition of the importance of the BM in the IS field, the concept is still fuzzy and vague, as there is little consensus regarding its compositional facets. Therefore, they developed a more comprehensive framework, see Figure 3.15, by providing a hierarchical taxonomy of the BM concept on a firm-level (see Table 3.6), using a deductive reasoning approach (referred to as the unified BM hierarchical taxonomy). The framework consists of four fundamental aspects which describe the BM concept within the digital business world.

Firstly, the framework includes four primary BM dimensions, along with their constituent elements [6], using the V4 BM dimensions from Al-Debei and Fitzgerald [7]. Secondly, it explores three major functions of BMs (within digital organisations) to explain the practical significance of the concept [6]. Thirdly, it explains the reach of the BM concept, showing its interactions and intersections with strategy, business processes, and IS [6]. And finally, it organises the BM modelling principles, that is, guidelines and features [6]. According to Al-Debei and Avison [6], the proposed BM conceptual framework is comprehensive and appropriate to the complex nature of businesses today. This proposed hierarchical conceptual framework forms the foundation for the development of the hierarchical taxonomy for the networked BMI concept presented in Section 4.3.

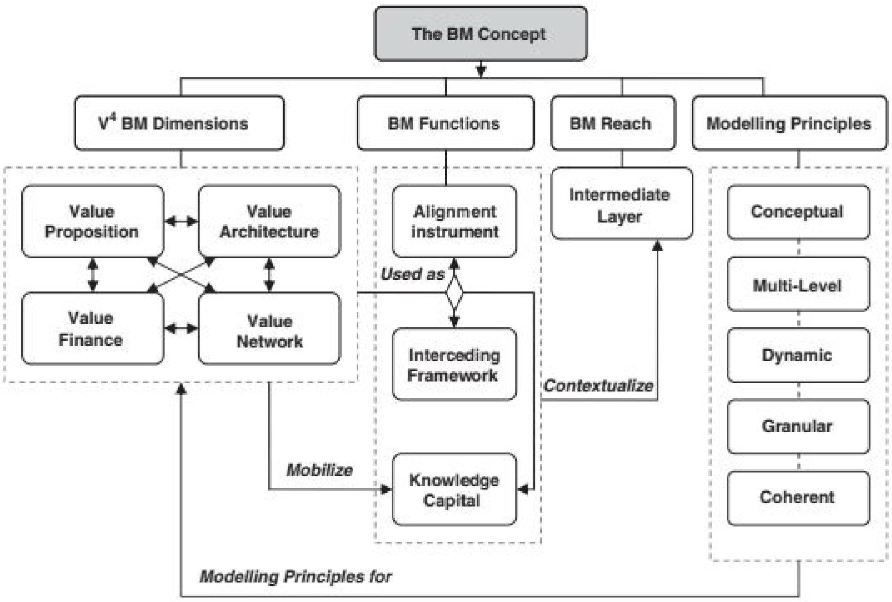


Figure 3.15: A unified BM conceptual framework [6]

Table 3.6: A hierarchical taxonomy of the BM concept [3]

Facet	Class	Description
V4 BM dimensions	Value proposition	A way that demonstrates the business logic of creating value for customers and/or to each party involved through offering products and services that satisfy the needs of their target segments.
	Value architecture	An architecture for the organisation including its technological architecture and organisational infrastructure that allows the provisioning of products and services in addition to information flows.
	Value network	A way in which an organisation enables transactions through coordination and collaboration among parties and multiple companies
	Value finance	A way in which organisations manage issues related to costing, pricing, and revenue breakdown to sustain and improve its creation of revenue.
Modelling principles	Conceptual	A conceptual tool, an abstraction and a blueprint of the existing business and/or the future planned business
	Multi-level	A way of designing, analysing and evaluating different units or levels within organisations such as products and services, business unit, an organisation, or even a network of organisations.
	Dynamic	A dynamic concept as the BM configurations and design change over time reflecting internal and external variations.
	Granular	A grainy controllable way of designing and evaluating business as the concept is subdivided into manageable elements
	Coherent	A comprehensive way of depicting a particular business entirely taking into consideration the interlinks between its different aspects.
BM reach	Intermediate layer	An interface or a theoretical intermediate layer between the business strategy and the ICT-enabled business processes. Nevertheless, it intersects with both: strategy and ICT-enabled business processes. The BM intersection with strategy represents a set of organisation's strategic-oriented choices for business establishment and management, while its intersection with processes signifies a set of business implementation practices and functions.

Facet	Class	Description
BM functions	Alignment structure	A theoretical tool of alignment providing a crucial instrument (i.e. bridge) for improving harmonization and consistency among strategy and business process including their supportive information systems.
	Interceding framework	A mediating construct or framework that connects technological potentials and innovations with the realisation of economic value and the achievement of strategic outcomes.
	Knowledge capital	An intangible and tactical information/knowledge asset useful in supporting strategic decision-making functions, and thus valuable in providing the organisation with an enduring competitive advantage.

3.3.4 Network-level: definitions

The need for network-based BMs is growing [111, 160]. Researchers agree that a single firm-level perspective on the BM is inadequate for describing joint value architectures since it is unable to include additional considerations regarding joint value proposition and different involved actors' roles and value flows in the network [111]. Consequently, authors have resorted to different literature streams to address actors' interconnectedness and used different methodological approaches to argue for a network-oriented view of a BM [111].

Some authors chose to incorporate the network element within existing BM definitions, whereas others decided to use new terminology to refer to such a view (e.g. ecosystem BM) [111]. Nevertheless, the argued shift from firm BM to ecosystem BM is noted as a change of management focus [243], in designing the BM that is based on the input of many actors [111]. Network-oriented BMs, therefore, aim to provide a better understanding of situations when it is impossible for a single-firm BM to orchestrate the relevant resources and activities needed to develop a joint service [176], not to mention the coordination of different actors and their roles [111]. As part of the first group of authors, Jocevski *et al.* [111] argued that the network-oriented view of BMs does not require a new theoretical concept, but the view can instead be seen as "*a meso-level value architecture that describes the value flow and dynamics of value creation, delivery and capture mechanisms at a network-level".*

As briefly introduced in Chapter 1, a strategic net or value net is an intentionally formed VN with a finite set of parties that can be managed to a certain degree with the aim of the strategic net is to gain or sustain a competitive advantage by focusing on some key activities [154]. Therefore, the following conceptualisation is considered appropriate and explanatory: a networked BM describes the way a strategic business net creates value [154] which are intentionally formed with a finite set of parties [155] that aim to gain or sustain competitive advantage by focusing on some key activities and outsourcing others and by gaining access to information, resources, markets, and technologies [154].

In summary, Lindgren *et al.* [136] suggested the following differences between firm-level and network-level BMs based on the case studies they conducted:

- Network-level BMs are powerful tools to innovate with, specifically when it is recognised that required competencies are not available in-house but can be accessed through partnerships with other firms.
- Participation within a network is triggered and driven by value equations (expectations, success criteria). Innovation is furthermore based on collaboration between partners who have the required competencies and access to markets. However, it can be a major challenge to bring these value equations and competencies together.

- The level of innovation is potentially high with a network-based BM, due to the large variety of competencies and ideas available within, as well as the technologies, products, markets or even industries accessible to, the network.
- The network-level BM has a much stronger focus on the basics of how joint innovation can create new value(s) and reduce costs for the stakeholders involved (compared to firm-level BMs).
- Incremental changes in each of the partners' structures, systems, technologies, approaches and/or products/services may have radically innovative effects.

The literature review indicated that although the networked BM is still an emerging research field, there seems to be increasing recognition of the need for the conceptualisation, definition, elements classification, and topology for this concept. A few of the primary research studies [111, 128, 160, 176, 177] attempted to unpack the concept of the networked BM and contributed to the current conceptual understanding and application thereof. Jocevski *et al.* [111] noted that there is a growing interest in a systematic perspective on how companies do business and think about their BMs within the VNs. Table A.4 in Appendix A contains a selection of network-based BM definitions or conceptualisations. Although a number of definitions or conceptualisations are primarily focused on networked BMs for IoT networks or IoT ecosystems (IoT empirical context) in the telecommunications or mobile service industries, Jocevski *et al.* [111] argue that the same conclusions and propositions may be applicable in more general terms, thereby including the application thereof in IoT ecosystems or networks in manufacturing industries.

For this study, elaborating on the previously defined BM definition, the view of the networked BM as a set of linked activities or functions to explain value creation and value capture [255] (including strategic, market, and customer components [246]) from a network perspective, but expanding it to value co-creation [161] within the network, where new customer value creation is co-shaped by organisations and other key players [236] to access (complementary) competencies, resources, or markets [136] to achieve a competitive advantage, is adopted.

3.3.5 Network-level: frameworks and elements

Various approaches have been proposed to analyse VNs and to understand the networked BM. Table A.5 in Appendix A presents a selection of these models or frameworks. Jocevski *et al.* [111] concluded that the dominant context in the empirical studies they analysed was that of IoT ecosystems. The IoT ecosystem consists of multiple components that allow businesses, governments, and consumers to connect to their IoT devices. These components include sensors and actuators which are at the centre of the entire IoT network. Despite this technical description to clarify the term, within the BM literature, the IoT ecosystem perspective is regarded to be in parallel with the network perspective [111]. Therefore, suggesting that all relevant stakeholders need to be involved with the value creation and exchange in the IoT to ensure a common understanding is established within the network [128]. Therefore, authors refer to BMs that concern the creation of IoT services, as ecosystem BMs since they tie the service and value architecture to the ecosystem within which the service is developed [111]. However, within the context of this study, the focus is primarily on the network perspective stream of literature.

To identify which of the selected network-level BM frameworks will be built on throughout this study, a comparison between the frameworks was done, see Table 3.7. The comparison aimed to select frameworks that address critical aspects that must be considered in the context of this study. Based on the comparison, the framework of the elements of the networked BM from Palo and Tähtinen [176] was selected because of the key elements addressed in the framework and the illustration of how value should flow within a network. Furthermore, the networked business model development framework [177] from the same authors was also selected because of the inclusion of the innovation process in the development of the networked BM. These two frameworks are presented and discussed below.

Table 3.7: Comparison of networked BM frameworks

Framework	Advantages	Disadvantages
Building blocks of a network-based BM based on BMC [136]	Simple, easy to use.	Not comprehensive, does not consider any key network element.
Framework of the elements of the networked business model [176]	Include key network elements, focus on value exchanges and flow, include a service.	Not comprehensive.
Networked business model development framework [177]	Include innovation process through time, include key network elements.	Not comprehensive.
Network-based BM ontology [160]	Consider human perspective and key network elements.	Not comprehensive, does not consider key network elements.
Network-oriented view of a BM [111]	Comprehensive on a high-level.	Not detailed enough, does not consider value exchange and flow.

Palo and Tähtinen [176] aimed to identify generic elements of a BM in the field of technology-based services and used those elements to build a networked BM. According to them, a networked BM reflects a situation when it is impossible for a single company (the focal firm) to govern all the relevant resources and activities needed in developing, producing, and marketing technology-based services. The authors suggested a theoretical framework of the elements of a BM with a distinction made between the single firm and business net. After empirical testing, the authors presented a framework of the elements of a networked BM, centered around a modular service with value exchanges and a service production net, see Figure 3.16. [176]

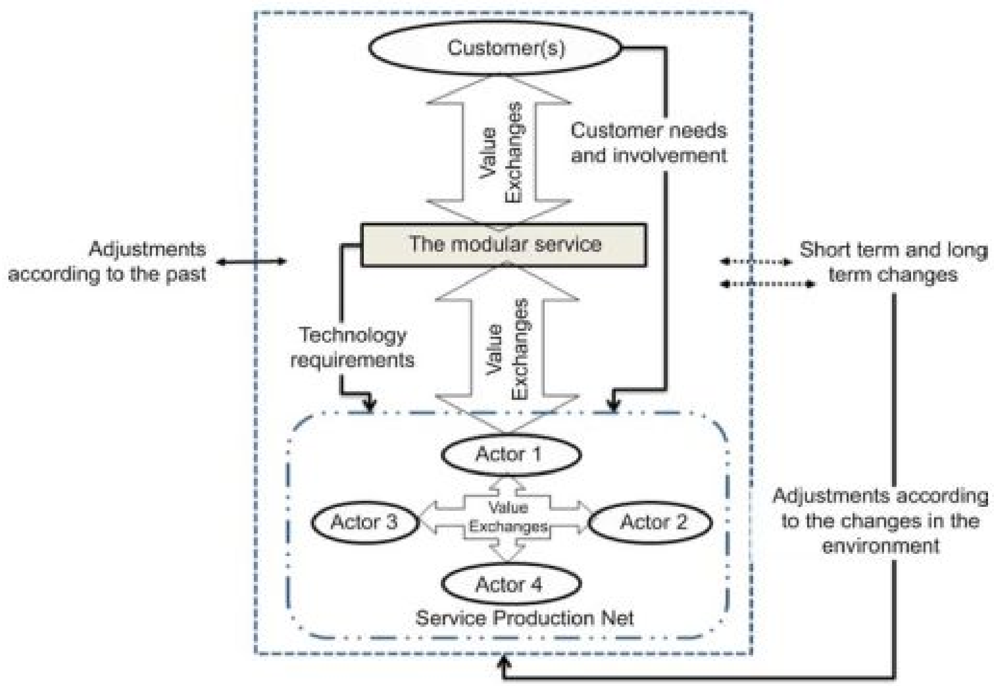


Figure 3.16: Framework of the elements of a networked BM [176]

Soon after, Palo and Tähtinen [177] provided another network-centric BM development framework (see Figure 3.17), this time focusing on technology-based services in emerging markets. For this framework, network-centric BM development starts with each actor entering the network with their individual firm-level BMs. The framework primarily consists of the following three elements:

i) Business net development with actors and their roles in the network.
ii) Business opportunity identification.
iii) Networked BM development.

The framework also considers a time dimension, beginning with service development, moving to a pilot phase, and ending in a market phase, which constitutes the three main phases of networked BM development. The networked BM evolves throughout these three stages, instead of only being the result of the development. The employment of a future perspective enables a better understanding of how current, firm-level BMs constrain possible opportunities. The empirical study suggests the construction of a networked BM needs to be started during the service development phase, even if that ‘construction’ is then limited to the actors having a mental picture of it. [177]The framework furthermore stresses the importance of entrepreneurial activities among actors within the network (associated with business opportunity development). Entrepreneurial actors can act as facilitators within the network, as they identify and create business opportunities. [177]

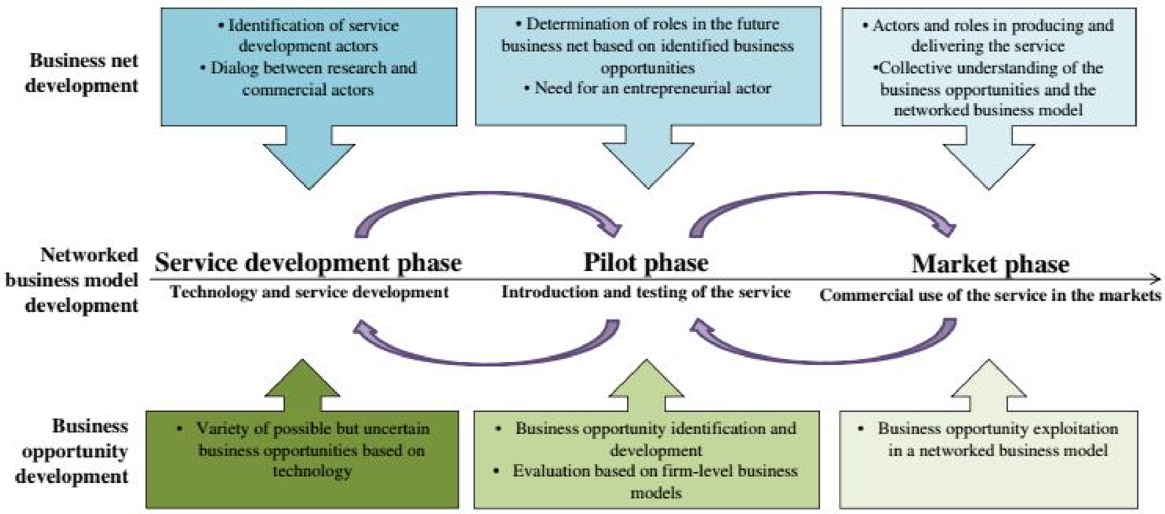


Figure 3.17: Networked BM development framework [177]

Furthermore, a network-based BM ontology, see Figure 3.18, was proposed by Nekoo *et al.* [160] and applied to an e-business case study. The ontology was developed by identifying BM elements as well as network features (Figure 3.19) whereafter a comparison of the elements and features was performed. It was concluded that different entities in the network consist of actors, goals, and resources with trust, shared-mental models, and infrastructure connecting the entities [160]. This ontology forms the foundation for the proposed strategic business net features presented in Section 4.2.

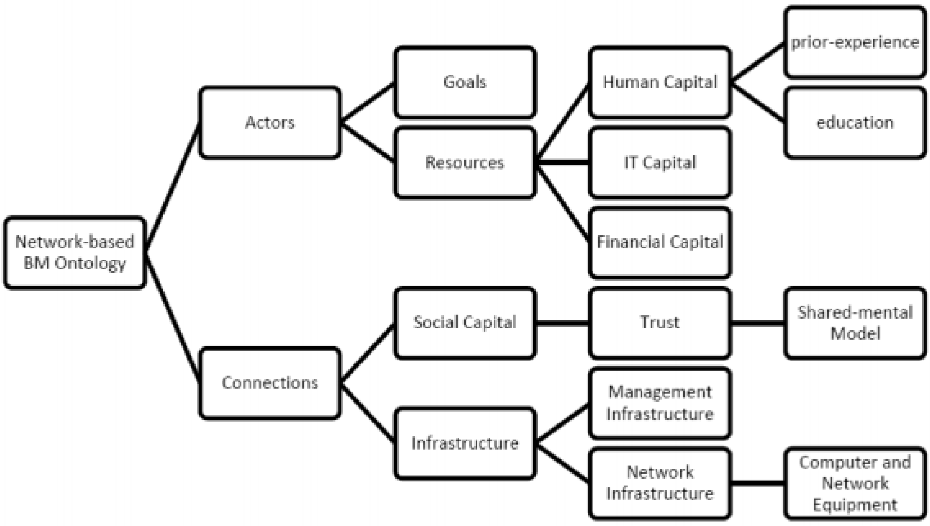


Figure 3.18: The proposed network-based BM ontology with details [160]

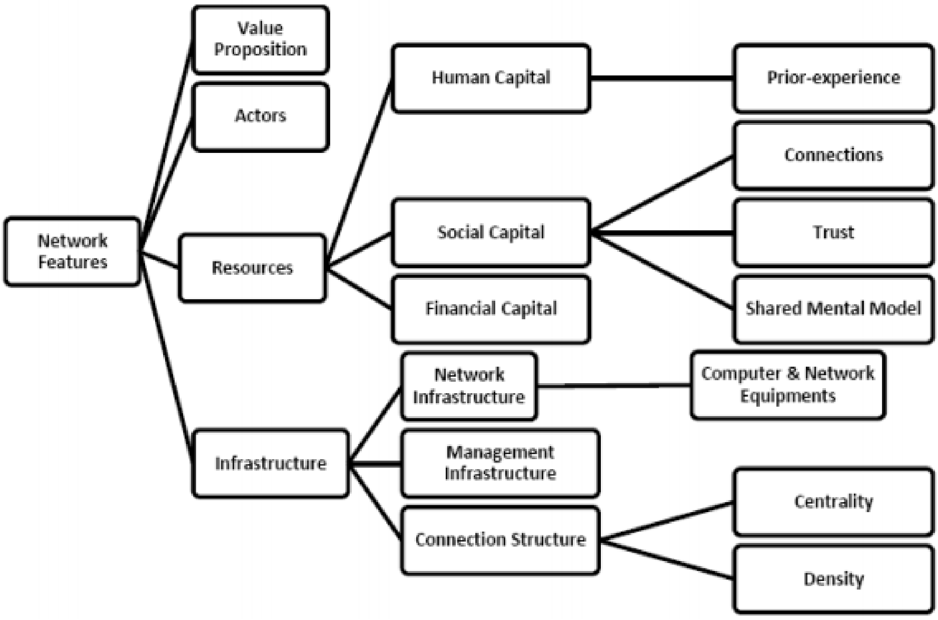


Figure 3.19: Network features [160]

In agreement with Laya *et al.* [129], this study follows the proposition suggested by Palo and Tähtinen [177], suggesting that a network-level BM is a collective BM (consisting of individual BMs [177]) which *"guides how a net of companies will create customer and network value by developing a collective understanding of the business opportunities and shaping the actions to exploit them".*

In summary, the study conducted by Jocevski *et al.* [111], in line with Bankvall *et al.* [20], suggested three viewpoints, both corresponding with the three levels of analysis inspired by the activities-resources-actors (ARA) model from Håkansson and Snehota [96], from which to interpret value architectures at different levels of analysis of which the network-oriented way is seen as a possible way forward:

- *"a single-firm view where the BM represents the value architecture of a particular firm;*

- *a dyadic-level view, where the BM is seen as a linking agent between two actors; and finally,*
- *a network-oriented view, where the BM explain value architecture represented through business relationship elements between several actors, therefore the BM be a relational aggregator."* [111]

Accordingly, the BM, as a tool to support strategy execution [42], could be seen as the service provider's strategic relational aggregator, based on the assumption that the relationship between two firms is based on a relation between the firms' BMs [87]. Within the BM, different value creating building blocks are related and interact [172]. Similarly, using the BM, a company can relate with its external environment and a network of other actors' BMs, in an activity systems perspective [254]. Nenonen and Storbacka [161] furthermore concluded that during value co-creation, the effectiveness of a BM is defined by the internal configurational fit between all the BM elements and the external configurational fit between the provider's and customers' BMs.

3.3.6 Business model study contribution

To summarise, Figure 3.20 below illustrates which BM frameworks on the firm-level and which BM frameworks on the network-level, were selected as foundational theoretical frameworks on which other research artefacts within this study is built. Furthermore, Figure 3.21 below illustrates the selected fundamental concepts contained in the BM literature body that forms part of the concept inventory and concept map presented in Chapter 4.

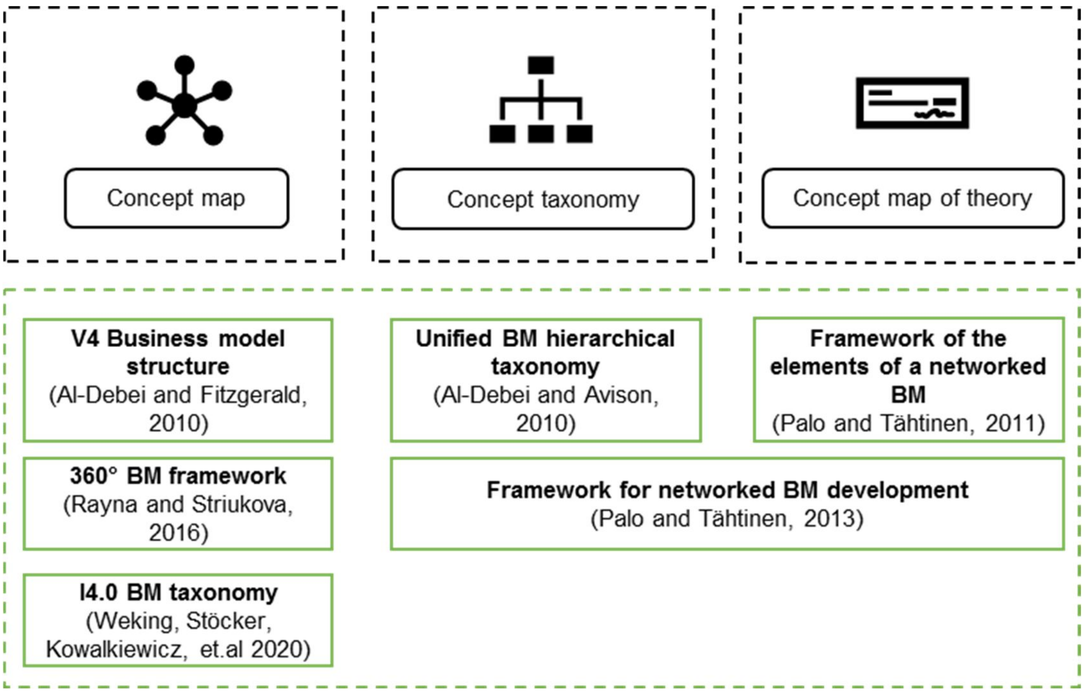


Figure 3.20: Selected theoretical BM frameworks

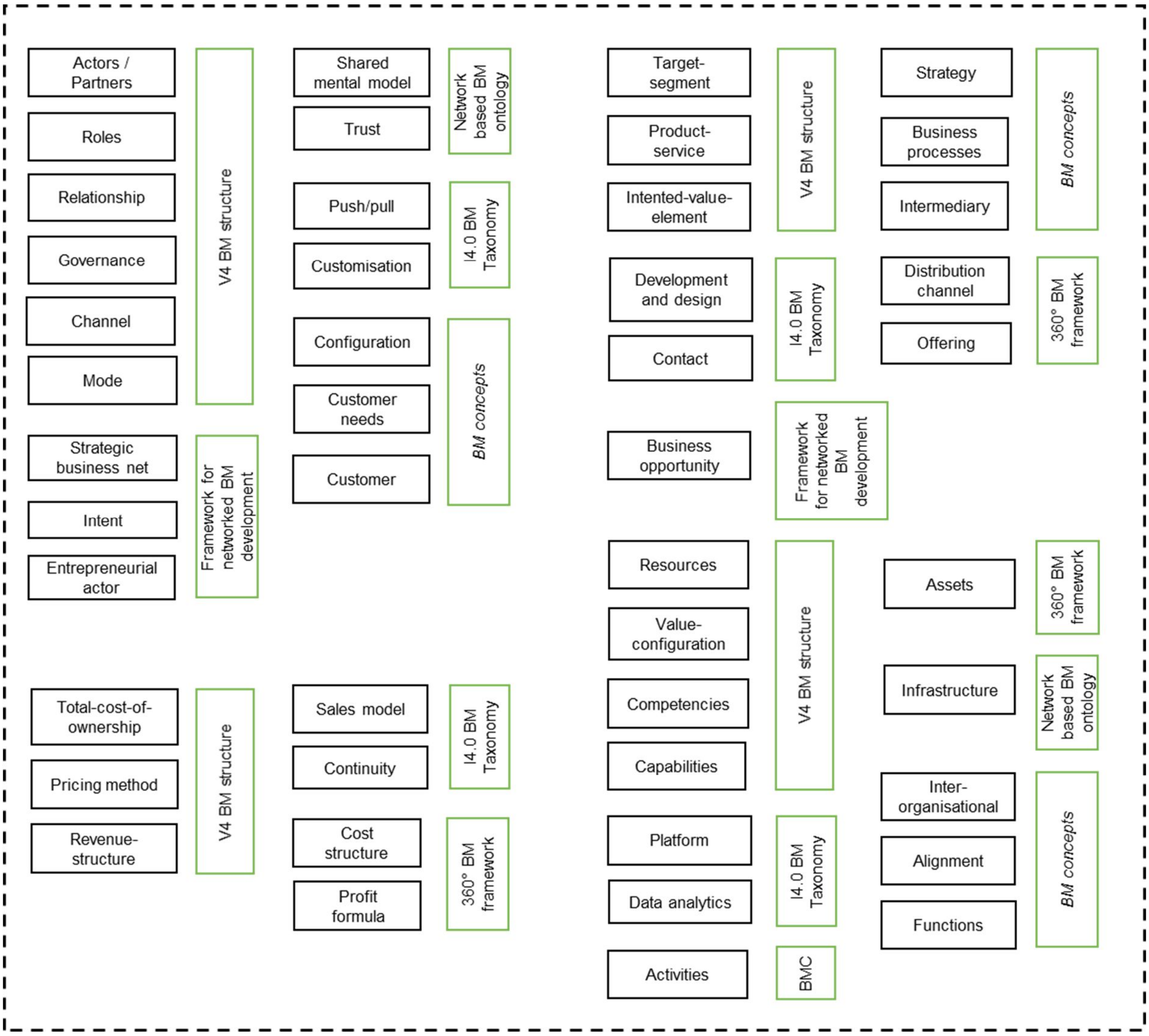


Figure 3.21: BM fundamental concepts

3.4 Business model innovation

3.4.1 Overview

Most BM conceptualisations or frameworks are however static, implying it is only applicable and valid for a specific point in time. Given the dynamic and complex business environments (such as the constant introduction and advancements of technologies and innovations), it is of utmost importance to consider these changes, caused internally or externally [75], through a time dimension or dynamic view [246] – BMI. In this dynamic view, the BM can be a *"(1) enabler of strategic changes in innovation processes (e.g. products/services), or (2) the source of competitive advantage acting as the innovation itself"* [28].

Innovation is based on the incorporation of existing or novel knowledge in a unique manner to perform some tasks better. The changes brought about through the innovation process can be referred to as incremental or radical (disruptive) changes. Traditional sources of technological innovation include product-, process-, service-, and organisational innovation, but research on BMI recognise the potential of the BM as a source of innovation [230, 241].

Chesbrough [47] argued that "*technological innovations are of little value without appropriate business models",* he went further and stated, "*a good business model can even make an inferior technology more successful than a superior one*". Due to the promising effectiveness of BMI over technological innovations, companies are increasingly shifting their focus to BMI [193].

Business model innovation is required since technological innovations do not create or capture value for organisations by themselves [47]. New unused sources of value creation can be discovered if BMI is adopted [13]. Business model innovation can also be used as a competitive advantage in the market, as innovations regarding BMs are often harder to replicate than product or service innovations [13, 230]. At the same time, BMI can result in a major threat for a company that fails to adapt according to external changes, in comparison with competitors inside and outside the industry that do [13, 230]. Osterwalder and Pigneur [172] provided the following list for when BMI is required:

- *"To fulfil an existing yet unanswered market need.*
- *To introduce new technologies, goods, or services to a market.*
- *To improve, disrupt or alter a settled market with an improved BM.*
- *An emergency exists with the current BM.*
- *To advance, refine or guard the current BM against an altering environment.*
- *To plan by investigating and assessing new BMs that could possess the potential to substitute existing ones."* [172]

The literature review conducted by Foss and Saebi [75] revealed that there are primarily two views on what exactly BMI is. They found that one research stream views BMI as a *process* (e.g., search, experimentation, transformation), while another research stream views it as an *outcome* (i.e., the innovative BM). Accordingly, studies are approached differently as they deal with different phenomena. If BMI is perceived as a *process*, a dynamic approach is taken into the organisational characteristics that enable or hinder the BMI process, and if BMI is perceived as an *outcome*, a more descriptive approach is taken to identify the content of the BMI. Consequently, the researchers identified four research focus areas, see Table 3.8. The study at hand regard BMI as a *process* and make use of conceptual findings and case study examples (in the form of a real-life scenario and a story) as part of the research methods. [75]

Table 3.8: Streams of BMI research [75]

Research focus	**Method**
1. Conceptualisation and classification of BMI	Conceptual, case examples Survey data
2. BMI as a process (e.g., importance of capabilities, leadership, learning mechanisms)	Conceptual, case examples Single/ multiple case studies Content analysis Experimental
3. BMI as an outcome (e.g., identifying/ describing innovative business models)	Single/ multiple case studies
4. BMI and organisational implications/performance	Survey data

According to Foss and Saebi [75], BMIs differ in terms of two dimensions, namely, the degree of novelty and the scope of the BMI. The degree of novelty refers to whether the BMIs are new to a firm, while not necessarily new to an industry; whereas others stress BMIs that are new to an industry. The scope of the BMI refers to how much of the BM is impacted, at one extreme, it may only impact a single component, whereas, at the other extreme, it may involve all components of the BM, including the architecture (linking). Some scholars suggest BMI can happen in a single component, others argue that "one or more" components need to change, while others stress that "two or more" components need to change. Whereas another group argue that an entirely novel combination of all BM components and the architecture linking them, is required. Therefore, Foss and Saebi [75] suggested the following dimensional analysis (topology) of BMI: [75]

Table 3.9: BMI topology [75]

	Scope		
Novelty		**Modular**	**Architectural**
	New to firm	Evolutionary BMI	Adaptive BMI
	New to industry	Focused BMI	Complex BMI

However, aligned with Clauss [52], Müller *et al.* [159] argued that BMI can originate from and predominate in one of the three BM elements: value creation, value offer (or value proposition), and value capture. Value creation effects include production equipment, workforce, partners, and suppliers. Value offer effects include products and services (including servitization). Value capture effects include customer groups, customer interaction and payment methods [159]. In line with Müller *et al.* [159], the present research study acknowledges that the three BM elements are highly interconnected so that innovation in one element by definition leads to changes of varying degrees in the other two elements [254].

Even though BMI is often regarded as the dynamic aspect of a BM, Foss and Saebi [75] stated that BMI can however be approached as static or dynamic. For a static view, BMI is seen as *"new types of innovative ventures that may affect firm performance".* Whereas, for a dynamic view, BMI is conceptualised as an *"organisational change process requiring appropriate capabilities, leadership, and learning mechanisms"* [75].

The dynamic nature of a BM is also emphasised by several other authors [75]. For example, the network-based BM framework proposed by Palo and Tähtinen [176] (discussed in Section 3.3.5) also considers adjustments needed due to changes in the environment, as the economic environment is continuously changing and impacts the BM. Palo and Tähtinen [177] (discussed in Section 3.3.5) furthermore employed a longitudinal research design in their emerging technology-based service framework, as they emphasised that it is critical in understanding the dynamics of BMs. This was done through the introduction of three stages in the framework from the past and present, as well as future, namely service development, pilot and market [177]. This logic and argument form an integral part of the concept maps proposed in Chapter 4.

Pieroni *et al.* [184] provided a review on approaches for BMI, specifically for circular economy and/or sustainability, based on a systematic review of academic literature and practitioner-based methodologies. They categorised the different approaches according to the three-stage dynamic capability view on BMI (discussed below in Section 3.4.3). Subsequently, they used the following five characteristic to distinguish between the approaches: nature of data, boundaries of analysis, level of abstraction, time-based view, and representation style, see Table 3.10 below. These characteristics were used as guideline to classify the characteristics of the conceptual framework and management tool in Section 6.2.

Table 3.10: Key characteristics of approaches: BMI aspects [184]

Characteristic	Alternatives	Meaning
Data nature	Qualitative	Support subjective analysis providing general guidance.
	Quantitative	Support objective analysis providing quantification.

Characteristic	Alternatives		Meaning
	Both		Quantitative and qualitative characteristics.
System boundaries	Organisational		Drivers focused on individual firms and their own value adding activities.
	Inter-organisational		Drivers shared by different organisations. Focus on the interrelationship with other actors to co-create shared value.
	Societal		Drivers triggered by societal (or regime) shifts. Focus on interrelationships with other organisations, to produced shared value.
Abstraction level of representation	Highly aggregated		Simple and concise descriptions, i.e., resembles a 'vision' or idea described in low depth (e.g., narrative or archetypes)
	Moderately aggregated		Accurate descriptions, yet parsimony to keep it simple (e.g., graphics).
	Detailed		Accurate and robust descriptions, adding depth and many details (e.g., flow charts and relationships).
Variation over time	Static		Describes the BM, focusing on components and their coherence (i.e., a model, blueprint).
	Dynamic		Focus on transformational perspective and how BMs evolve over time requiring changes in capabilities.
Representation style	Method	Guideline/ manual	General guidelines to be followed during the BMI and design.
		Process model	A set of activities and steps that represents the complete or parts of the process for BMI.
	Tool	Cards	Paper-based tool describing opportunities/design options.
		Serious game	Paper-based/computational tool that simulates a part or the complete BMI process.
		Visualisation tool	Paper-based/computational tool using visual techniques to represent the logic of value generation/flow within one/multiple organisations.
		Simulator/ Software	Computational tool supporting the application of BM tools (might include concepts of decision-making theory.

3.4.2 Definitions

Table A.6 in Appendix A contains a selection of BMI definitions from various viewpoints, which indicate a lack of clarity in the literature about the nature of BMI. Many of the definitions lack specificity and differ concerning the nature of the unit of analysis. Foss and Saebi [75] summarised the views on BMI as follows: "*some scholars take a partial view in which changes in a single component of a BM can constitute BMI; others define BMI as innovation in technologies, VNs, and financial hurdle rates, such definitions emphasise the components of a BM; another group of scholars stresses that what is being innovated is the architecture of a BM rather than its individual components"* [75].

The definition provided by Foss and Saebi [75], namely "*BMIs are designed, novel, non-trivial changes to the key elements of a firm's business model and/or the architecture linking these elements*" as a response to internal and external incentives, is commonly used throughout the literature body, and therefore this study also adopted this definition. Considering this commonly used definition, Weking *et al.* [242] argued that *"designed"* implies that BMI is a deliberate change to a current BM and *"novel, non-trivial changes"* excludes minor changes, such as a change in a supplier, to existing BMs. Business model innovation, therefore, consists of changing, by creating, diversifying, acquiring or transforming, a BM as a response to internal and external changes or incentives [75].

3.4.3 Frameworks

The literature regarding BMI as a dynamic process contain different approaches with different phases. The most prominent BMI frameworks are described in Table A.7 in Appendix A. All these BMI frameworks are generic and designed on a high-level containing a varying number of stages or steps [245] which is structured in a linear or simple cyclic flow. The different frameworks also have a difference in orientation and focus, while some are design-oriented, others are process-focused [245]. The frameworks are focused on a single firm, with a lack of providing concrete design guidelines for each step. Furthermore, only two of these frameworks, the process proposed by Osterwalder and Pigneur [172] and the Cambridge BMI Process, contains a set of practical tools for each stage or phase. These BMI processes have the potential for improvements regarding the level of analysis i.e., networked-based considerations, as well as refinement regarding the tool content and adding design guidelines to aid managers in decision making.

To identify which of the selected BMI frameworks will be built on throughout this study, a comparison between the frameworks was done, see Table 3.11. Based on the comparison and consideration of the frameworks in the context of this study, the dynamic capabilities-based approach from Teece [219], which was adapted by Pieroni *et al.* [184], was selected as the overarching BMI approach. To provide a more structured approach to the framework, the Generic BMI Process with associated activities, proposed by Wirtz and Daiser [245], was selected as the process model to be used in the framework as it easily aligns with the dynamic capabilities-based approach. These two frameworks are presented and discussed in more detail below.

Table 3.11: Comparison of BMI frameworks

BMI framework	Advantages	Disadvantages
Wheel of Business Model Reinvention [236]	Iterative, based on dynamic capabilities.	Does not cover all phases.
Five Stage BMI Process [172]	Include tools, detailed.	Linear, not applicable to network-level.
Repeatable BMI Process [112]	Iterative, systematic, and structured.	Does not cover all phases.
Circular BMI Process [135]	Iterative, comprehensive.	High-level.
BMI Tool Framework [86]	Simple to use, iterative.	Does not cover all steps.
Dynamic capabilities-based view [219]	Dynamic, iterative, applicable to network-level.	High-level.
4I-Framework [77]	Clear focus, iterative.	Does not cover all steps.
Cambridge BMI Process [84]	Comprehensive, detailed, include tools.	Complicated.
Generic BMI Process [245]	Comprehensive, generic, include activities.	Focused on firm-level.

As mentioned in Section 3.4.1 above, Pieroni *et al.* [184] used an adapted dynamic capabilities-based view from Teece [219] to classify the different BMI approaches. This multi-disciplinary, three-stage model was proposed by Teece [219] to explain how organisations should be prepared to continuously adapt and develop innovations, including BMs. The approach also includes the role of human-behaviour in the BMI process by opening space for change management aspects (e.g., values, mindset, behaviours, engagement, leadership. According to Pieroni *et al.* [184], this model represents more adequately the 'real world' phenomena [184]. The dynamic capabilities-based view on BMI includes the following three phases:

1. **Sensing**, referring to the sensing of external threats and opportunities [219]. During this phase, relevant global megatrends, business opportunities, customer needs, competition, technology, and changing environments are recognised, as well as their linkages to the BM [220].
2. **Seizing**, referring to the operationalising of the identified opportunities and threats by developing existing or creating new BMs [148]. These capabilities require a systemic approach to BMI as it needs to include the combination of technological, market, BM knowledge and continuous learning. The ecosystem or VN of the company helps to develop new BMs by providing a set of resources, knowledge and complementary assets that would otherwise be unavailable if the company would only focus on its own strengths [46].
3. **Transforming** (or reconfiguring), referring to the building of new competencies and the implementation of organisational renewal, which is required for the ongoing BMI [148]. These capabilities also help the company to proactively prepare for the future, since BMI is a continuous process [220]. This may prepare the company for successful transition management.

In their study, Wirtz and Daiser [245] aimed to synthesise the wide-spread insights on the BMI process, by systematically analysing the existing BMI research body. After scrutinizing and comparing the BMI processes of 20 publications on an abstract level, the authors derived seven generic BMI process phases, which, according to them, should be taken into account when dealing with BMI, see Figure 3.22 and a short description below, provided by Wirtz and Daiser [245]:

1. **Analysis:** This phase focuses on analysing the current BMI situation. Examining stakeholder roles, defining business objectives, identifying value flows in the market, and identifying key competitive drivers.
2. **Ideation:** This phase focuses on generating BMI ideas, uncovering BMI opportunities, creating a customer value proposition, and innovating the BM content and/or structure.
3. **Feasibility:** The developed BMI must be questioned concerning the feasibility of the planned BMI endeavour. This includes the sensing of the feasibility and profitability of the proposed BMI, before realising the intended changes. It also includes defining underlying assumptions about the business environment, identifying key resources, and processes and analysing critical interdependencies. Within this phase, customer surveys and evaluation feedbacks are used.
4. **Prototyping:** If the feasibility and profitability of the proposed BMI are confirmed, a prototype of the BMI should be developed. The prototype helps to evaluate different BMI design alternatives/concepts and to refine and optimise the BMI design alternatives/concepts. Allow comparison with the current BM and a more profound evaluation of the change impact.
5. **Decision-making:** The responsible managers must decide whether and in which form the proposed BMI is going to be implemented. Decision makers should choose the best concept between the different BMI alternatives.
6. **Implementation:** This phase includes changing the BM, testing, realisation, and go-live of the BMI as well as the necessary change management to support successful implementation of the BMI.
7. **Sustainability:** This phase focuses on scaling up the BMI, building the required skills in the organisation and promoting organisation-wide learning. Implementing isolating mechanisms to prevent the BMI from copycats and imitators and reduce potential

substitution effects. Continuous BMI monitoring and controlling to sense potential market reactions and modify the BMI in response to changes.

This generic approach to the BMI process, suggested by Wirtz and Daiser [245], also provides a comprehensive and holistic perspective on the BMI process. However, the steps proposed cannot be allocated to any phase without any overlap, but they nevertheless provide a wide-ranging aggregation of the recommended steps in the BMI literature body [245]. The authors furthermore acknowledged that the generic BMI process is not a ready-made, one-size-fits-all concept that can be blindly accepted without making any modifications. It should rather be regarded as a BMI process framework that provides researchers and managers alike with a BMI process blueprint, which they can adapt to their specific needs and requirements. [245]

The last important conclusion from the study conducted by Wirtz and Daiser [245] concerns the multi-directional character of the BMI process. Implying that the BMI process is a flow of semi-structured activities that need to be matched with specific organisational and BMI requirements, instead of being a standardised, unidirectional, and sequential process. Therefore, a BMI initiative need not follow all process phases, and phases may be skipped or even passed several times. However, Wirtz and Daiser [245] noted that the initial planning of the BMI initiative should start with the extensive process, taking into account each possible BMI process phase, and each decision concerning deviations from this plan or upcoming variances from the course of the BMI initiative, should always be based on a holistic BMI process perspective. [245]

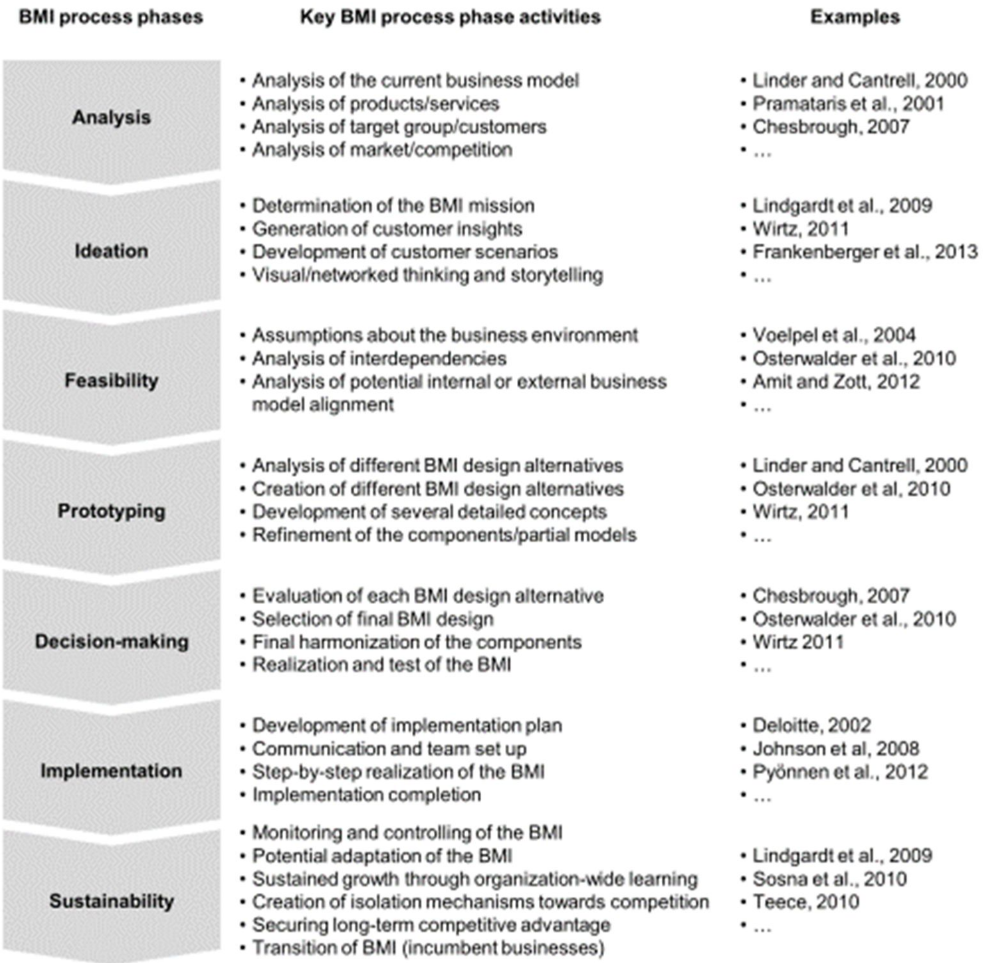


Figure 3.22: Generic BMI Process [245]

3.4.4 Business model innovation study contribution

To summarise, Figure 3.23 below illustrates which BMI frameworks were selected as foundational theoretical frameworks on which other research artefacts within this study is built. Furthermore, Figure 3.24 below illustrates the selected fundamental concepts contained in the BMI literature body that forms part of the concept inventory and concept map presented in Chapter 4. Most of the fundamental concepts contained within this literature body has already been identified as part of fundamental concepts of the BM literature body, as these two bodies are closely related to each other.

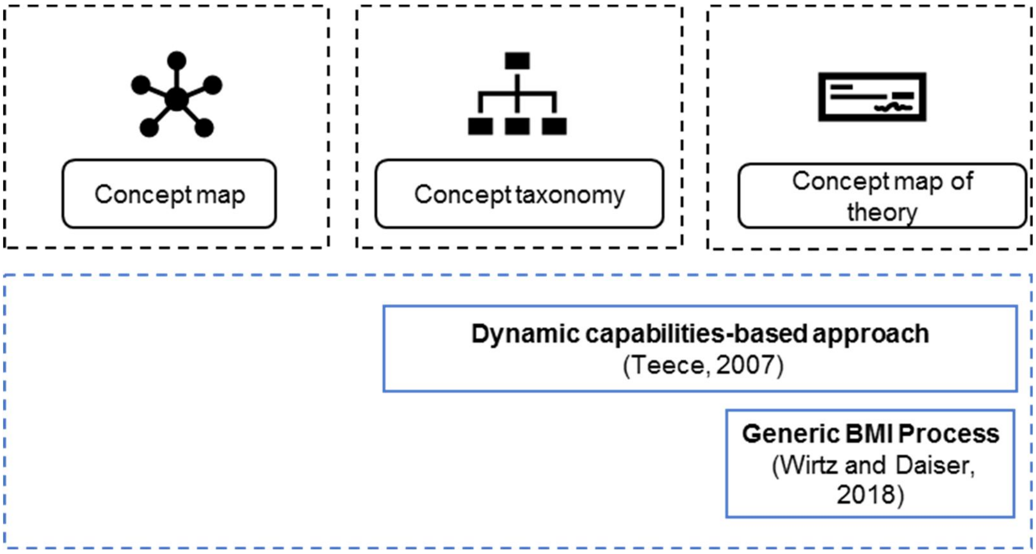


Figure 3.23: Selected theoretical BMI frameworks

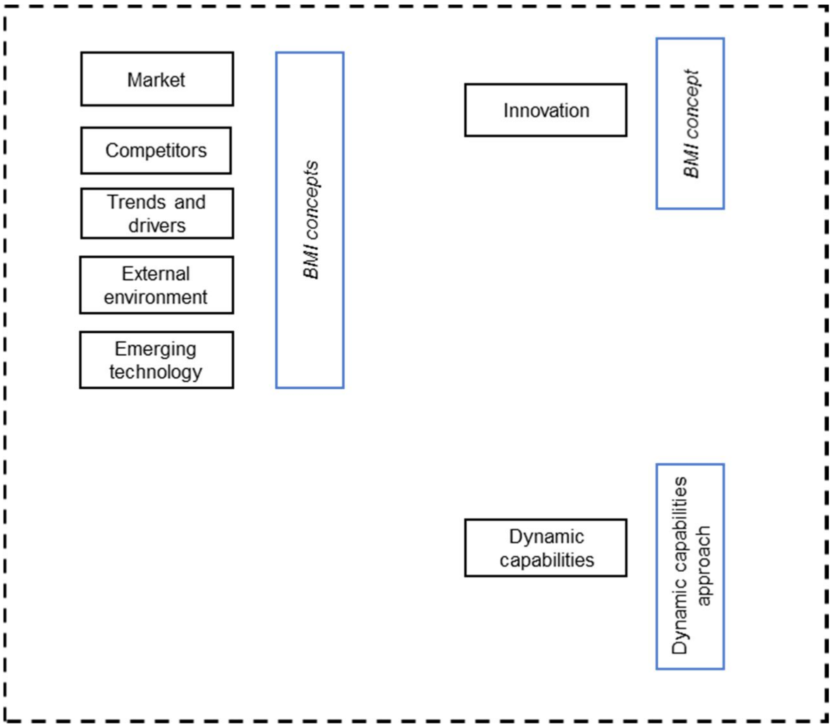


Figure 3.24: BMI fundamental concepts

3.5 Value network

3.5.1 Overview

Although various researchers are interested in the concept of 'value', it is often not clearly defined. According to Khalifa [119], the concept has become one of the most overused and misused concepts in the social science and management literature. To provide some understanding of the concept, the Cambridge Dictionary defines 'value' as "*the importance or worth of something for someone"* [41], whereas the Oxford Dictionary defines the term as "*the regard that something is held to deserve; the importance, worth, or usefulness of something"* [174]. Noteworthy, de Bono [61] stated, "*A value is not a value unless it is perceived to be one. No matter how real a value may be, it has no value at all until the value is perceived".*

Regardless of the growing body of research in the field of perceived value, the conceptualisation of perceived value remains unclear [68]. However, Woodruff [247] defined perceived value as: "*customer's perceived preference for an evaluation of those product attributes, attribute performances, and consequences arising from use that facilitate (or block) achieving the customer's goals and purposes in use situations."*

Michael Porter popularised the value chain concept through his studies on competitive advantage [186], see Figure 3.25 below. The value chain framework enables strategic thinking about business activities in terms of costs and contribution. The framework's activities are divided into primary and support activities which form a company's competitive advantage (in terms of cost advantage or differentiation). The primary activities involve the physical creation and delivery of the product to customers, whereas support activities are involved in sustaining the primary ones. Porter emphasised the important role of IT as it is the lever to create competitive advantage, create new business, and change the way firms operate. Therefore, responding to technological changes is critical for survival. [187]

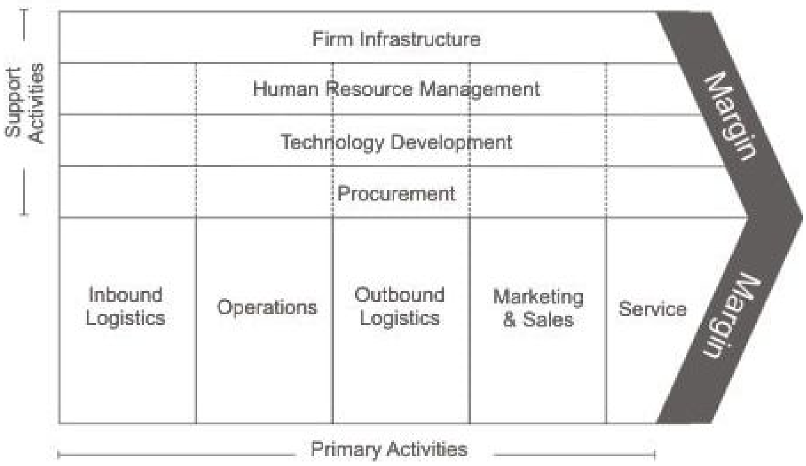


Figure 3.25: Porter's value chain [187]

The concept of VNs emerged from the value chain concept, due to the lack of appropriate analysis potential provided by the value chain concept. To clarify the difference between the concept of chain and network, simply put, the term 'chain' refers to sequential flow while a 'network' implies multi-dimensional connectedness [224, 230].

A few studies within the literature explore the relationship between BMs, value chains, and/or business ecosystems. One such study was conducted by Leviäkangas and Öörni [134] which consequently lead to a meta-model for transport-related services that include the incorporation of new technologies. The meta-model, see Figure 3.26, consists of the following four elements: *"end customer value (value proposition to the end-user), business value (shareholder value), collaborative value (business value to the supply chain) and societal value (value creation in the supply chain and control of negative externalities)"* [134]. To identify value creation levels within the VN, the first three levels of the meta-model forms part of the conceptual taxonomy, concept map of theory, and conceptual framework presented in Chapter 4, as well as the management framework presented in Chapter 6.

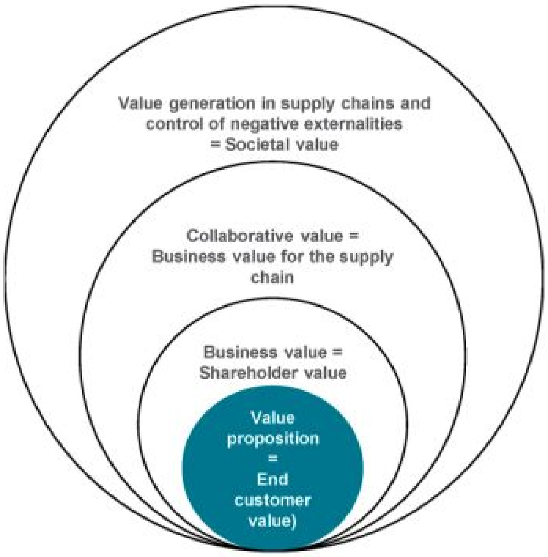


Figure 3.26: Meta-model of the views of BMs, VNs and business ecosystems [134]

The meta-model starts with the value proposition, which should be in line with the end-user needs, whether monetary, non-monetary, or both. Within the next level, business value, individual companies incorporate and design their BMs so that they can maximize their own value, thus building value for their shareholders through the improvement of revenue flows, controlling costs, or both. Furthermore, collaborative value concerns VNs that help companies consider the possibilities of collaboration to improve the prospects of business value. However, it is implicitly assumed that the value of collaboration comes at a price (e.g., shared R&D, IP rights agreements, strategic commitments) that may decrease short-term returns but increase long-term returns through valuable positioning in the VN. At the last level, when all stakeholders are considered, the company considers even wider benefits that could be generated to possibly address the societal or socio-economic value. [134]

Collaboration can be described as "*the linking or sharing of information, resources, activities, and capabilities by organisations to achieve jointly an outcome that could not be achieved by the organisations separately*" [35] quoted by Grudinschi, Hallikas, Kaljunen, Puustinen and Sintonen [93]. It is important to understand the importance and benefits of collaboration to build healthy partnerships and to motivate involvement because if there are no benefits, the motivation to collaborate disappears [93].

Furthermore, according to Peppard and Rylander [181], it is important to understand both the perceived advantages and disadvantages of actors regarding their participation in the VN because *"perceived value is a key driver of behaviour… it is the perceived values that steer what people and firms are willing to do and not do"* [181]. These perceived positive and negative effects of VN participation is especially important for opportunity networks which are emerging networks of which *"no one knows what they will look like in the future"* [181].

Participants may acquire perceived values when participating in the network, such as access to new, complementary resources; reducing costs; reducing time to market; access to new markets or customers; risk reduction and risk sharing; access to new technologies; and learning [167] (also referred to as perceived advantages, the opposites are referred to as perceived disadvantages). These perceived advantages and disadvantages were used by Dara [59] to propose an actor selection template that forms part of the management framework and is presented in Appendix F.

According to Herrala and Pakkala [104], the objective of all network actors should be to satisfy, internal or external, customers. Furthermore, the network should work together to deliver the product or service to the customer at the right time, to the right place and at the right price [104]. However, the way economic value is created is fundamentally changing [155], including the way value is perceived by customers. Therefore, the well-known concepts of supply or value chains do not do justice in describing how value is created and perceived in today's complex networks [114]. This change is driven by the increasing importance of knowledge, technological complexity, global competition, and the availability of digital information technology [44]. Individual companies, including major multi-nationals, cannot perform all relevant value chain activities internally, nor is it economically sensible for them to try [155].

Using a historical approach, Ricciotti [194] investigated this evolution from value chain to VN through the analysis of 66 papers. During his study, six key concepts emerged that guided this evolution, namely: sustainability, globalisation, collaboration, intangible assets, flexibility, and agility with digitalisation and dematerialisation being the foundation of these transitions [194]. Schneider *et al.* [201] noted that to take advantage of new, digitalisation-based opportunities, today's organisations must rethink their mindset about value creation. When considering where value is created and added in value chains and VNs, there is a distinct difference. Within the value chain, organisations create value through the transformation of input into output, where value is added in each step and customers pay for the total quality of the product produced [194]. Whereas, within the VN, organisations create value, not through the transformation of objects per se, but in their mediation [71] and customers are needed to form part of the value creation process [212].

Ricciotti [194] finally concluded that within the value chain or VN literature body, the object of study has been 'value chain thinking' which is the broader vision of value creation. Since the VN broadens a company's perspective [178] from the perspective of a single player to the perspective of many players, any problem that arises is seen as part of the network [194]. Value chain thinking is important as it takes a longer period into consideration; it creates a flexible plan to capture business opportunities; it aims to be forward-looking; it increases the benefits and encourages learning activities; it is cyclical and non-linear, and it offers sustainability and profitability [194].

Within the manufacturing industry, the VN concept refers to the collaboration of the manufacturer with different external stakeholders such as service partners, distributors, and suppliers [123]. Where the goal of such VN is to facilitate collaboration between stakeholders to compensate for limited resources and missing capacities on a firm-level [123] to ultimately reduce costs, increase speed, and achieve higher efficiency [160]. Therefore, it is important for network actors to create synergies through the alignment of costs, risks, and revenues. Companies become nodes within the VN causing a shift in the company's perspective from an internal to an inter-organisational perspective [194].

For companies, the trend of smart products and services, enabled by new technologies and IoT, necessitates new know-how in unknown fields [114]. Consequently, traditional manufacturing companies are forced to co-operate with new players within new VNs [114]. Unlike value chains, VNs often do not have clear hierarchies and are rather characterised by ties between participating actors. Networks need to be arranged to create unique value for customers by providing smart products and services, while the participants profit from the engagement effort [114]. In doing so, companies have to find new partners (companies, research institutes, etc.) [114]. Laya *et al.* [128] agreed and stated that providing services based on ICT is seen as a complex process for everyone involved and therefore networks of businesses participating in the creation of the value proposition of the services, require a collaborative way of reasoning and simplified guidance to implementation.

3.5.2 Definitions and classifications

Different scholars attempted to coin the idea of the VN by suggesting different terms that essentially describe the same logic. Table A.8 in Appendix A provides a summary of a selection of these conceptualisations contained in the literature. Despite these different conceptualisations, Van Middendorp [231] provided the following synonyms for the term 'value network' contained within the literature body: *"networks and organisations, strategic alliances, strategic networks, smart business networks, business ecosystems, value webs and the business group."*

During the analysis of networks, it is however important to distinguish between the 'networks of organisations view' and the 'network organisation view' [2], as it differs in terms of the assumed role of management as well as the manageability in the network [154]. The 'networks of organisations view' emphasise the self-organising aspects of networks where networks cannot be managed by a single firm [213]. This view furthermore sees firms and networks of firms as *"complex adaptive systems, comprising of interacting sets of organisational and social relationships in which each actor is pursuing its own goals"* [213]. Whereas the *'network organisations view',* adopted throughout this study, views network organisations with deliberately created structures, negotiated roles and goals which can indeed be managed in order to be efficient [154]. Regarding the management of the network, it is important to note that a network cannot be managed in a strong sense, implying the full control of another actor's resources and activities [155]. To distinguish between these two views on networks within the literature body, Möller and Rajala [154] refer to the 'network organisations view' as intentional business networks, called nets, value nets, or strategic nets.

In addition to the different conceptualisations of the 'value network' concepts, various scholars have also proposed different classification frameworks for the different types of VNs, see Table A.8 in Appendix A.

One of the main elements of the networked BM framework suggested by Palo and Tähtinen [176] was value exchanges between the actors, service and customers which represent flows of money, other benefits, resources and activities. Within their framework, Palo and Tähtinen [176] refer to the value creation logic of the net, such as the flows of competencies, resources and benefits between the actors as well as money and revenue flows [176]. Biem and Caswell [22] on the other hand suggested that the flow of offerings such as product, service, information, coordination, revenue, and brand should be separated from the flow of financials when developing a VN. The reasoning behind it is the fact that generation could or could not be transaction-based and giving offering 'away' is a valid network-based strategy. This is a different view of transaction-based economics [22]. For this study, a clear distinction is made between the different types of value flows within a VN.

3.5.3 Frameworks

Various approaches have also been proposed to create a modelling language for firm interactions to analyse VNs [22]. A distinction is made between VN analysis frameworks, contained in Table A.9 in Appendix A, and VN development approaches, contained in Table A.10 in Appendix A. None of the identified VN development approaches (frameworks or methodologies) deemed to be comprehensive in how to develop, configure and map a VN, therefore none of these frameworks was included as-is in this study, however, the key aspects or components addressed by these approaches were included in the framework, either as concepts or as activities in the management framework.

However, to identify which of the selected VN analysis frameworks will be built on throughout this study, a comparison between the frameworks was done, see Table 3.12. The comparison aimed to select frameworks that address the most applicable and critical aspects that must be considered in the context of this study. Based on the comparison, the ARA model from Håkansson and Johanson [94] in combination with the model of economic entity from Biem and Caswell [22], was selected because of the key network elements contained within these frameworks. Furthermore, due to the fundamental aspect of tangible and intangible exchanges, Allee's VN analysis methodology from Allee [12] was also selected. Since the Unipartite and bipartite network analysis of innovation systems from Hennemann and Liefner [101] presents a different perspective on the visualisation of the network, it was also included in this study. These frameworks are discussed in more detail below.

Table 3.12: Comparison of VN analysis frameworks

Framework/Model	Advantages	Disadvantages
ARA model [94]	Focus on business relationships, simple, easy to understand, visual relationships.	No clear structure, not comprehensive.
e3-value model [91]	Simple, easy to understand.	Lack strategic focus, not comprehensive.
c3- value model [239]	Strategic analysis, easy to understand.	Focus only on direct customer, direct competitor, neglect interdependencies in ecosystem.
Value network strategy model [11]	Exchanges create value, network is constantly changing.	Network is unmanageable, complicated to analyse, no start or end.
Model of economic entity [22]	Strategic analysis, visual, end customer is the main valuator.	Not comprehensive, no clear structure of value network.
Allee's value network analysis methodology [12]	Mostly visual, detect patterns of exchange between participants, include tangible and intangible exchanges, focus on value exchange.	No purpose assigned to network, assumption on unmanageability of network limits its potential for strategic analysis.
Unipartite and bipartite network analysis of innovation systems [101]	Overview, multi-dimensional, visual relationships, flow of value.	Not comprehensive, not specifically focused on value networks that include different firms.

Both the e3-value model and the c3-value model build on the widely referenced actors-resources-activities (ARA) model. The ARA model aims to explain business relationships using a 'network approach' [96], including interactions across multiple organisational boundaries. Håkansson and Snehota [96] stated that taking the 'relationship view' implies that it is based on how business relationships are developed by companies and voluntarily created.

They furthermore stated that when two or more parties have mutually oriented interactions with each other, a business relationship exists [96]. These relationships can either constrain or create opportunities due to the interdependencies that exist over time in terms of technology, knowledge, social relations, administrative routines and legal ties [96]. Within this framework, a business network consists of business relationships that have two dimensions that evolve over time: elements of relationship exchange (activities, resources and actors) and functions that a relationship can take (on a single actor or at a dyadic or network-level) [96].

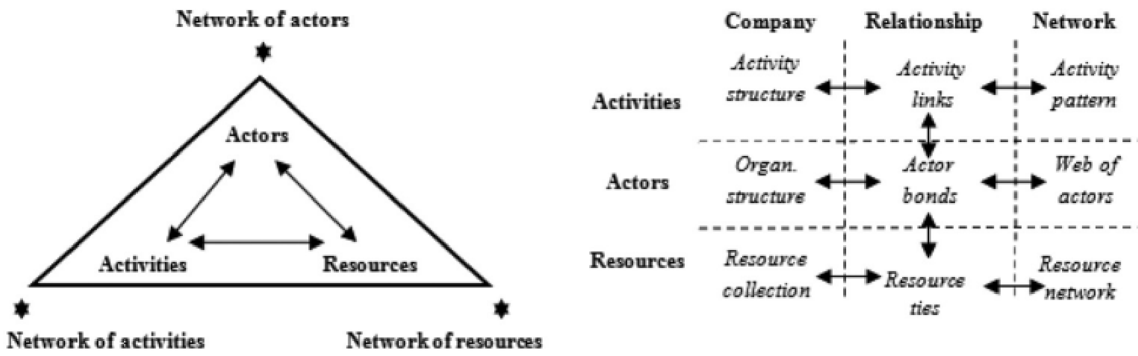


Figure 3.27: The ARA interaction model [96]

In another study, Allee [12] proposed a value network strategy to map out the value exchanges across the VN. This framework or strategy is used as one of the theoretical foundations of the VN mapping tool (SBN configuration process) presented in Section 4.5. Allee's mapping method relies on the following three elements – roles, deliverables, and transactions [12]:

- Roles: Fulfilled by people, organisations, business units, groups, or teams which participate in the network by providing contributions and executing functions.
- Transactions, or activities: Start with one network participant and end with another. The arrow represents movement and the direction of what flow between the two participants. Solid lines represent product and revenue exchanges, and dashed lines represent intangible flows of market information and benefits.
- Deliverables: The actual 'things' that move from one role or participant to another. It can be physical (e.g., a document or a table) or it can be non-physical (e.g., a message or request that is only delivered verbally).

Allee [12] provided the following example of a VN map that shows an external facing VN focusing on market innovation for a technology company, see Figure 3.28. Within this VN map, the nodes depict roles in an activity, and the arrows with labels indicate all the important transactions through which deliverables are conveyed from one role to another [12].

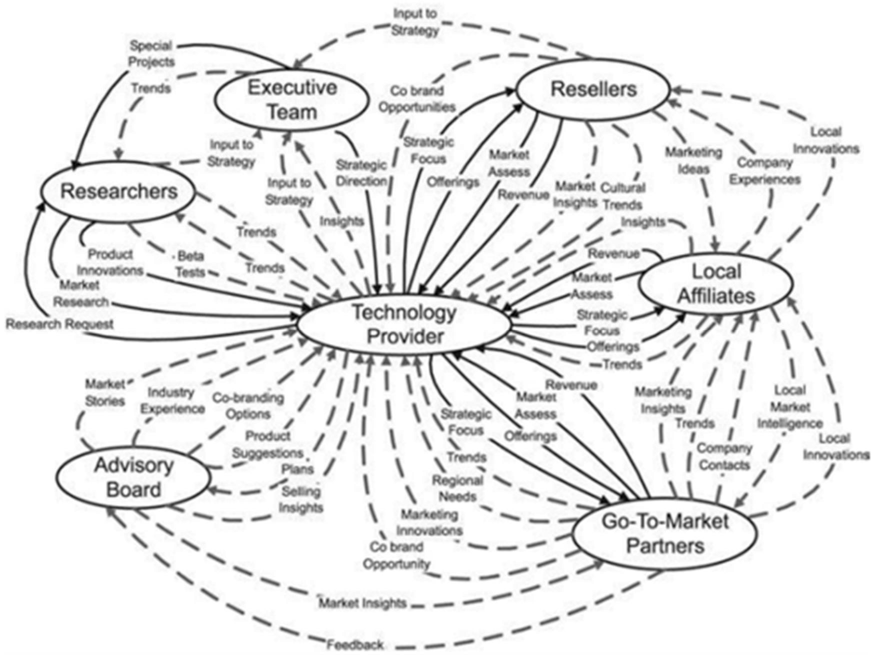


Figure 3.28: A VN focusing on market innovation for a technology company [12]

Furthermore, Allee [12] also proposed VN analysis beyond mapping, including exchange analysis, impact analysis, and value creation analysis. These analyses can be regarded as being on the lower level (or organisational/process level) of the VN, and therefore they were not considered as the management framework and tool contained within this study is focused on the intermediate level of the network.

In their study on the VN, Biem and Caswell [22] proposed the model of an economic entity for VN analysis. This model is an extension of the ARA model, and both the e3 and c3-value models, aiming to include strategic analysis with the assumption that the end-customer is the primary evaluator of the value of the entire network. According to Biem and Caswell [22], the VN can be seen as an economic entity that can be analysed from three perspectives: the actor perspective, the capability perspective, or the asset perspective. The network consists of offerings (product, service, knowledge, brand) which refer to any transferable from one economic entity to another [164] through unidirectional links [22]. Furthermore, a network-centric offering is *coordination* which is prominent in the network-based perspective [22].

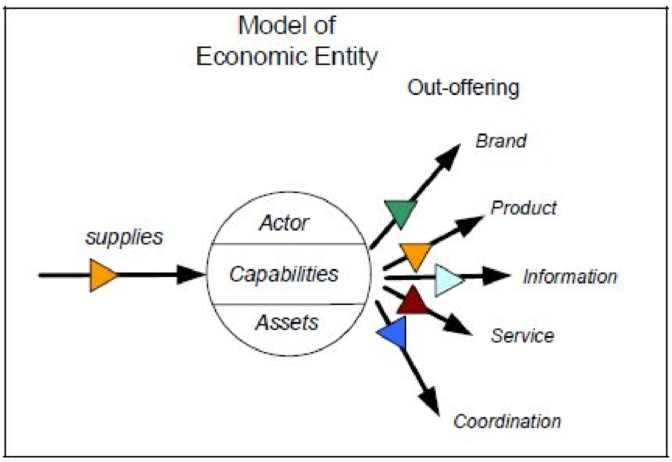


Figure 3.29: Model of economic entity [22]

In their turn, Hennemann and Liefner [101] focused on regional and national innovation systems and the involvement and connection of different actors from these different systems in the innovation phases. In addition to the unipartite model, they proposed the use of bipartite data representation as a new form of analysis of innovation systems, see Figure 3.30. Their conceptual base is based on innovation systems theory, including ideas from knowledge networks theory. Using bipartite representation, they demonstrated how interwoven the innovation process is, and which type of potential collaborator is most influential in that process. This mapping logic is used as one of the theoretical foundations of the VN mapping tool (SBN configuration process) presented in Section 4.5. To provide a brief overview of their approach (illustrated in Figure 3.30):

- The bottom nodes present different potential collaborators (e. g. suppliers, customers, universities, public research organisations, business service providers, or technical service providers) in distinguished local spaces.
- The top-nodes are formed by five different phases of a typical innovation process for the firm. These are information exchange, idea generation, prototyping, development of pilot applications and entering the market.
- Explicit and implicit (tactic) knowledge is transferred over distance to other actors or regions, therefore it must be mapped making use of bi-partite network mapping (based on knowledge theory).

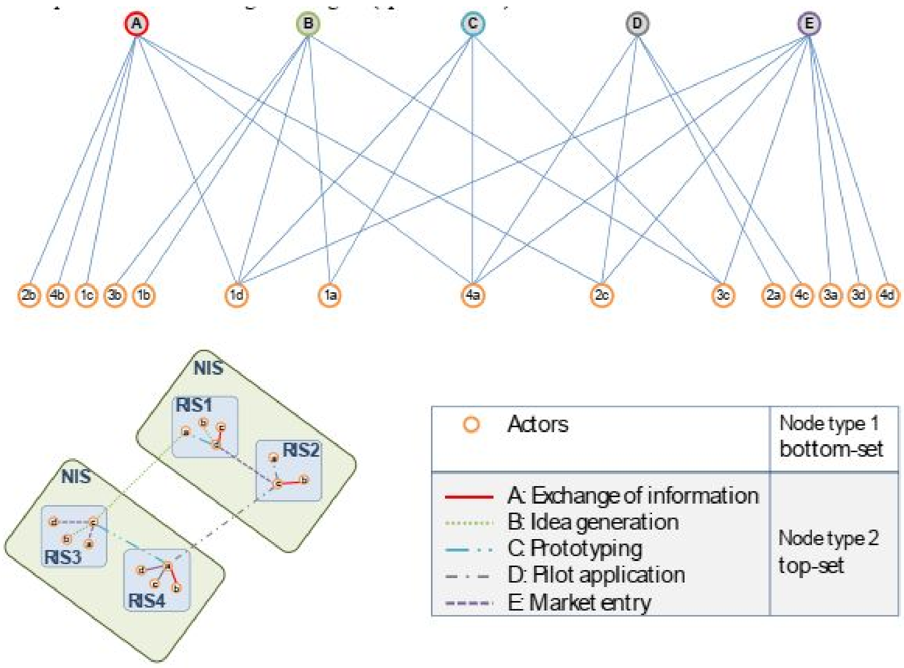


Figure 3.30: Transforming the unipartite network into a bipartite representation of an innovation system [101]

There are different perspectives on the initiation and development of VNs. The first view is that the VN emergence as a consequence of an innovation idea (i.e. innovation pull) [114]. But theoretically, it could also be used as a strategic tool to evaluate entire branches and collaboratively develop innovation ideas (i.e., VN push) [114]. Another view is that the VN emergence as a consequence of a BM [201], therefore the preliminary completed BM initiate the development of the VN. A further view is equating the BM and VN for different reference systems, as Müller-Stevens and Lechner [157] argued, that what the BM is for the individual organisation, the VN is for a set of interacting organisations. Due to the different views, the literature contains different methods or methodologies for the development of VNs, Table A.10 in Appendix A provide a brief summary of a selection of these frameworks or methodologies.

Al-Debei, Al-Lozi and Fitzgerald [5] illustrated the development of a VN model using UML for telecommunications companies and their VN, see Figure 3.31. They furthermore identified and explained the main constructs of the VN model, see Table 3.13. These design constructs were included in the selection of the networked BM elements, contained in Section 4.2.

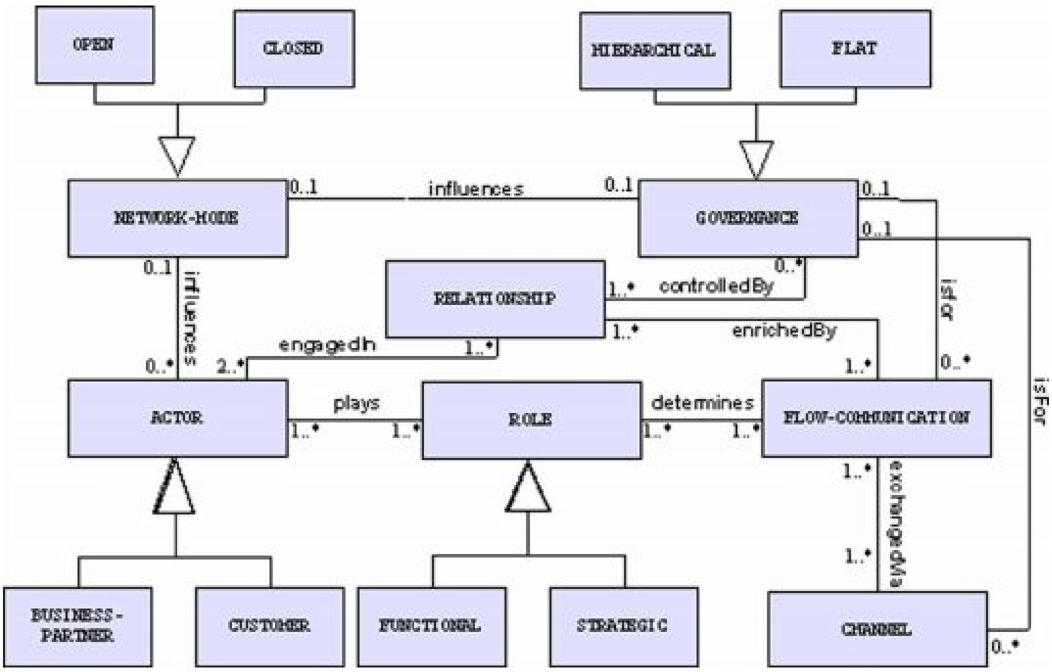


Figure 3.31: The development of a value network model [5]

Table 3.13: Design constructs of VN development [5]

Design construct	Description
Network-mode	The way in which the VN is created and expanded. Network modes differ in terms of requirements, functions, and methods. It can be open or closed. An open network-mode refers to the possibility of participation of any actor to the VN while a closed network-mode refers to the participation of only a selected number of actors. The choice for a network-mode is dependent upon the purpose of the VN.
Actor	The identification of the core actors needed to collaborate and co-operate to engineer, launch, and deliver a particular product or service effectively. The selection procedure depends on the selected network-mode. In a closed network-mode specific actors need to be identified who need to collaborate to deliver the product or service of the VN. In an open network-mode the potential contributions of an extensive set of actors must be screened to determine the delivered value of the network.
Role	Each VN actor fulfills functional or strategic roles which indicate the importance of different actors within the VN. Functional roles are fulfilled by actors that contribute to the VN through their knowledge, experience, and specialties. Such roles are considered from an operational point of view. Strategic roles are fulfilled by actors who contribute directly to a key objective or function of the VN. Functional roles depend on the industry and goal of the VN.
Relationship	The identification of the sorts of links that need to be established with the VN actors. Actors follow different approaches with different types of relationships. The relationships could, for example, take the form of strategic alliances and partnerships, affiliations, joint ventures, mergers, acquisitions, transactional (e.g., cost/ revenue share).

Design construct	Description
Flow-communication	It refers to objects communicated between the actors of a VN. Analysing is important as it helps service designers and engineers to represent value exchange streams amongst the actors to make them more controllable, manageable, and effective. Furthermore, the relationships with different actors are enriched by materials communicated between them. These materials can take the form of information, knowledge, money, products, services, hardware, software, documents, agreements, and any other objects. These different kinds of flowed materials or objects can be classified in three categories: (1) goods/services; (2) intangible benefits; and (3) monetary or economic benefits. To understand flow communications of a VN, visual maps could be employed.
Channel	It refers to the examination of the communication mediums or ports used to communicate materials and objects amongst actors because of their relationships.
Governance	It defines the actors who are managing, controlling, and directing the VN. The concept of governance can be viewed at two levels: (1) the industry level; and (2) the VN level. At the level of an industry, governance is managed and tackled by regulatory commissions and other legal bodies. At the VN level, governance relates to whom within the VN, has control and power over what kind of objects and resources, e.g., data, relationships, channels, functions, patents, brands, and transactions. For analysing governance issues and examining where and how actors can extract value, the control points concept is utilised. Control points are areas in the VN where power and control can be applied. They normally result from the various roles played by actors in the VN. Thus, control points are not only functional but are also strategic, and the more control points an actor has the more important they are in the VN. Value networks can be governed hierarchically or in a flattened mode. A hierarchical governance mode means that there is one, or a few, actors that dominate the power. A flattened mode implies that all actors are sharing costs, risks, knowledge, capabilities, etc. more equally to collectively address innovation. This is normally the case when the innovation requires a wide range of knowledge domains scattered across various actors from different backgrounds.

Schneider *et al.* [201] furthermore proposed that the VN could be designed according to a linked system of partial models (Figure 3.32), which simplify the description and analysis of VNs for implementing promising BMs. These partial models can be divided into three levels, strategic, tactical, and operational and based on the seven aspects (partial models): business model, requirements, activities, resources, organisational structure, interactions, and operational structure. [201]

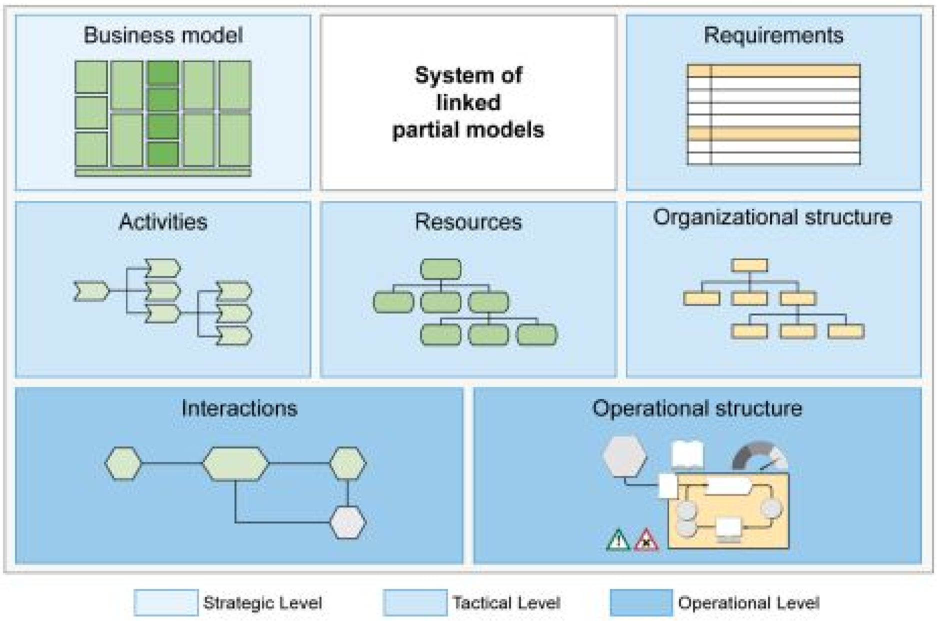


Figure 3.32 Linked system of partial models to describe the VN [201]

Transforming BM from firm-level to network-level, with the adoption of new technologies might be overwhelming, therefore it is imperative to understand the key potentials, challenges, and critical success factors for VN participation. Table 3.14 below discusses the key potentials identified within the literature body, whereas Table 3.15 discusses the key challenges identified regarding VN participation.

Table 3.14: Key potentials relating to VN participation

Key potentials		Reference(s)
Benefits (motives/ perceived values)	Organisations participate in VNs to compensate for their own weaknesses and to exploit other tangible and intangible benefits from others that participate in the VN. When different people and organisations engage in collaboration, they are aware that they receive some advantages or benefits from the collaboration. If there are no potential benefits or perceived advantages, then the motivation to collaborate disappears. A strategic alliance can thus be created only if all participants believe that they can benefit from the co-operation.	[104], [59], [97], [127], [194]
Business opportunities	During the evolution phases of a business net, business opportunities are identified, created, and potentially exploited by the actors in the network. Therefore, there is a need to develop a collective understanding of the business opportunities and guiding actions to exploit them. Working in a network lead to more business opportunities as the company is not restricted to opportunities only achievable by their own resources. Furthermore, more opportunities can be worked on simultaneously due to the availability of more resources.	[154], [177], [127], [129]
Competitiveness	Industrial competitiveness is no longer a single organisation's concern and requires multiple firms in the supply chain to interact. The combination of resources and capabilities enable VNs to become more competitive through restructuring their businesses and adopting new technologies (such as AM) which will enable them to introduce new products and services. Furthermore, advantages of collaborating in VNs, such as decreased lead time, increased quality, and increased customisation, will in turn increase local and global competitiveness.	[154] ,[144], [76], [194]
Customisation / personalisation	Customisation is one of the end goals of the use of AM in the tooling industry. It refers to the ability for an end-user or customer to provide insights regarding a part or product to be tailored according to his/her needs, have it produced in a fraction of the conventional lead time, and have it ready to be used or tested without the need for post-process treatment. To enable this customisation goal, network actors need to combine their skills, knowledge, capacities, and resources. Although it is expected that I4.0 technologies have the potential to make personalisation more efficient, SMMEs should consider for which products, or product components individualisation or customisation adds value since offering personalised products does not always imply more profitable products.	[223], [251], [74]
End-to-end solutions	Small companies or SMMEs alone are not able to provide end-to-end solutions (fulfilling an increased number of specific customer needs) to customers as they do not have sufficient resources (financial, capital, human). Value networks (containing various actors, including SMMEs) will enable the provisioning of end-to-end solutions to customers as each actor in the network fulfils their role as part of the single network. Therefore, nothing needs to be outsourced to a third party outside the network – everything gets done by actors inside the VN to produce the entire solution for the customer.	[185], [76]
Flexibility	Given the ever-changing business environment, the ability to quickly act is fundamental for organisations. Participation in VNs eases the process and speed of change as various actors can anticipate potential changes, enabling faster reactions. Network participation furthermore increases flexibility as one organisation does not own all resources or capabilities that require change. When comparing small companies to larger organisations, smaller companies have mainly	[144], [160], [104], [22], [53]

Key potentials		Reference(s)
	succeeded in adopting AM since there is more opportunity for innovation, flexibility, and specialisation.	
Joint risks (risk sharing)	All risks associated with transformation (from firm-level to network-level and from product-orientation to solution-orientation) is not carried by one organisation solely, but all VN actors carry a part of the risk. Therefore, risks are shared among the network actors.	[104]
Performance	Membership of a value network increases the innovation degree and consequently the company's performance. The use of a network-level BM indirectly improves firms' abilities to achieve high performance. Furthermore, the application of ICT not only enables the management and optimisation of operational information but also help the company, its partners, and customers to improve the performance of their products and services and the entire VN.	[160], [194], [111]
Knowledge	There exists a huge demand for existing and new AM knowledge (or specialised know-how) as most companies do not have the knowledge in-house and thus lack the absorptive capacity for AM, thus they are less likely to invest and implement AM technologies. This lack of knowledge also prohibits companies to benefit AM technology on full scale. Participating in a VN can increase access to knowledge and existing know-how through knowledge flows across organisational boundaries. The knowledge which is transferred within networks plays an important role and can be used as a competitive advantage. Furthermore, in AM, the most frequently mentioned suggestion of an attractive offering is knowledge.	[97], [26], [251], [144]
Value co-creation	Within a network, value is co-created by the collaborating actors. It is furthermore a business strategy that promotes and encourages active involvement from the customer to create on-demand and made-to-order products. With co-creation, consumers get exactly what they want as they contribute to making it happen.	[97], [129], [111]

Table 3.15: Key challenges relating to VN participation

Key challenges regarding participation in value networks		References
Attraction	Innovation (including product, process, and BM innovation) within a network requires an environment where multiple and diverse actors can collaborate with their resources and capabilities. However, this can only be accomplished if the BMs (network-level and firm-level) are attractive and beneficial to all the actors involved, i.e., 'win-win' solutions are created.	[129], [185]
Alignment	Alignment needs to be approached from various perspectives to ensure operational feasibility. Internal firm-level alignment concerns the alignment of strategy, the firm-level BM, and the business processes of each network actor. Internal network-level alignment concerns the alignment of the network-level BM and firm-level BMs, as well as between all the firm-level BMs. External alignment concerns the alignment of the network-level BM with changes in venture needs, stakeholder priorities, and the external environment. These different forms of alignment are required to achieve coherency, complementarity, and consistency in terms of resources and capabilities to ensure the successful performance of the entire VN. It is however not an easy task to link multiple network partners in one coherent framework.	[129], [161], [177], [62], [59]
Barriers	Barriers prevent benefits from being captured. There are a variety of entry barriers to manage when joining a VN, especially if the actor is an SMME. These barriers include technical barriers, organisational barriers, innovation barriers, financial barriers, and implementation barriers.	[152], [127]
Change impact	Although the changes to the 'as-is' BMs of some network actors may be limited, the impact of these small changes on the VN may be significant.	[136]

Key challenges regarding participation in value networks		References
	Therefore, the impact of firm-level changes must be carefully considered on the network-level.	
Change management	The transformation from producer to service provider with production, requires a specific change management approach in three dimensions: activities, structure, and behaviour. Adjusting the activities within the company, the organisational structure and the behaviour of the employees increase the degree of professionalisation in the company's service management. Furthermore, the implementation of BMI has a strong project and change management character at the beginning. Employees are often resistant to change either due to fear of the new and unknown or not seeing a viable reason for it due to the current BM still operating soundly. Therefore, the management of organisational change is an important aspect to consider.	[201], [75], [127]
Collaboration	Collaboration refers to the sharing of information, the development of joint strategic plans and the synchronisation of operations. Such effort aims to generate economies of scale, reduce duplicate operations and achieve greater customer confidence through customised services. Throughout the implementation of AM technologies, manufacturers require increased collaboration with suppliers and customers. The VN partners' value equations (expectations, success criteria) trigger and drive their participation. Collaboration between partners who have (access to) the required competencies and markets provides the basis for successful innovation. Bringing these equations and competencies together by establishing collaboration is a major challenge. A small network or the presence of a lead partner in a larger and/or more diversified network reduce that challenge.	[154], [136], [160], [144], [152], [129], [185], [194], [76]
Communication	Establishing communication channels between all actors to ensure smooth collaboration and minimal misunderstandings is challenging. The communication channel design construct involves the channel actors of a VN might use to facilitate flow communications. Different technological systems can be used to support the inter-organisational relationships and to facilitate communication between the firms, making partnerships easier and more functional.	[104], [59], [127], [184]
Demand	Customer demand for AM products is continuously changing, with fluctuations in demand, and sporadic or low demand for single units, therefore resulting in immature demand. These demand characteristics must be considered in designing the BM and associated VN as SMMEs often need to proactively create a demand for these products.	[234], [144], [26], [76], [251], [185]
Dependence	Part of the nature of the VN, is dependence on other actors, which means that no company can solely rely on their own resources, but their outcomes and performance are based on the outputs from other actors within the network. Since SMMEs often have a lack of capital and expertise, they must rely on collaboration with external partners, causing a tight dependence on external supply network partners. There are furthermore fewer suppliers in AM-based supply chains, which can lead to increased dependence on these limited suppliers.	[144], [76], [152], [111]
Design-implementation gap	During BMI, a design-implementation gap can exist as there are accumulated challenges along the BMI process that lead to failures and non-implementation. Considering the three main phases in the Cambridge BMI process, the design-implementation gap can happen in the concept design phase because ideas are not followed up, in the detail design phase because concepts are not implemented or in the implementation phase because new business models may fail in the market.	[184]
Intellectual property	Intellectual property rights are exclusive rights held by the owners of a variety of knowledge-based assets that qualify for legal protection under applicable IP laws. Within the AM industry, there are various discussions regarding IP concerns such as ownership of designs, component counterfeiting and copying of components through 3D scanning. Therefore, IP implications and licencing strategies are a challenge with AM because the changes in the production decoupling	[26], [152], [185]

Key challenges regarding participation in value networks		References
	point, between the manufacturer and the consumer, has legal implications on who owns the design or source code.	
Governance	Governance refers to the actors who manage, control, and/or direct the VN. Value networks themselves can be governed hierarchically or in a flattened mode. The hierarchical governance mode involves one or few actors who dominate the power in the VN. Whereas a flattened governance mode implies that all VN actors share costs, risks, knowledge, capabilities, etc. more equally. Networks are claimed to be better adapted to knowledge-rich environments because of their superior information-processing capacity and flexible governance compared to markets and hierarchical organisations.	[154], [22], [129] [59], [111]
Network complexity	The development of network-embedded BMs and the configuration of VNs are more challenging to analyse since there is additional complexity. The network of interlinked business exchanges and of the interactions, aiming at creating and developing value, needs to be addressed and understood as a whole.	[20]
Partner selection	Careful consideration must be given towards proactive partner selection as they need to add value to the VN and will directly influence the operation and performance of the VN. Partners (closed actor participation) must provide access to critical resources and capabilities. A structured process must be followed to select the appropriate and most valuable partners to form part of the VN.	[177], [114], [59]
Power dependence	Power dependence denotes the influencing forces where one party can partially control and influence another party, as the other party needs those resources or competencies held by the first party. The power may be mutual, meaning that both parties have influencing power over one another, and if in balance, their dependence on each other is equal (as is their power). A power imbalance would imply that one party depends more on the other party than the reverse. The limited availability of raw materials and shortage of suppliers of AM materials lends to a high negotiating power to the material suppliers (causing a shift in power and power dependence).	[250], [76]
Relationships	Relationships can be classified by the level of closeness, co-operation, type of interaction and if the relationship is short-term or long term. Relationship building is a key element in the success of alliances. Alliances are characterised by incomplete contracts because it is essentially impossible to envision all possible outcomes of an alliance. This may lead to uncertainty and ambiguity. One way of managing this uncertainty and ambiguity is by forging strong relationships, but operationally this requires the parties in the alliance to interact in a highly co-operative manner. Specialisation alliances are more limited in terms of the number of relations that need to be built; rather than needing to integrate each function within respective party firms, it is only necessary to form relationships across the specific functions involved in the alliance. However, this is challenging because the partners are from different industries.	[154], [104], [158], [62]
Resource dependence	Within the VN, firms (i.e. different actors) are interconnected, and therefore their activities are co-dependent and usually revolve around the activities of one specific focal firm. Therefore, their resources also exhibit dependency that provides a basis for the emergence of new solutions.	[111]
Risks	There might be unintended outcomes or negative risks introduced by network participation and AM adoption. SMMEs are often owned by an individual and several risk factors are involved with the small-scale businesses. The literature shows that SMMEs hesitate to implement advanced manufacturing technologies due to the high risk. Furthermore, developing a viable BM to commercialise especially novel technology is a challenging task and the risk of failure is high. However, the successful development and configuration of VNs result in lower unit cost, fight against inefficient cross-subsidies, optimised risk-sharing, risk-absorption and improved risk management.	[234], [76], [152], [159], [104], [194]

The following critical success factors, see Table 3.16, were identified to achieve the above-mentioned benefits for VN participation and to enable the implementation of the networked BM. If these factors are not achieved, the mission of the VN and consequently the goals of the BM cannot be achieved. These factors were considered in developing the concept taxonomy in Section 4.3, the conceptual framework in Section 4.6, as well as the management framework in Chapter 6.

Table 3.16: Critical success factors for the development and operationalising of VNs and networked BMs

Factor	Description	References
Alignment and configurational fit	Alignment and configurational fit from various perspectives must be ensured as it defined the effectiveness of a networked BM in value co-creation. These perspectives include internal firm-level, internal network-level and external alignment.	[177], [59], [129], [62]
Benefits (motives)	If there are no benefits, then the motivation to collaborate within a VN disappears. Therefore, understanding the importance and the potential benefits and perceived advantages of collaboration may play a crucial role in building healthy partnerships and motivating organisations to become involved in collaborations. A true partnership should create value for all partners involved in the collaboration, i.e., 'win-win' solutions.	[194], [97], [127], [59]
Collaboration	Collaboration is working together to achieve a goal, with a collective, fierce determination to reach an identical objective by sharing knowledge, learning, and building consensus. Leadership is key to drive the collaboration between partners as the whole VN is stronger than its parts.	[154], [160], [185], [129], [194]
Collective understanding	Creating a collective understanding of the business opportunities and the operations and requirements of the networked business model and participation in the VN is key. This collective understanding will aid in developing actions to exploit the opportunities and prevent misalignments. A collective understanding of the common objective among all partners will enable effective collaboration.	[177]
Common/ joint objective/ goal	Partnerships cannot exist if certain conditions are not met. Companies need to have shared opinions about the value that they are to create together, be convinced that they need each other to create that value and to agree on how the created value is divided between the parties. If these conditions are not met, organisations cannot really commit themselves to pursue a common objective and will continue to operate as independent entities.	[104], [160]
Communication	Communication is the glue that forms the bond between the network partners. There are a variety of ways to enable communication between partners that must be exploited. Without proper communication between actors, collaboration will not be possible, and the common objective will not be achieved. Leaders play a vital role in facilitating communication and knowledge sharing, especially when it comes to communication with their own team members. It is furthermore important to select and implement the correct ICT to enable communication and the flow of information throughout the network.	[104], [59], [127], [184]
Dynamic	The entire context of this study is known by its dynamic nature – therefore most aspects are characterised by constant change. In nature, the value net is dynamic, it consists of dynamic exchanges between partners with dynamic and flexible roles in an ever changing, dynamic business environment. Further, partners need dynamic capabilities to ensure successful transformation and operationalisation of the VN. Therefore, the networked BM cannot exist in isolation or be a static model, but it needs to be developed and constantly adjusted according to the environment, making it dynamic (BMI).	[154], [22], [176], [177], [160]
Information flow / exchange	Without timely, real-time, and accurate information, close partnerships are not possible and benefits from the network cannot be exploited.	[104], [22]

Factor	Description	References
	Information flow must be managed and enabled to improve the overall performance of the VN. All other flows (material, resource and money) need reliable and real-time information to run properly. This means that the information is the most important element between the firms binding them together into networks.	
Relationships	Relationship building is a key element in the success of alliances. Functional differences need to be understood and overcome before relationships can be developed properly. Operationalising relationships in specialisation alliances requires managers to understand the proper level of relationship building that is required.	[154], [104], [158], [62]
Shared values	Innovation and collaboration across organisations are based on their shared values, such as transparency, privacy, or sustainability. On the highest level of abstraction, shared values provide a common ground among different stakeholders with diverse interests regarding normative, strategic, and operative concerns. Defining shared or common values between partners is therefore important in the development and functions of VNs. This requires individual companies to adjust their BMs to the common value chosen to ensure alignment.	[136], [32]
Strategic visioning and planning	It is important to create a strategic vision (or shared mental model) on what the network aim to achieve through the development of a 'roadmap'. Strategic visioning is followed by the planning of executable activities towards realising the vision, that must have a strong strategic foundation. If visioning and planning are not followed by action, the network has little to show for its efforts. Visioning the networked business model and planning its activities can however be challenging because there only exist vague ideas about the future business potential of AM technologies.	[154], [97], [160]
Trust	Efforts must be made to develop and maintain relationships of (mutual) trust among all network actors and stakeholders. Trust influences an actor's willingness to be honest and co-operate. In a partnership approach, trust is both the glue that holds the partnership together and the lubricant that allows it to operate effectively.	[154], [22] , [104]

3.5.4 Value network study contribution

To summarise, Figure 3.33 below illustrates which VN frameworks (including the value meta-model to demonstrate the different levels of value creation within a network), were selected as foundational theoretical frameworks on which other research artefacts within this study is built. Furthermore, Figure 3.34 below illustrates the selected fundamental concepts contained in the VN literature body that forms part of the concept inventory and concept map presented in Chapter 4.

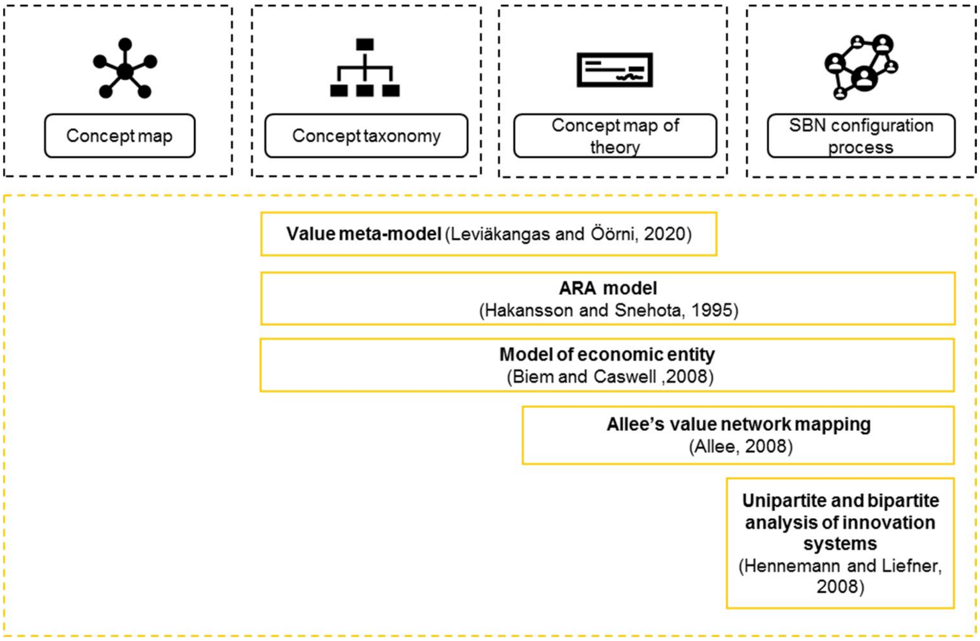


Figure 3.33: Selected theoretical VN analysis frameworks

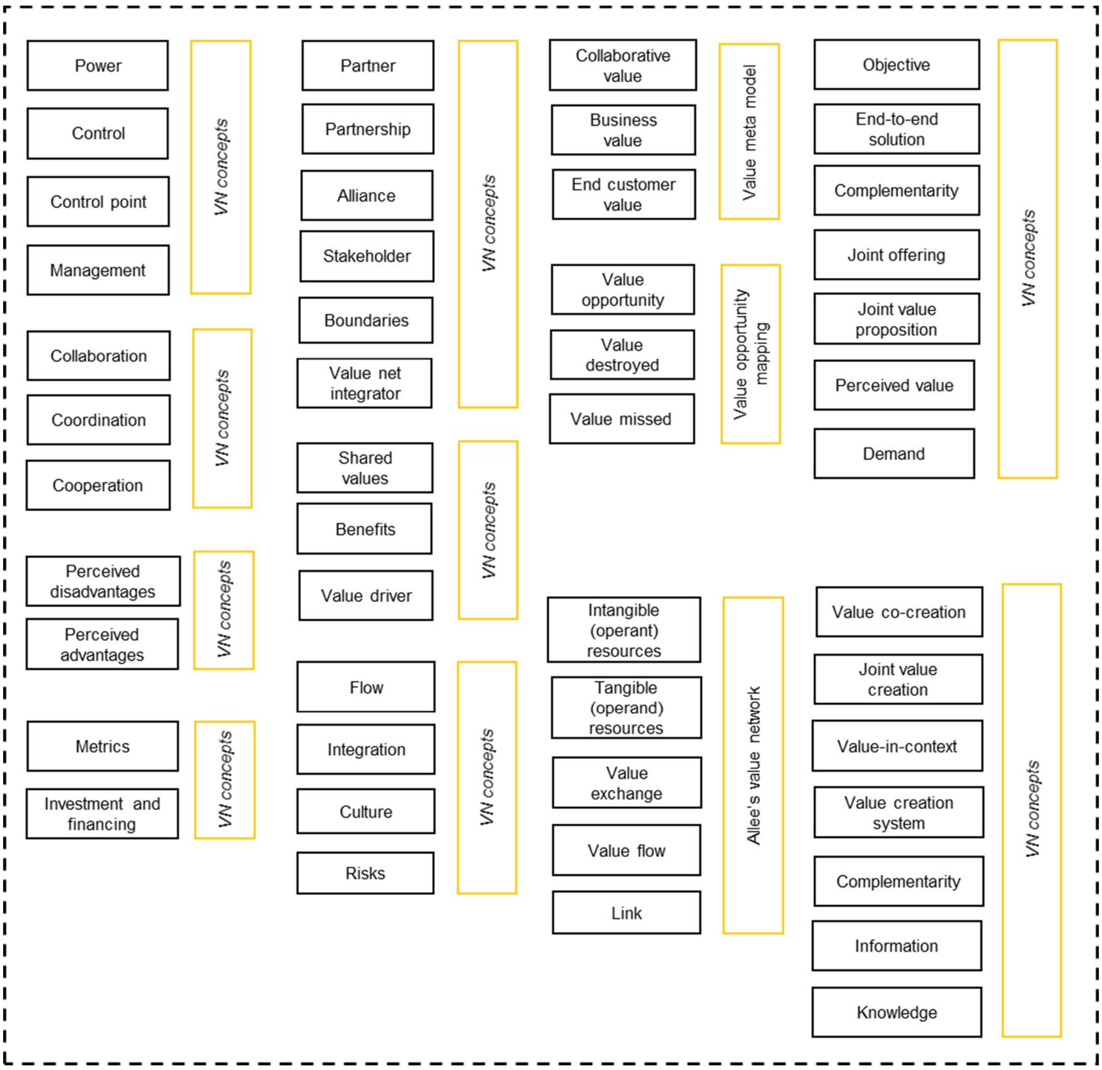


Figure 3.34: VN fundamental concepts

3.6 Additive manufacturing

This section aims to answer the following research-sub question: *What are the main influences of AM on SMMEs, the BM, BMI and the VN that could support the framework development? (SRQ2).* Figure 3.35 below illustrates the logic followed in this section to answer the question.

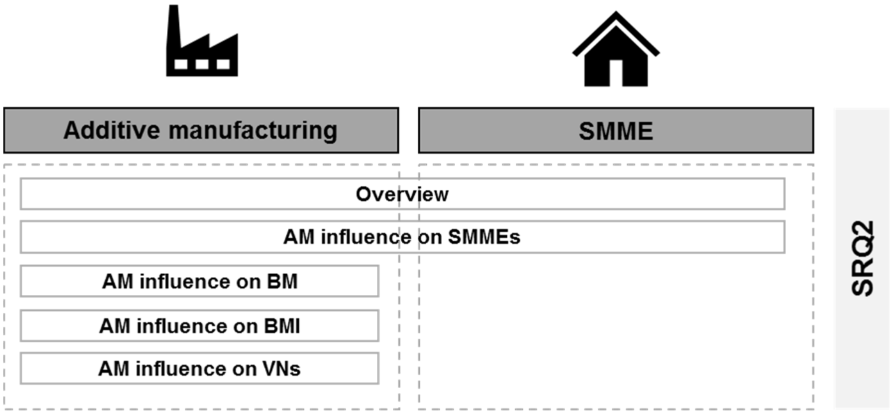


Figure 3.35: SRQ2 approach and structure

3.6.1 Overview

Industry 4.0 is narrowing the gap between the digital and physical world and therefore has the potential to cause a paradigm shift regarding BMs, production technology and the organisation of work [182, 230]. Several authors have defined the concept of I4.0 in different contexts, however, the general idea behind I4.0 is that of a 'fourth industrial revolution' caused by the rapid advancements in technology. This new industrial revolution is based on digitalisation (the increased use of computer technology) and is closely related to technical terms such as *"Cyber-Physical-Systems, Internet of Things, Big Data, Augmented Reality, Cloud Computing, Machine Learning, and Additive Manufacturing*" (which is the focus of this study) [182, 230].

Additive manufacturing, one of the emerging I4.0 technologies, is changing the way in which value activities, including strategic, organisational and operational activities [144], are performed and gives rise to new value propositions along the VN [125, 230]. It enables the development of new products, new BMs, new supply chains, and new VNs. Hannibal [98] summarised the impact of AM as follows: *"1) Disruption of the industrial ecosystem and emergence of AM service providers, 2) Increased customer interaction and new partnership dynamics, 3) Challenges to intellectual property rights and the emergence of AM platform business, and 4) Regional diversification of AM services".*

There are different types of applications of AM, including rapid prototyping, rapid tooling, and rapid/ direct manufacturing [76]. These applications are used in various industries (which are ever expanding) such as health; aerospace; automotive; consumer goods and electronics; industrial equipment and tooling; construction; and energy. According to the ASTM, AM can be divided into seven distinct areas or process categories, associated with different technologies and materials, see Table 3.17 below [17]:

Table 3.17: AM processes, technologies, and materials [17]

Process category	Technology	Materials
Binder Jetting	3D Printing, Ink-jetting, S-Print, M-print	Metal, polymer, ceramic
Direct Energy deposition	Direct Metal Deposition, Laser Deposition, Laser Consolidation, Electron Beam Direct Melting	Metal: powder and wire
Material extrusion	Fused Deposition, Modeling	Polymer
Material Jetting	Polyject, Ink-jetting, Thermojet	Photopolymer, wax
Powder bed fusion	Selective Laser Sintering, Selective Laser Melting, Electron Beam melting	Metal, polymer, ceramic
Sheet lamination	Ultrasonic Consolidation, Laminated Object Manufacture	Hybrids, metallic, ceramic
Vat polymerization	Stereolithography, Digital Light Processing	Photopolymer, ceramic

When implementing AM in a business, the affected products can be divided into those demanding major design changes and those only needing minor design changes or entirely new products that don't exist yet (these are however excluded from the context of this study). Major design changes could for example be used to improve product capabilities, while minor design changes are more suitable when wanting to retain a traditionally manufactured product but change the production method to AM – to improve the process. With each category, there is a different set of value adding aspects and difficulties. The process of identifying components for minor design changes could be mostly automated, as it generally considers quantifiable data. For components demanding major design changes, there need to be skilled engineers involved since the identification process is usually based on more complex criteria that utilise different aspects of the possible design improvements. Fontana, Klahn and Meboldt [73] noted that it is important not to limit screening and assessment to existing components, but rather fully explore the possibilities and potential of AM on a larger scale. [73]

Furthermore, it is important to understand that each process category, technology, material, and application area has specific requirements, constraints, potentials, and limitations. Therefore, when trying to identify possible parts or components to be manufactured using AM manufacturing technologies, a clear understanding of the AM material-process-machine combinations is vital. Selecting parts to be manufactured using AM is therefore no easy task, therefore, Uzair Khaleeq, Rivette, Siadat and Baqai [227] proposed an integrated design-oriented framework for resource selection in AM. Although the details of the framework are not in the scope of this study, the following fundamental decisions are important for the development of a framework with application value to the AM sector: product design/ redesign; functional specifications, product-process requirements; material-process-machine combinations [227].

Franco *et al.* [76] conducted a systematic literature review of 136 papers on the effects of AM adoption on the BM and concluded their study with a list of 22 consolidated and 13 inconclusive effects of AM adoption. Therefore, to consider the effects of AM adoption on the BM, the researcher did not have to conduct a new systematic literature review but only used the results of the comprehensive completed review. Below is a list of the 22 consolidated effects, implying they have been conceptually discussed and empirically examined in the literature, followed by the list of the 13 inconclusive effects. The most applicable effects to SMMEs in developing economies have been indicated in bold.

The conclusive effects were concerned with the following indicators [76]: *"enhanced mass customization capability,* ***facilitated the manufacture of complex parts, increased collaboration with the supplier,*** *increased customer/client interaction, increased department integration, increased logistic efficiency,* ***increased product design freedom,*** *increased* *product digitalisation, **increased production flexibility, increased supply chain decentralisation,** reduced business risk, **increased servitization possibility,** increased product/service value, increased product diversity, increased sales, less outsourcing, limited product size, reduced AM equipment reliability/availability, reduced product life cycle, reduced production complexity, reduced product weight, and support for a lean manufacturing approach".*

The inconclusive effects were concerned with the following indicators [76]: *"competitiveness, cost, dependence on the supplier, negative environmental impact, health and safety, inventory level, product quality and quality control, production efficiency, responsiveness, supply chain complexity, supply chain flexibility, worker qualifications, and number of workers/ workloads".*

Most of the research studies in the primary dataset focused on developed countries (specifically in Europe where I4.0 originated) with a different aim, and therefore most of the and findings are not directly applicable (in their totality) to developing countries yet. Therefore, all findings, trends, themes, and requirements cannot be assumed as immediately feasible and applicable to any country, especially not for South Africa. This led to the identification of the following key trends or themes which are applicable to the South African context. The identification and introduction of these trends or themes help to set the background of this research study and provide the reader with a better understanding of the context.

Table 3.18: Key trends or themes within the context of the study

Trend / Theme	Description	Reference(s)
Advanced Manufacturing technologies	The use of innovative technology to improve products or processes, with the relevant technology being described as 'advanced', 'innovative', or 'cutting edge.' Advanced manufacturing industries "increasingly integrate new innovative technologies in both products and processes. The rate of technology adoption and the ability to use that technology to remain competitive and add value to define the advanced manufacturing sector. Additive manufacturing technologies form part of advanced manufacturing technologies.	[144], [152], [74], [217], [242]
Circular economy	A systemic approach to economic development designed to benefit businesses, society, and the environment; also referred to as closed loop and closely associated with sustainability. It is based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems.	[184], [200]
Customer orientation/ centric	A business approach that puts the customer first (understanding their challenges, intentions, and the customer self), thereby valuing the needs and wants of the customer over the needs of the business. Using this approach in AM leads to direct co-creation with users.	[208], [97], [26], [127], [185], [242]
Cyber-physical system (CPS)	The integrations of collaborating computation, networking, and physical processes with feedback loops where physical processes affect computations and vice versa. These systems enable physical and virtual workflows to enable communication, data-accessing and data-processing services between humans, machines, and products available on the internet.	[152], [145], [242]
Decentralised (distributed) supply chain and manufacturing	AM caused the move from centralised to decentralised supply chains and manufacturing, where consumer goods move further away from the 'central' manufacturer, and closer to the end customer as parts can be manufactured at multiple geographical locations. The focus of this approach includes localisation and accessibility for the consumer.	[26], [76]

Trend / Theme	Description	Reference(s)
Design for Additive Manufacturing (DfAM)	It refers to the knowledge, tools, rules, processes, guidelines and methodologies used to adjust by AM designers in the design of AM components to make it cheaper, faster, or more effective to manufacture.	[227]
End-to-end solutions	Increasing specific customer needs is leading to a trend towards providing customers with end-to-end solutions (instead of only products). It describes a process that takes a system or service from beginning to end and delivers a complete functional solution, usually without needing to obtain anything from outside the organisation. Companies can achieve this either through partnerships and collaborations with other actors, or in-house if the company is capable of it. However, covering the whole chain in-house is something that few companies are capable of and this should not be viewed as a must-do, but rather form partnerships through VNs.	[76], [185]
Information and Communication Technologies	ICT is a broader term for IT, which refers to all communication technologies. These technologies are the basis for linking value chains to VNs. Advancements and developments in ICT are a driving force of industrial revolutions. The development of services based on ICT usually involves aspects from various industries and it develops at intersection of various activities executed by different actors driven by the current digitalisation trend. In such complex and dynamic environments, collaboration with key partners from the very start is crucial in order to ensure that the service is successful. ICT technologies can be an efficient way to support the implementation of new services.	[176], [177], [128], [201], [242]
Internet of Things	IoT (also referred to as the Internet of Everything or Industrial Internet of Things) describes the connection and communication of physical 'things' over the internet. The term Industrial Internet of Things (IIoT) is often used to denote the international description of I4.0. It describes the application of the IoT in the industrial context, that is the connection of devices in a factory. Integrating product development through the manufacturing chain with the help of IoT will lead to improved product quality. This also directs decentralisation of manufacturing process, enabling real-time decision-making. Embedded systems allow implementing total quality control practices, rather than using sampling to detect errors. Considering the IoT as an enabling set of technologies, they make possible the development of solutions that provide flexibility, scalability, and novelty for customers and end users. The dominant context for network-based BMs in empirical studies is one of IoT ecosystems.	[74], [152], [159], [129], [111], [145], [217], [242]
Localised manufacturing	A form of decentralised manufacturing where enterprises use a network of geographically dispersed manufacturing facilities to enable production in the local area of the customer.	[26], [127]
Personalised production	Personalised production or custom manufacturing means that a unique product is designed or engineered to order for a single customer. Personalisation lets businesses adapt a differentiation strategy to compete on added value for the customer instead of competing on price. AM technologies have potential for customer-centric and personalised production systems as they allow consumers to produce parts, products, and machines, as users of dedicated AM technologies. In such a model, end users of AM can use the technology to produce a variety of parts for themselves and others, which then implies a fundamental change to the global structure of manufacturing, amplifying the change from centralised to decentralised supply chains.	[26], [223], [217], [242]
Product-service-system (PSS)	PSS refers to the bundling products and services to lock-in customers while concurrently locking-out competitors. A PSS can be seen as a *"market proposition that extends the traditional*	[251], [208], [76], [217]

Trend / Theme	Description	Reference(s)
	functionality of a product by incorporating additional services", or rather as a "*system of products, services, supporting networks and infrastructure that is designed to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models".* It enables organisations to generate new sources of added value and competitiveness, empowering the relationship with customers through customised, innovative, and long-lasting integrated solutions.	
Service dominant logic (SDL)	SDL helps to better understand the transition of companies from solely focusing on selling goods to widening their integrated service solutions. It refers to a mindset for a unified understanding of the market exchange and the nature of organisations, markets and society. Although the SDL concept suffers from a lack of rigidity and empirical support, it is, however, helpful for understanding the service transition process, as it reaches beyond the ordinary goods focused understanding of value creation and allows the integration of the customer perspective in value creation activities.	[53], [129], [111]
Servitization	The servitization phenomenon that has pervaded manufacturing has resulted in organisations offering complex packages of both product and service to generate superior customer exchange value and thus enhance competitive edge. In the PSS literature, servitization is referred to as the P-S transition and represents the transition between pure product to pure service offerings. Within this transition exists combinations of products and services known as PSS. The introduction of servitization furthermore represents a perspective shift from a product-based BM to a demand-oriented one which enable a switch from payments per product to pay-per-feature, pay-per-use, or pay-per-output models.	[208], [159], [76], [242]
Sustainability	Sustainability envisions a balanced integration of economic performance, social inclusiveness, and environmental resilience, to the benefit of current and future generations. Sustainability is a trend that requires a long-term commitment to reshape the whole approach to business of a manufacturing firm. Enhanced sustainability requires changes in the way companies generate value, understand and do business. Companies are compelled to interact within an ecosystem of actors, moving from a firm-centric to a network-centric operational logic. This transition requires rethinking their incumbent BMs, in order to enable a decoupling of value creation a resource consumption. Hence, BMI towards sustainability is a fundamental capability for companies.	[251], [74], [159], [184]
Transformation	A transformation refers to a dramatic change in form or appearance. The focus of this study is on BM transformation - changing from an old BM to new one suited to a specific industry. In this case it is the transformation from a product-centric to customer or solution-centric BM. Services require organisational principles, structures and processes new to the product manufacturer, therefore there is a need of new capabilities, metrics and incentives. Developing this new set of capabilities necessarily diverts financial and managerial resources from manufacturing and new product development, the traditional sources of competitive advantage for the organisation. Thus, the transitioning from product manufacturer into service provider constitutes a significant managerial challenge.	[251], [127], [152]
Value co-creation	Value co-creation is a process that entails the spontaneous, collaborative, and dialogical interactions between people, systems, infrastructure, and information and making or producing something new and a function of interaction. Value co-creation drastically reduces costs as trial and error is not utilised, instead	[53], [129], [111]

Trend / Theme	Description	Reference(s)
	consumers are asked about what they prefer and even take part in design under certain conditions. Value is co-created through the integration of existing knowledge, the development of new knowledge (and other resources), and is influenced by the context, or environment, as well as the resources of others.	

3.6.2 Additive manufacturing and SMMEs

Industry 4.0 is well anticipated, but the majority of research, including research on service infusion in manufacturing, focus extensively on large enterprises and only marginally on SMEs [159]. However, large firms and SMEs or SMMEs differ in many ways [144]. Some of these general differences include that SMMEs have fewer available resources, less specific divisions of labour, and less bureaucracy than large firms, and these characteristics influence their development and innovation activities [144]. More innovation-specific differences include SMME's risk aversion in innovation activities, lack of systematic development procedures, and greater capacity to absorb new knowledge and technologies [144].

Mittal *et al.* [152] also noted that the academic research is focused on addressing implementation techniques created for, or by, larger organisations or MNEs. Yet many of the larger companies act as suppliers to SMEs and/or have SMEs as suppliers. Therefore, the actions of MNEs have an impact on their smaller supply chain partners and their requirements influence the positioning of SMEs within VNs. Additionally, Rogers, Baricz and Pawar [197] suggested that in the future of AM, SMEs role may be even bigger than that of larger firms, because of their agility and ability to transform. There is however a lack of understanding of AM adoption and integration in SMMEs. To enable support on the adoption and integration of existing systems with AM, particular features of SMMEs must however first be understood [144, 159].

Over the last decade, SMMEs faced some of the most disruptive and severe periods of economic challenges [205]. These challenges were caused by the rapid growth of the Internet, communication technologies and globalisation that reduced timing and distances [205]. In addition to the general challenges, the adoption of AM is also associated with numerous challenges for SMMEs. Rauch, Seidenstricker, Dallasega and Hämmerl [190] listed the following constraints (limitations and barriers) of SMMEs that want to introduce smart manufacturing technologies: "*culture, implementation, people, resource management, security, and strategy*".

To overcome the challenges of AM adoption, many actions might be taken, such as investments into technological advances innovations in design, strategic value chain changes, manufacturing relocation and developing specialised know-how [144]. However, the greatest adoption challenge for SMMEs remains financial barriers [145]. Therefore, to advance the progress of AM, SMMEs should take strategic and operational actions. Strategic actions include *"developing strategies by identifying the benefits of AM, selecting the focal application areas, and deciding on "make or buy"; scouting and collaborating to accumulate AM information, and advancing digitalisation; and starting with lead customers, creating demand through prototypes and activating supply chain partners"* [144]. Operational actions include *"reducing technical and material uncertainties through learning, small-scale experiments and research; giving resources to designers to learn and experiment, scaling up AM deliveries in selected niche products and markets; and creating new assessment criteria and metrics for AM manufacturing"* [144].

3.6.3 Additive manufacturing and the business model

For a long time, the manufacturing industry was characterised by mass production, division of labour and rationalised value creation processes [200]. Manufacturing companies often neglected direct contact with their customers and concentrated on the development of tangible goods [200]. Today's manufacturing industry is however confronted with a fundamental change in value creation [200]. Through the adoption of AM, companies can create more value through enhanced products and services, although capturing the value can become extremely challenging and therefore it is imperative to find suitable BMs [192]. Researchers agree that together with IoT (digital technologies), many manufacturers with a focus on products will turn to servitization, and support consumers with non-traditional, customer focused services [149, 168]. This transformation leads to the need to shift the focus from product-oriented BMs to solution (product and service)-oriented BMs.

As mentioned in Section 1.4, Savolainen and Collan [200] specifically investigated BMs used in AM. They categorised BMs that are applicable to AM into four classes namely, incremental and disruptive applications in closed and in open market models. The authors concluded that due to the conceptual nature of AM-technology, incremental AM-adoption in closed business environments will be most likely in the future [200]. Therefore, this study considers the configuration and development of networked BMs and strategic business nets within closed markets.

In comparison with more traditional mass production methods, AM makes it economically feasible to produce small batches of customised products [74], resulting in a smaller operational footprint [222]. Additive manufacturing is a direct production method that makes use of 3D computer-aided design (CAD) models, implying no tools or mould are necessary and manufacturers do not have to incur any switch over costs [74]. In addition, AM enables on-demand manufacturing, scalability [222], together with material utilization as no material is wasted [74]. One of the key features of AM is the ability to produce hollow part structures and the manufacturing of novel, complex and performance enhancing geometries [74, 125, 222]. Although AM has many advantages and potentials, it is however associated with problems regarding the development and standardisation of new materials as well as the development of multi-material and multi-colour systems [74]. Furthermore, post-processing is often required to improve the product properties of AM manufactured parts [74]. Table 3.19 below provide a brief comparison between the attributes of conventional or traditional manufacturing and AM [225]. Table 3.19 below provide a brief overview of the benefits and limitations of the two manufacturing types [225].

Table 3.19: Comparison between attributes of conventional manufacturing and AM [225]

Attribute	Conventional manufacturing	Additive manufacturing
Component size	Small-large	Small
Customizability	Low	High
Design freedom	Low-medium	High
Material selection	Large	Small
Need for moulds and tools	High	Low
Post-processing needs	Low	Medium-high
Preferred batch volume	Large	Small
Production speed	Slow-fast	Slow
Time-to-market	Medium	Short

Table 3.20: Comparison between benefits and limitations of conventional manufacturing and AM [225]

	Conventional manufacturing	**Additive manufacturing**
Benefits	On-demand production	High manufacturing speed
	Customisation of products	Economies of scale
	Less waste	Advanced material combinator
	Production of complex parts	Higher strength
	Production of lighter parts	Higher precision
Limitations	High AM machine cost	Hold of inventory
	Slower manufacturing speed	Increased lead time
	Limited materials	Low response to demand changes
	Increased material costs	Increased safety stock
	Limited product dimensions	More transportation

As part of the servitization phenomenon, driven by I4.0, organisations started to offer complex packages of both products and services to generate superior customer exchange value and thus enhance their competitive edge. Due to this transformation phenomenon, the carriers of value creation are changing from product to product and service, and from service to society, see Figure 3.36. This evolutionary process is divided into four stages with different carriers of value creation. In the first stage, it is only the product, in the second stage it is both the product and service with the product being the absolute dominant, in the third stage it is still product and service, but the service becomes dominant, and finally in the fourth stage is where value is created as a service implying everything related to product and production can be treated as a service, thus services are provided by the whole society. [217]

When considering this value creation evolution process, it can be assumed that most developing countries are currently at the first stage with the aim of transforming to the second stage. On the contrary, developed countries are striving towards the fourth stage or socialisation. Furthermore, when looking at the diffusion of innovation theory [117], developed countries can be regarded as innovators and early adopters, where developing countries (including South Africa) can be seen as the late majority or laggards.

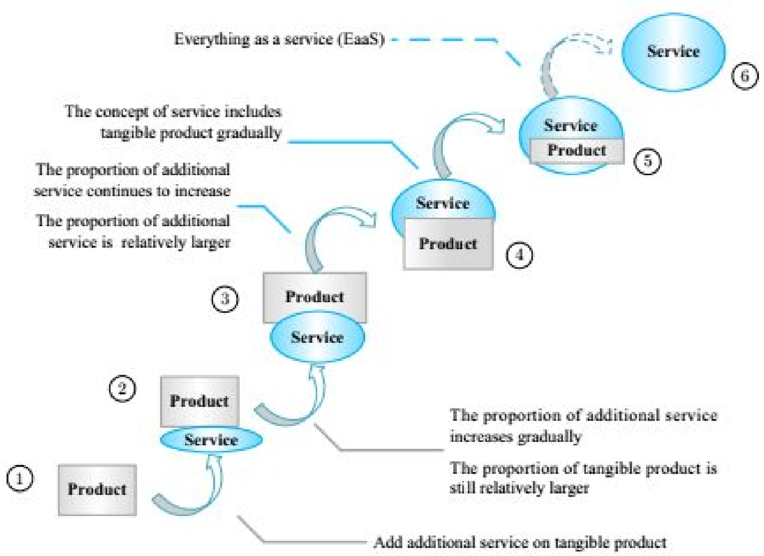


Figure 3.36: Evolution of products and services in the carriers of value creation [217]

The findings of the study conducted by Müller *et al.* [159] confirmed that it is worth it for SMMEs to pursue servitization as it leads to innovative BMs, starting with repair and maintenance, followed by technological training and consulting as well as CPS-related services, such as digitisation of processes, real-time product co-development or data processing and analysis. In their PSS categorisation framework, Zanetti *et al.* [251] used the PSS subcategories of product-oriented, use-oriented, and result-oriented. Visnjic, Wiengarten and Neely [235] argued that the introduction of servitization represents a perspective shift from a product-based BM to a demand-oriented BM, which enables a switch from payments per product to pay-per-feature, pay-per-use, or pay-per-output models [159]. In their turn, Ibarra Zuluaga, Ganzarain Epelde and Igartua López [108] suggested three different approaches enabling companies to get closer to I4.0, namely service orientation, networked ecosystems, and customer orientation. Although these different authors propose different perspectives or approaches, the most common perspective among all studies is customer orientation. Therefore, many SMMEs are shifting their value capture logic to a customer-oriented one, emphasising that the importance of customer retention is intensified through I4.0 [248].

The choice of BM centric or perspective has a significant impact on the organisational structures and capabilities that would support the operationalisation of the new BMs [26]. However, different scholars propose different orientations or perspectives (and categorisations) for BMs when adopting AM and services. Hämäläinen [97] proposed a customer-centric and value-based business model framework for companies in the machine industry which primarily consists of customers, customer value proposition, customer relationship, customer involvement, customer business environment, and customer activities and processes.

Bogers *et al.* [26] suggested a framework for AM-based solutions in BMs and supply chains, where BMs can be either manufacturer-centric or consumer-centric, and supply chains can either be centralised or decentralised, with the aim towards decentralised supply chains with consumer-centric BMs. However, Tziantopoulos *et al.* [225] concluded that a hybrid production method (combination of traditional manufacturing and AM) seems to be more feasible compared to existing studies focusing only on either centralised or distributed supply chain systems to ensure commercial viability. Therefore, in addition to being solution-oriented, manufacturers need to transform their BMs to being consumer-centric, whether a purely AM or a hybrid manufacturing method is followed. Bogers *et al.* [26] proposed the following comparison of manufacturer-centric and consumer-centric BMs (for a focal consumer goods manufacturer), see Table 3.21:

Table 3.21: Comparison of manufacturer-centric and consumer-centric BMs [26]

	Manufacturer-centric	**Consumer-centric**
Efficiency	• Process transparency • Economies of scale • Quality monitoring	• Low inventory cost • Print on demand • Low operating cost • Model reuse
Complementarities	• Portfolio-centric product development • Designer creativity	• Indirect linkage to portfolio and product designers • Multi-partner platforms
Lock-in	• Direct relation to product portfolio • Company-centric community and sharing	• Support in creation and printing • Availability of platforms • Community-driven sharing
Novelty	• Freedom for designers • Unique design for special editions • Co-creation optional	• Co-creation central to design • Personalised designs • Localised markets • Optional subscription

According to Dukat [65], referenced by Ålgårdh, Strondl, Karlsson and Farre [9], there are three key 3D-printing BMs, but a combination of these are also possible:

- *"In-house 3d printing: The manufacturing company has the in-house capability to 3D-print components.*
- *Contract based manufacturing: The manufacturing company outsources its work to a 3D printing company.*
- *3D printing service: Clients place their order or design desired products online on the 3D printing companies' website."*

In addition to these three key BMs, there is one more BM that is typically used by AM hobbyists and home users. Table 3.22 below summarises the key difference between these BMs [65].

Table 3.22: 3D printing BM comparison [65]

	In-house 3D printing	**Contract manufacturing model**	**3D printing as a service**	**Retail 3D printing (home use and hobbyists)**
Time to set up	VERY HIGH: R&D and plant set-up (10-25 years).	MEDIUM: Plant set-up (1-3 years).	MEDIUM: Online ecosystem and key partnership (1-2 years).	VERY LOW: 3D printer, familiarising with design platform (0-2 months).
Level of investment	VERY HIGH: R&D and plant set-up.	MEDIUM: Plant set-up.	MEDIUM: Online platform.	LOW: Home 3D printer and raw material.
Level of customer interaction	VERY LOW: Zero interaction before production. Only sales interaction.	HIGH: Build-to-order based on customer design and preference.	MEDIUM: Production based on customer design received online.	HIGH: Customer is the user or is strongly connected to the user.
Use of online technologies	LOW: In-house design team, face-to-face sales interaction.	MEDIUM-LOW: In case of taking online orders (online design).	HIGH: Online orders, online design, online payment.	MEDIUM-LOW: Accessing design from crowdsourcing communities.
Requirement of logistics	MEDIUM-HIGH: Mass procurement of raw materials and supply of finished products.	MEDIUM: Small batch procurement of raw materials, and supply of finished goods.	HIGH: Supply of finished products to individual customers.	LOW: No requirement except in case of retail home delivery.

In their study, Mellor, Hao and Zhang [147] aimed to address the need for existing and potential future AM project managers to have an implementation framework to guide their efforts in adopting AM to produce high value products and generate new business opportunities. Consequently, they constructed and tested a normative structural model of implementation factors related to AM technology, supply chain, organisation, operations, and strategy, see Figure 3.37 below. Most of these elements were included in the management framework developed in Chapter 6 to ensure AM implementation is addressed.

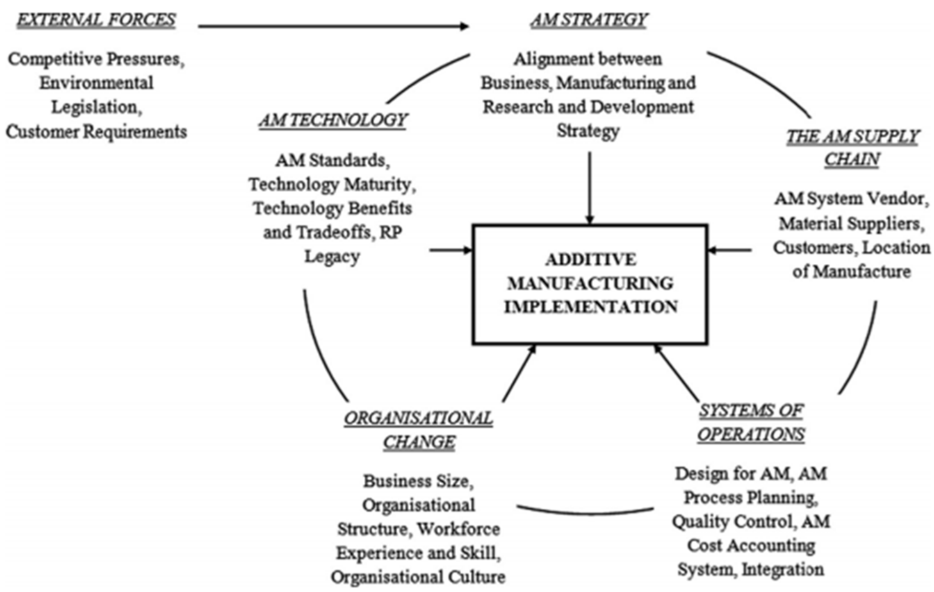


Figure 3.37: The proposed framework of AM implementation [209]

3.6.4 Additive manufacturing and business model innovation

Additive manufacturing not only supports process innovation but paves the way for product innovation, which creates possibilities for market expansion [163]. Selling new products to new markets could significantly alter the value proposition of a firm – leading to BMI. Accordingly, Rayna and Striukova [192] investigated the relationship between 3D printing technologies and BMI. Within their study, they concluded that 3D printing technologies have the potential to change the way BMI is carried out, by enabling adaptive and modular BMs.

This implies that depending on the environment, companies can decide to adopt a narrow (focused on one market) or wide, long (e.g., design, manufacturing, and distribution) or short (just design) BM. Furthermore, regarding the modular aspect, BMs can become ‘mobile’ by moving the BM up, down, or sideways as needed, see Figure 3.38 below. Horizontal movements concern the inclusion of existing or new markets. These kinds of movements are often risky because it is often associated with significant investments before even entering the market. However, 3D printing technologies make lateral moves less risky, because products can be manufactured on demand with minimal costs. Besides being used for entering existing markets, the same strategy may be used for entirely new markets. Additionally, 3D printing technologies can enable companies to rapidly move upstream or downstream. For example, manufacturers can now focus on design and service as well, or design firms may decide to manufacture as well. This also means that companies can more easily adapt the ‘length’ of their BM by taking on more activities, or by giving up some of them. [192]

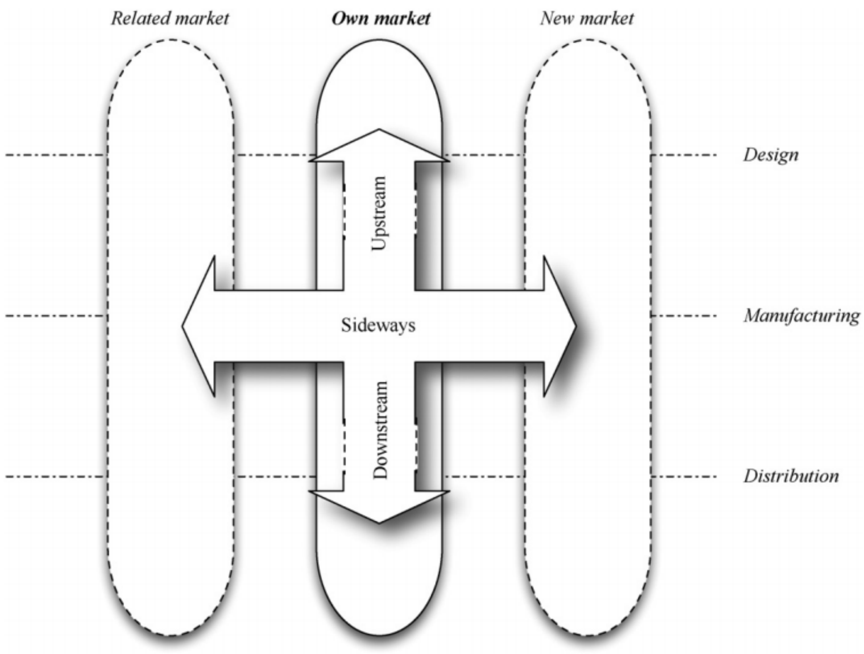


Figure 3.38: 3D printing enables adaptive 'mobile' BMs [192]

3.6.5 Additive manufacturing and value networks

Additive manufacturing is changing the way value activities are performed and gives rise to new value propositions along with the VN [230]. Additive manufacturing technologies allow for the production of complex multi-component products into single component products, therefore, simplifying value chains. Due to the reduction of lead time, shorter delivery times will be possible [125, 230]. Furthermore, given the fewer production stages, value chains become less hierarchical [74, 230]. Gebler, Schoot Uiterkamp and Visser [83] agree that shorter, smaller, more localised, more collaborative, and more sustainable value chains can be possible with the adoption of AM and other advanced manufacturing technologies [230].

Martinsuo and Luomaranta [144] found that SMEs in different supply chain positions (OEMs, subcontractors, AM service providers, and designers) experience different challenges when adopting AM. These challenges were categorised into technology related, strategy related, operational, organisational, and externally related – illustrating that the challenges faced by SMEs with AM adoption influence every aspect of the business [144]. Therefore, different actors within the VN may need to take different actions to secure their success in an industry where AM is present [198].

The potential and benefits provided by AM, will only be achieved if the broader supply chain adopts AM technology [205]. Therefore, it is required that AM adoption must be understood as a shared concern and as a systemic innovation process in the supply chain, instead of just a firm-specific implementation task [205]. Consequently, business managers in both larger companies, as well as SMEs need to collaborate to explore the AM technology´s benefits and discover solutions to reduce technology and business barriers and risks [97].

Collaboration with external partners can be achieved through participation in collaborative VNs (which is partially included in the definition of a strategic business net used throughout this study). A collaborative network is a collective name for networked entities, inter or intra organisational, that collaborate to achieve collective or compatible goals [40], quoted by Torn and Vaneker [223]. For SMEs, it is already a common practice to join networks, therefore it is regarded as an adequate approach [152]. Due to the high variation of on-demand manufacturing, organisations often experience either excess capacity or shortages. SMEs can therefore collaborate with competitors to better cope with the variety, for instance, outsource the production of personalised parts to other participating SMEs with similar production facilities. This enables the physical barriers of the factory to disappear to facilitate distributed manufacturing between the connected firms. [223]

Additive manufacturing enables the production of prototypes to allow value chain element independence, and therefore, achieving time reduction on design and manufacturing processes [8]. As mentioned before, AM is associated with numerous advantages, but also challenges. Firstly, the cost and speed of production is a key challenge for manufacturers [74]. Another challenge is the automation of AM systems and process planning to improve manufacturing efficiency [74]. Furthermore, within the AM industry, the set of competitors is continuously changing together with non-linear, localised collaboration with ill-defined roles and responsibilities within the industry [74]. However, Martinsuo and Luomaranta [144] stated that co-operation is a requirement for adopting AM as most SMEs cannot compete in the AM market with their own resources alone.

In general, the adoption of new manufacturing technologies is driven by the need to generate added value for customers and to raise the process efficiency in the whole value creation system [58]. The value creation system is, however, not only production and logistic processes, but it also represents the point of view on how an organisation creates, sells, and delivers products [237]. In their paper, Kritzinger *et al.* [125] applied an AM perspective and defined and categorised the value creation system and its activities according to six main processes, namely: *"product development, supplier, administration, production, customer and product lifecycle",* see Figure 3.39.

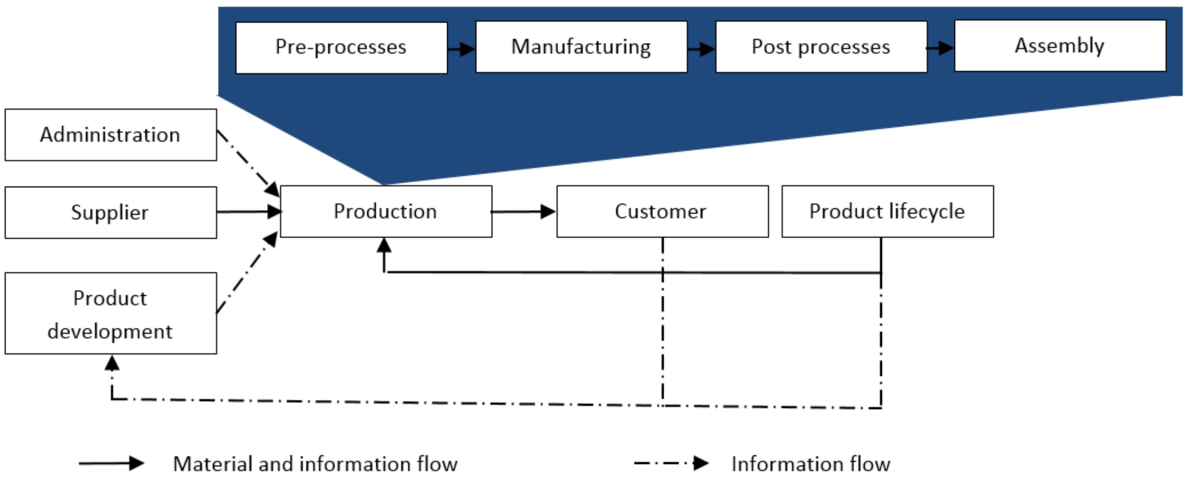


Figure 3.39: The AM value creation system [125]

According to Despeisse, Yang, Evans, Ford and Minshall [63], in the context of AM, the opportunities for sustainable value go beyond the manufacturing process itself with benefits being realised across all stages of the product's lifecycle including:

1) Beginning of Life (BoL):
   a) design of products and processes,
   b) manufacturing system configuration,
   c) business model;
2) Middle of Life (MoL):

d) efficiency in use phase,
e) product life extension;

3) End of Life (EoL):
f) closing the loop.

Porat and Hovstadius [185] argued that the main benefits of AM are commonly connected to either the design and engineering of components, the manufacturing process, or the value chain. However, Kritzinger *et al.* [125] argued that with AM technologies, the added value is mainly generated in the product design and use phases, whereas the manufacturing processes.

The adoption of AM in an industry will however also lead to numerous supply chain, value chain and VN changes. Changes to engineer-to-order supply chains include a shift in the focal firm from being the manual manufacturing to being the 3D modelling and additive manufacturer, some supply chain members will be eliminated, some new supply chain members will enter the market due to AM adoption, and some consumers will be eliminated and some new consumers will enter the market, see Figure 3.40 below. [166]

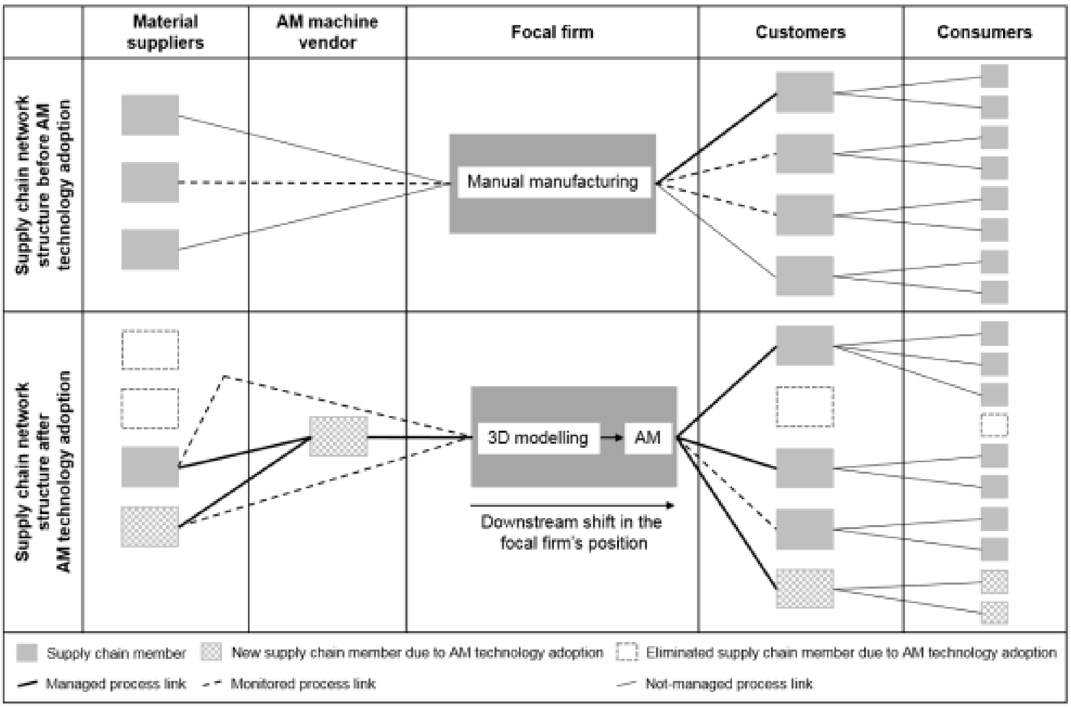


Figure 3.40: Impact of AM technology adoption on network structure in engineer-to-order supply chains [166]

Network structures are generally described and discussed relative to three major levels: upstream, midstream, and downstream. Upstream refers to suppliers and manufacturers of products. Midstream concerns the transportation processes and warehousing, while downstream consists of the retailers and final distribution to end customers. [225]

Tziantopoulos *et al.* [225] proposed two supply chain reconfiguration patterns driven by AM technologies, see Figure 3.41. In the first SC reconfiguration pattern, the AM machines are installed in centralised locations, the upper- and mid-stream levels. Additive manufacturing technologies are installed as stand-alone systems in centralised locations or centralised distribution centers. Furthermore, within this configuration pattern, the CAD files will be provided to AM producers by OEMs and the CAD file flows will replace the product flows from upper-stream to midstream levels. [225]

In the second SC reconfiguration pattern suggested by Tziantopoulos *et al.* [225], AM machinery will be installed in distributed locations or at the end customer site. This will lead to the emergence of localised manufacturing, and user manufacturing. In a distributed AM supply network, a significant share of manufacturing will take place downstream a supply chain, while the CAD file flows will replace even more product flows from upstream and midstream to downstream levels. This will lead to shorter supply networks, decreased transportation needs and reduced overall lead time. Moreover, distributed AM production will further decrease the complexity of supply chains. [225]

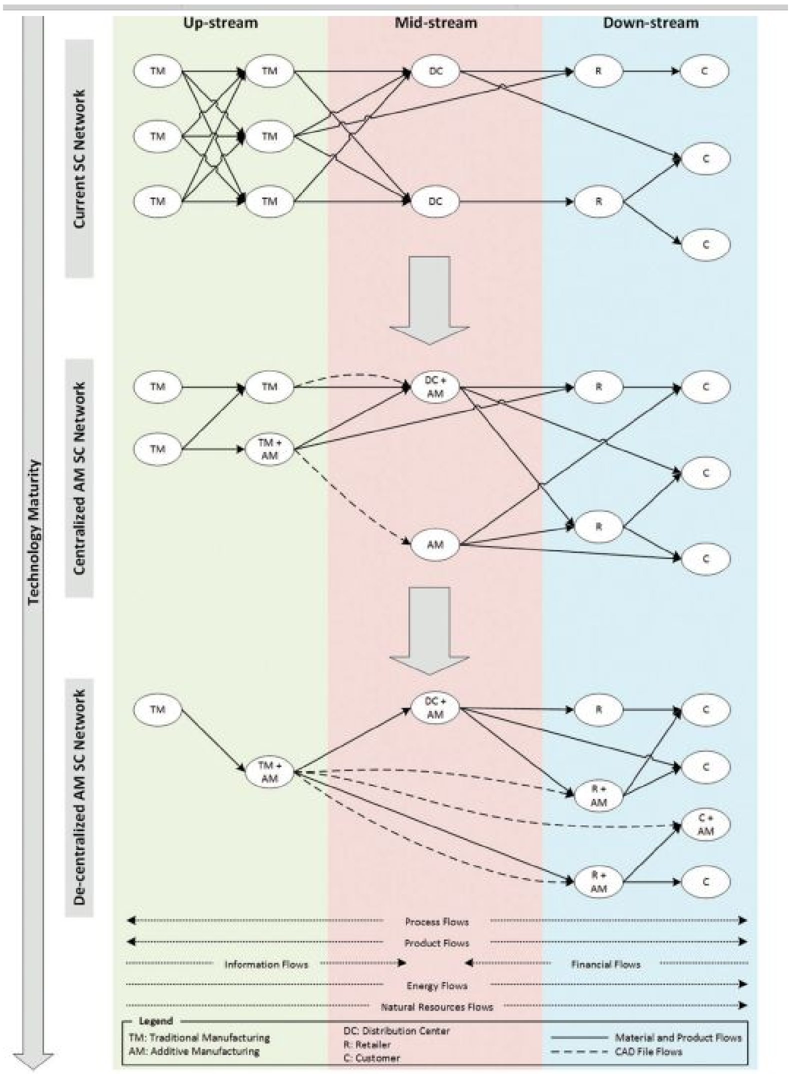


Figure 3.41: Supply chain network reconfiguration framework driven by AM technologies [225]

3.7 Limitations of the review

The structured literature review has a few limitations. The first limitation is that only one researcher screened and selected the papers, which may have led to possible researcher bias. It was furthermore only limited to a few databases and did not explicitly consider grey literature, hence important articles and findings may have been omitted. However, during the application of the framework in Chapter 7, grey literature was considered to ensure the inclusion of the most important aspects, specifically regarding AM. Due to the space limitation of the review, only a brief overview could have been presented of each concept and the context, consequently important detailed findings could have been excluded.

Furthermore, the current study did not elaborate on the impact of AM on individual BM components, nor the impact on individual role-players within the VN, however, the findings were leveraged to create a holistic view related to the BM and VN. Lastly, although it is acknowledged that there is a huge amount of related and relevant adjacent literature bodies, those bodies were not included, therefore, definitions, frameworks, concepts, and frameworks presented in this chapter (relating to BM, BMI, and VN) were the only ones considered for this study.

3.8 Conclusion: Chapter 3

In this chapter, SRQ1 and SRQ2 were answered through the analysis of the selected articles that formed part of the primary data set. This chapter was the first step within phase two of this study's design. The chapter aimed to set out and summarise the concepts under investigation, as well as creating an understanding of the context of the study.

Due to the vast number of frameworks contained within the three primary literature bodies, it is acknowledged that the rest of the study is dependent on the selected theoretical frameworks (summary presented in Table 3.23), therefore careful attention was given to select the most holistic and applicable frameworks within the context of this study. If other frameworks were to be selected, the research artefacts and findings would most probably look a little bit different. Definitions and explanations of the fundamental concepts (concept inventory) identified throughout this chapter is presented in Table B.1 in Appendix B, which forms the theoretical foundation for the subsequent sections and other research artefacts designed in the following chapters.

Table 3.23: Summary of selected theoretical frameworks

Literature domain	Theoretical framework	Concept map	Hierarchical taxonomy	Concept map of theory	SBN configuration process	Primary contribution
BM	V4 BM structure [7]	√	√	√		Four value dimensions: value network, value proposition, value architecture, value finance. Networked BM elements.
	360° BM framework [191]	√	√			Networked BM elements.
	I4.0 BM taxonomy [242]	√	√			Networked BM elements.
	Unified BM hierarchical taxonomy [6]		√			Taxonomy structure according to facets and classes. Taxonomy facets: V4 BM Dimensions, BM Functions, BM Reach, Modelling Principles.
	Framework of the elements of a networked BM [176]	√	√	√		Actors (including customer). Value exchanges. Customer needs. Adjustments according to the past and according to changes in the environment.

Literature domain	Theoretical framework	Concept map	Hierarchical taxonomy	Concept map of theory	SBN configuration process	Primary contribution
	Framework for networked BM development [177]	√	√	√		Three development phases: service development, pilot, and market. Two dimensions of networked BM development: business net and business opportunity.
BMI	Dynamic capabilities-based view [219]		√	√		Three-stage dynamic capabilities-based view: sensing, seizing, and transforming.
	Generic BMI Process [245]		√	√		Seven BMI process phases: analysis, ideation, feasibility, prototyping, decision-making, implementation, and sustainability.
VN	Value meta-model [134]	√	√	√		Three level of value creation: end customer vale, business value, and collaborative value.
	ARA model [96]	√	√	√	√	Mapping levels: actors, and activities which were changed to function.
	Model of economic entity [21]	√	√	√	√	Mapping level: capabilities.
	Allee’s value network mapping [12]	√	√	√	√	Value exchange and flow. Tangible and intangible value exchanges. Unidirectional or bidirectional value flow.
	Unipartite and bipartite analysis of innovation systems [101]				√	Unipartite and bipartite network mapping. Colour coding of value exchanges.

The following chapter, Chapter 4, aims to integrate and synthesise the data identified within this chapter, as part of the first design cycle iteration.

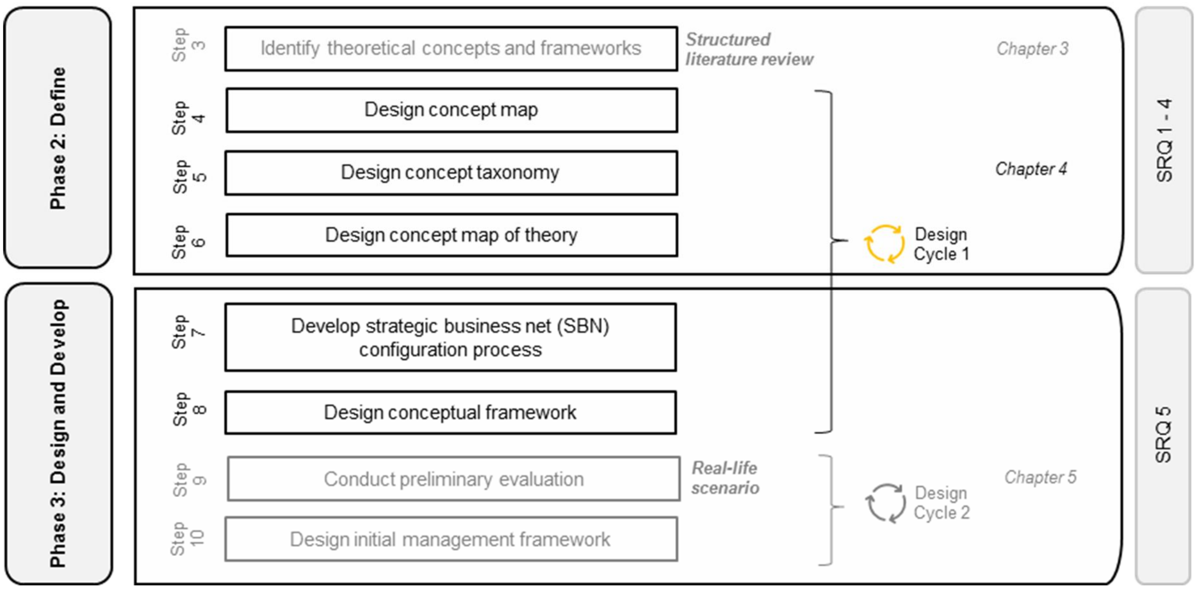
.

Chapter 4: Conceptual framework development

Chapter 4 aims to synthesise and integrate the literature findings from Chapter 3. The synthesis enabled the development of a concept map (based on the fundamental concepts identified in Chapter 3), followed by a hierarchical concept taxonomy (SRQ3), concept map of theory (SRQ4), and ultimately a conceptual framework to conclude Design Cycle 1. The identified need to develop a new value mapping (visualisation) process is also addressed within this chapter by proposing a new process, referred to as the *strategic business net configuration process.* Furthermore, each research artefact contained within this chapter forms part of the systematic approach followed in the development of the management framework presented in Chapter 6.

Chapter 4 key objectives:

- Discuss the systematic development approach followed (Section 4.1).
- Present a concept map of the fundamental theoretical concepts (Section 4.2).
- Present the proposed elements for a networked BM (Section 4.2).
- Present a hierarchical taxonomy of the networked BMI concept (Section 4.3).
- Present a concept map of theory to visually illustrate the networked BMI concept (Section 4.4).
- Present the strategic business net configuration process (Section 4.5).
- Propose a conceptual framework (Section 4.6).



4.1 Systematic development approach

A systematic approach was followed throughout this study to design and develop the management framework, presented in Chapter 6. Figure 4.1 below illustrates the steps followed throughout this approach. This chapter discusses the approach followed during Part A-D as well as the research artefacts presented as output of each part.

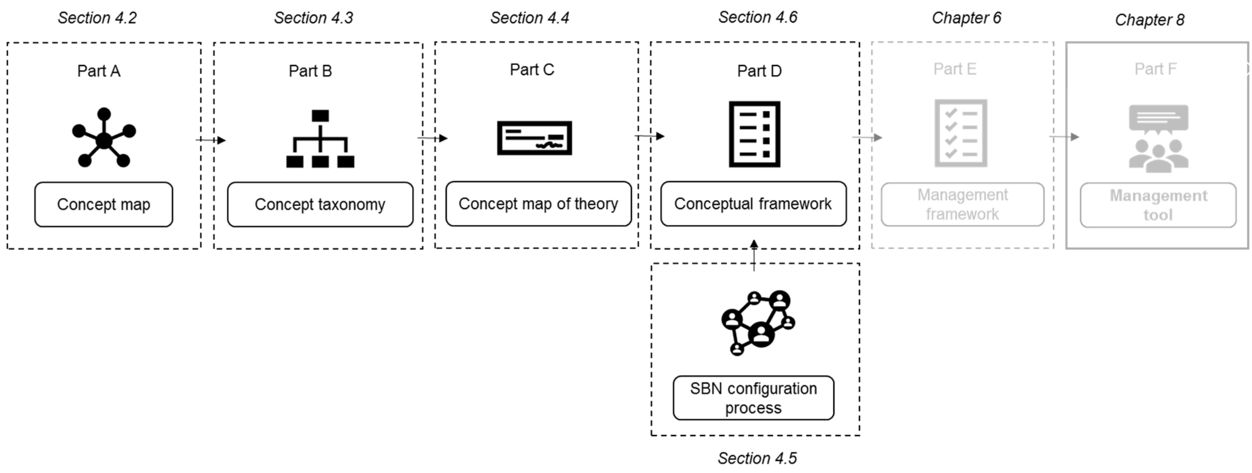


Figure 4.1: Systemic development approach

4.2 Part A: Theoretical fundamental concept map

As illustrated in Figure 4.1, *Part A* concerns the development of the theoretical concept map. A concept map is a graphical tool used to structure and represent knowledge. It consists of nodes and links to show the relationship between the nodes. Figure 4.2 below briefly illustrates the development approach of the concept map. The concept map aimed to integrate the fundamental concepts identified within each of the three primary literature bodies (BM, BMI, VN). The V4 BM structure framework consisting of four value dimensions, proposed by Al-Debei and Fitzgerald [7], was selected as the framework to categorise the selected concepts to provide some structure to the map (discussed in Section 3.3.3). The concept inventory presented in Appendix B contains descriptions and explanations of the fundamental concepts, together with an indication regarding applicability to the three primary literature domains.

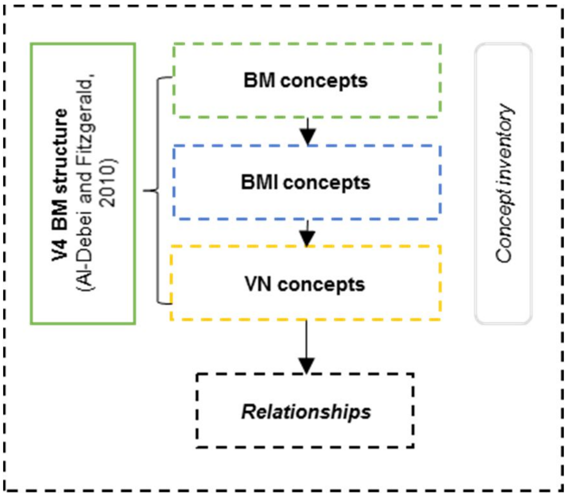


Figure 4.2: Concept map development approach

To complete the concept map, different types of relationships were proposed between the concepts. Figure 4.3 below illustrates the proposed potential relationships between the different concepts. To map the relationships, the concepts' descriptions in the concept inventory (Appendix B) were used, together with the researcher's understanding of the concepts. Therefore, the proposed relationships are just one suggestion, and it is acknowledged that additional relationships may exist as well as other types of relationships.

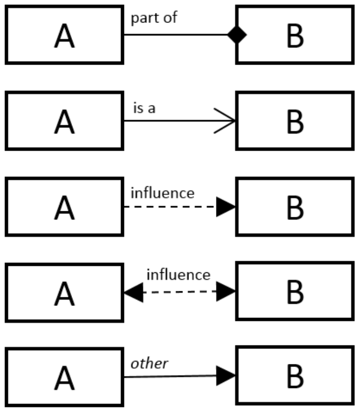


Figure 4.3: Possible relationships between concepts

The concepts identified within each of the literature bodies in Chapter 3 are illustrated in Figure 4.4. Whereafter, the proposed concept map is illustrated in Figure 4.5. The concept map proved to have multiple important contributions to this study. It firstly contributed to the researcher's understanding of the literature bodies through the careful selection and organisation of the fundamental concepts and to make sense of how everything is connected and influencing each other, based on the proposed conceptual relationships between the concepts.

The use of a quantitative method (coding) to select the most important concepts was not a feasible option because of the dispersed nature of the selected primary literature body as well as the use of different terms or concepts by researchers to describe the same logic. Therefore, a qualitative approach needed to be taken where the most important concepts, according to the researcher's understanding, were selected to enable a holistic, brief, and overview of the selected literature body. The concept map can furthermore be used by future scholars to get an initial and introductory overview of the literature body if a study in a similar domain is pursued.

The identification and mapping of the fundamental concepts enabled a broad understanding of the networked BMI concept. However, as part of the BMI process, it is still important to develop specific BM elements. Therefore, a specific set of concepts were selected as elements for the networked BM framework. Figure 4.6 below illustrates the selected elements with the associated primary theoretical framework containing the element. To ensure the selected elements are a good representation of the theoretical frameworks contained within the literature, the selected elements were compared with all the selected theoretical frameworks (discussed in Chapter 3) of each of the three primary literature bodies, see Table 4.1. Furthermore, Table 4.2 contains a brief description of each of the selected elements. These elements were also evaluated by the subject-matter experts in Chapter 6.

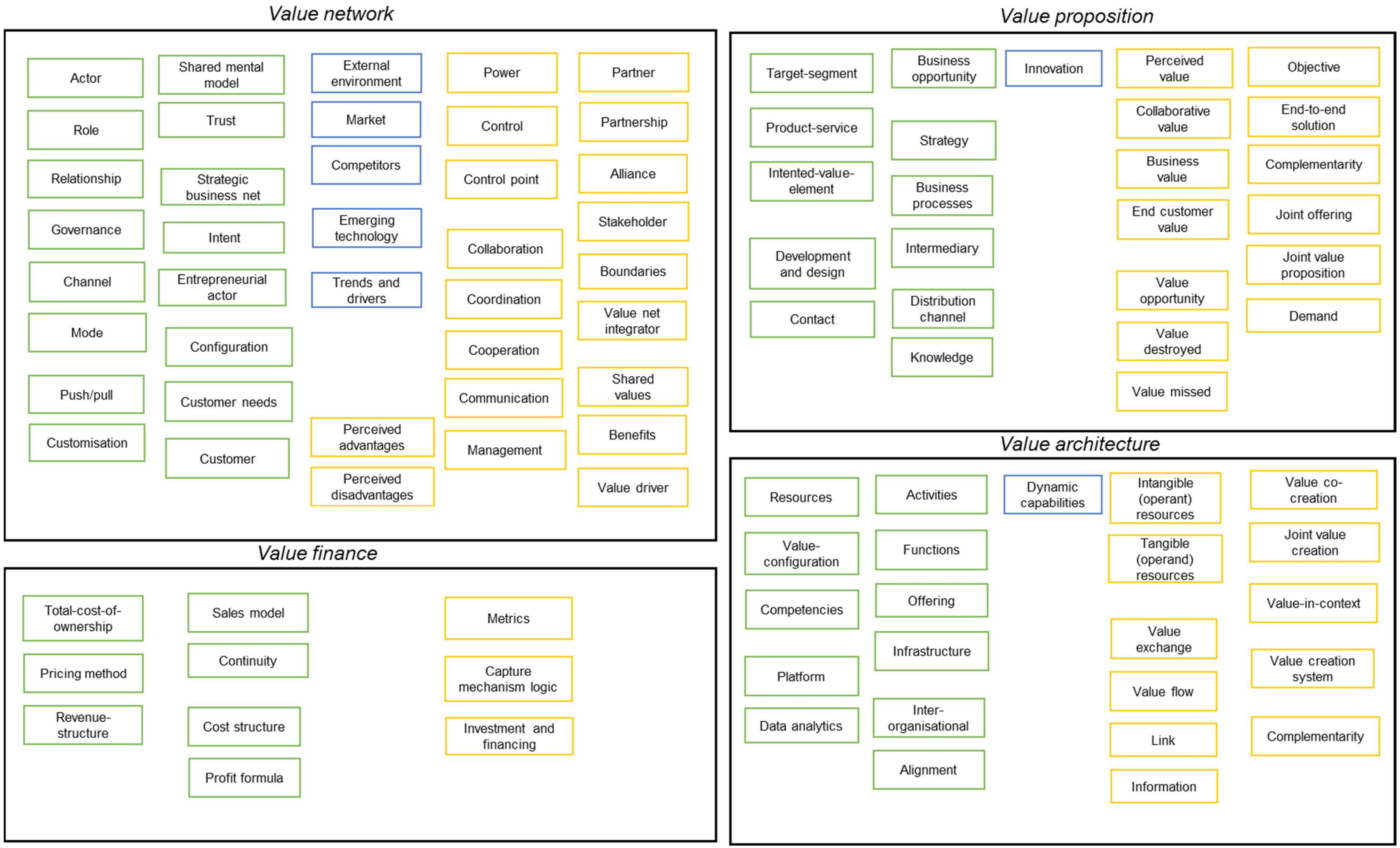


Figure 4.4: Fundamental concepts identified in the primary literature bodies

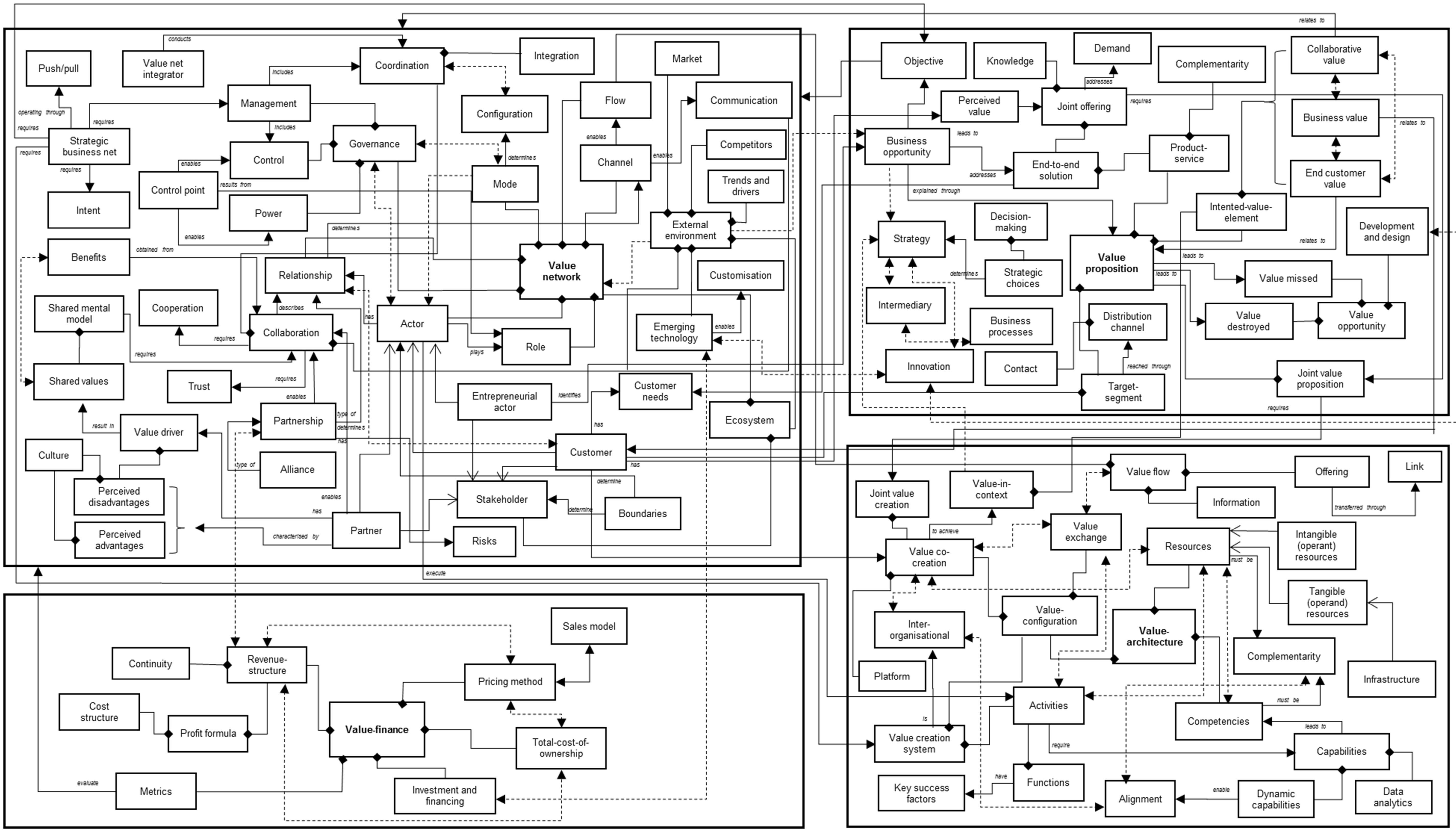


Figure 4.5: Theoretical fundamental concept map

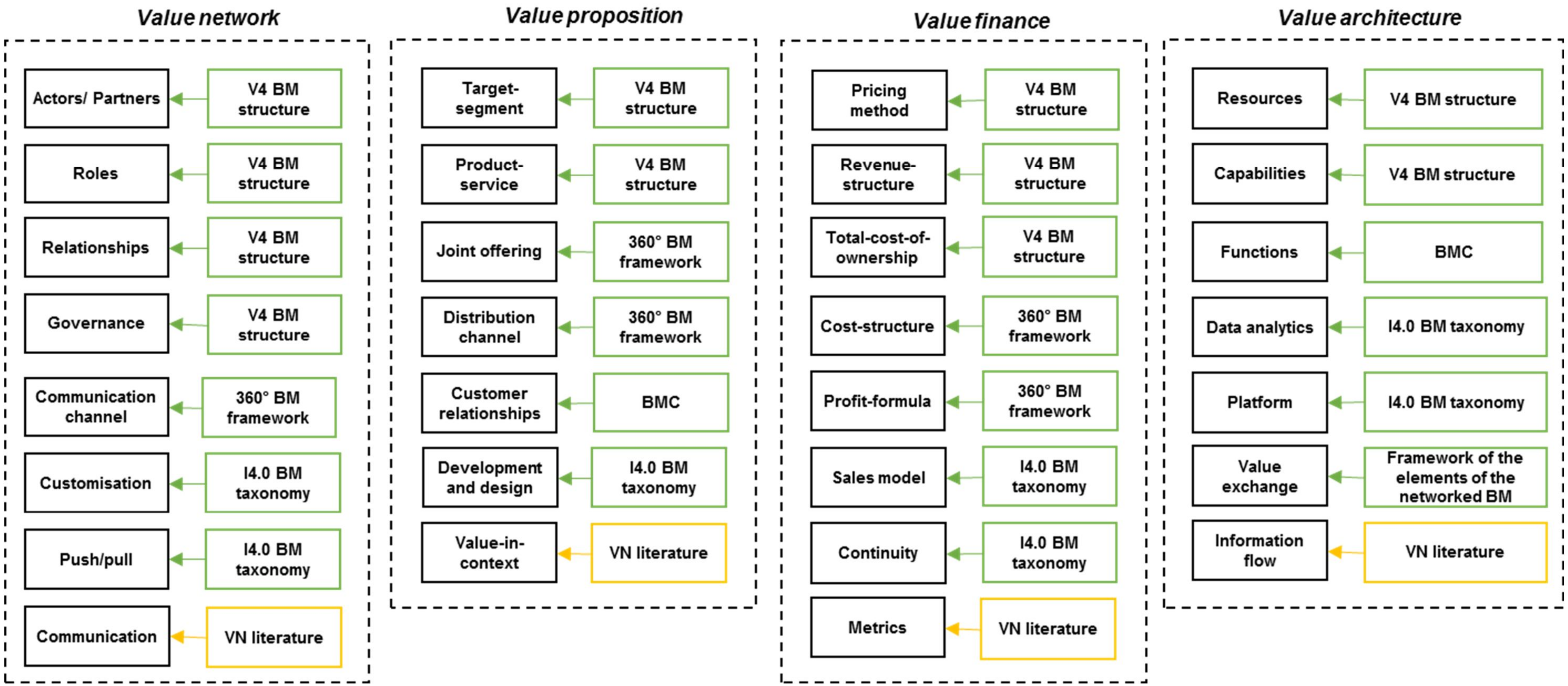


Figure 4.6: Selected networked BM elements

Table 4.1: Selected networked BM elements contained in theoretical frameworks

Value dimension	Element	BM firm-level frameworks				BM network-level frameworks				Value network frameworks				
		The V4 Business Model Structure [7]	**360° Business Model Framework [191]**	**Business Model Canvas [170]**	**I4.0 Business Model Taxonomy [242]**	**Framework of the elements of the networked business model [176]**	**Networked business model development framework [177]**	**Network-based BM ontology [160]**	**Network-oriented view of a BM [111]**	**ARA model [94]**	**Model of economic entity [22]**	**Allee’ s value network model [12]**	**Value network development model [5]**	**Value network literature**
Value network	Actors / Partners	x		x	x	x	x	x	x	x	x		x	
	Roles	x			x		x			x		x	x	
	Relationships	x								x			x	
	Governance	x	x										x	
	Communication channel		x	x									x	
	Customisation				x									
	Push/pull				x									
	Communication													x
	Control													x
Value proposition	Target-segment	x	x	x	x	x								x
	Product-service	x	x		x	x								
	Joint offering		x						x					
	Distribution channel		x	x	x								x	
	Customer relationships			x										
	Development and design				x									
	Value-in-context													
Value finance	Pricing method	x	x											
	Revenue structure	x	x	x	x									
	Total-cost of ownership	x												
	Cost structure		x	x										
	Profit formula		x											

Value dimension	Element	BM firm-level frameworks				BM network-level frameworks				Value network frameworks				
		The V4 Business Model Structure [7]	360° Business Model Framework [191]	Business Model Canvas [170]	I4.0 Business Model Taxonomy [242]	Framework of the elements of the networked business model [176]	Networked business model development framework [177]	Network-based BM ontology [160]	Network-oriented view of a BM [111]	ARA model [94]	Model of economic entity [22]	Allee' s value network model [12]	Value network development model [5]	Value network literature
	Sales model				x									
	Continuity				x									
	Metrics													x
Value architecture	Resources	x	x	x				x		x		x		
	Functions			x					x			x		
	Capabilities	x	x							x				
	Information flow													x
	Data analytics				x									
	Platform				x									
	Value-exchange					x						x		

Table 4.2: Selected networked BM elements descriptions

Value dimension	Element	Description	Reference(s)
Value network	Actors / Partners	It refers to legal and economic independent entities representing an organisation, company, customer, person, or research institution that partake in the strategic business net.	[7], [22]
	Roles	It describes how a specific actor contributes to the fulfilment of a particular function within the strategic business net.	[7], [12]
	Relationships	It describes the type of links established between actors within the strategic business net.	[7], [5]
	Governance	It refers to who within the strategic business net has control and power over what kind of objects and resources e.g., data, relationships, channels, functions, patents, brands, and transactions. It can either be hierarchical where one or few actors dominate the power or flat where all actors share costs, risks, knowledge, and capabilities more equally.	[5], [7]
	Communication	It refers to the exchange of information between actors, functions, or resources through a medium or channel. It also includes determining what must be communicated to whom and when.	[170]
	Communication channel	It refers to the communication mediums or ports used to communicate materials and information among actors (including customers) because of their established relationships. Channels could be physical or electronic and can range from manual to fully automated.	[7]
	Customisation	It refers to how individualised the product-service is (mass production/ mass customisation/ mass individualisation).	[242]
	Push/pull	It describes the kind of production paradigm used (pull, on-demand/ push and pull).	[242]
Value proposition	Target-segment	It refers to the clustering of the strategic business net's customers into different groups based on shared common properties and characteristics.	[170], [7], [199]
	Product-service	It describes the product(s) and service(s) provided to customers which form part of the joint offering produced and delivered by the strategic business net.	[7]
	Joint offering	It refers to the total offering provided to the customers, which are created by the group of actors that form part of the strategic business net, including factors such as availability, technical support, quality of service.	[111]
	Distribution channel	It refers to how the joint offerings are going to reach the customers.	[170], [191]
	Customer relationships	It describes the type of relationship established with customers.	[170]
	Development and design	It refers to who develops and designs the products (hired or employed experts/ customer or user designed/ development community or crowdsourcing). It includes who owns the CAD design files and products.	[242]
	Value-in-context	It refers to how the value associated with the joint offering is unique in the specific context (closely associated with unique selling points and value-added benefits or value offer to the customers).	[242]

Value dimension	Element	Description	Reference(s)
Value finance	Pricing method	It refers to how different joint offerings delivered by the strategic business net are priced (e.g., fixed, dynamic, or a mixture).	[6], [7]
	Revenue structure	It refers to the type of revenue sources utilised, e.g., reselling consumables/ sale/ leasing/ rental partner. It also includes how the profitability of different joint offerings are split among customer segments.	[7], [191]
	Total-cost of ownership	It refers to the overall costs with respect to all core arrangements that are needed to create, provide, market, deliver, and maintain the joint offering throughout its lifespan (including development, support, maintenance, collaboration costs).	[7]
	Cost structure	It refers to the allocation of costs within the strategic business net.	[113]
	Profit formula	It refers to the financial benefit which is realised when revenues gained exceeds that of expenses, costs, and taxes needed to sustain the activities conducted as part of the strategic business net.	[191]
	Sales model	It refers to what the customer is paying for (ownership/ service delivery or use/ availability or result).	[242]
	Continuity	It refers to how continuous the revenues are (once/ mixed/ continuous).	[242]
	Metrics	It refers to the standard measurements to evaluate or measure the profitability and performance of the strategic business net and individual partners.	[12], [59]
Value architecture	Functions	It refers to the actions performed by the actors within the strategic business net to produce and deliver the joint offering, using different, complementary capabilities and resources, usually motivated by a potential profit.	[22], [94]
	Capabilities	It refers to the ability to do something through the integration of knowledge and skills and adapting and flexing to meet future needs, or the fulfilment of future functions which form part of the future strategic business net.	[22]
	Resources	It refers to the tangible, static resources that require some action to make them valuable (e.g., people, facilities, equipment, materials, infrastructure, tools), as well as the intangible, dynamic resources that are capable of creating value (e.g., knowledge, time, energy, skills, attitude, capacity).	[113], [161]
	Information flow	It refers to the flow of timely, real-time, and accurate information (including facts, data, knowledge) between network actors to enable close partnerships, the exploitation of network benefits, and overall network performance.	[104], [22]
	Data analytics	It refers to the source of high-value data (internal data/ customer's data).	[242]
	Platform	It refers to the kind of digital platform, if any, that forms an essential part of the BM (IoT/ merchant only/ innovation only/ merchant and innovation).	[242]
	Value exchange	It refers to the transfer of tangible or intangible values from one actor to another and how the value flow between the functions and actors to enable value co-creation within the strategic business net.	[22], [11]

Furthermore, in addition to the selected elements that form part of the *value network dimension* of the networked BM, a few other concepts also specifically stood out within the identified primary literature studies. Therefore, it was decided to classify these concepts as *strategic business net features*, which need specific attention during the design and development of the strategic business net. These features specifically refer to the formation and functioning of VNs. A ‘network organisations view’, implying network organisations consist of negotiated roles and goals which can indeed be partially managed to be efficient [154] (discussed in Section 3.5.2) was taken to select these elements. Furthermore, the idea of ‘network features’ is in line with the study conducted by Nekoo *et al.* [160] (discussed in Section 3.3.5). Figure 4.7 demonstrates these features and Table 4.3 provides a brief description of each feature.

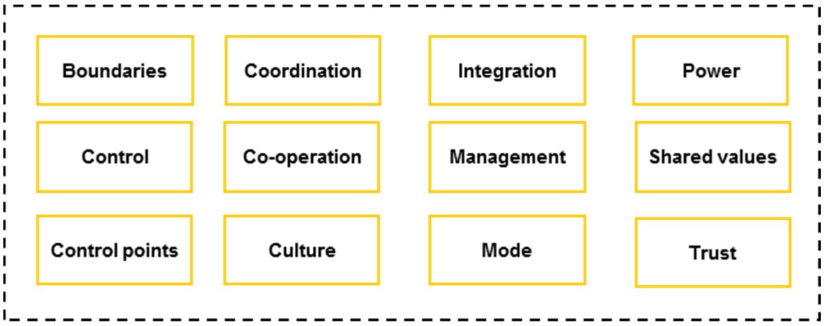


Figure 4.7: Selected strategic business net features

Table 4.3: Selected strategic business net features descriptions

Strategic business net feature	Description	Reference(s)
Boundaries	It refers to which actors are included to participate in the strategic business net as partners, which actors are only classified as potential stakeholders of the strategic business net and which actors are excluded.	[254]
Control	It refers to the power of one or more actors to influence or direct other actor's behaviour or the execution of functions or activities within the strategic business net.	[7]
Control points	It refers to areas in the strategic business net where power and control can be applied - functional and strategic (the more control points an actor have, the more important are they in the network).	[7]
Coordination	It refers to the organisation of the different actors and their roles, functions, capabilities, and resources within the strategic business net to enable collaboration and value co-creation.	[177], [160]
Co-operation	It refers to the process of working with other actors towards the same goal.	[144], [160], [114], [59]
Culture	Organisational culture refers to the cumulative deposit of knowledge, experience, beliefs, values. The cultures of the respective actors’ need to be aligned and adaptable to ensure successful network operation.	[152], [205]
Integration	It refers to the integration of the functions, capabilities, and resources of different network actors to deliver the joint offering and to reach the network’s goal or objective. It also includes the integration of findings/ outcomes on the network-level into existing firm-level processes and structures.	[152], [223], [76]
Management	It refers to the process of dealing with or controlling functions, activities, and actors within the strategic business net.	[155]
Mode	It refers to the way in which the network is established and expanded (open/ close).	[5]
Power	Power dependence denotes the influencing forces where one actor can partially control and influence another actor, as the other actor needs those resources or competences held by the first actor.	[250]
Shared values	Shared values (tacit or explicit) provide a common ground or understanding among different actors.	[136], [32]
Trust	It refers to the firm belief in the reliability, truth, or ability of strategic business net actors to fulfil their roles and to successfully perform their functions and activities.	[154], [22] [104]

4.3 Part B: Networked BMI hierarchical taxonomy

Based on the proposed concept map illustrated in Section 4.2, it can be concluded that the networked BMI concept is still fuzzy and vague; therefore, this section aims to provide a proposed framework of its constituent facets, completing *Part B* of the development process, as well as answering the sub-research question: *What is a possible hierarchical taxonomy for the networked BMI concept? (SRQ3).*

The theoretical concept map, therefore, guided the development of the conceptual diagram of a hierarchical taxonomy of the networked BMI concept. The aim of the taxonomy was to model, structure and represent the knowledge gained through the integration of the key findings from the relevant literature bodies to provide a better holistic understanding of the concept under investigation and to guide the development of further approaches to the concept.

The taxonomy was furthermore used to set the boundaries and objectives (a set of requirements) for the conceptual framework presented in Section 4.6. The proposed taxonomy intended to integrate the selected definitions, conceptualisations, and elements from the respective theoretical frameworks into a unified and comprehensive framework. The proposed unified BM concept framework from Al-Debei and Avison [6] was used as the initial foundation (discussed in Section 3.3.3), whereafter the researcher enriched the concept map by adding new facets (one side or aspect of something) and classes (characteristics or components of a particular object or in this case a facet) with a suitable hierarchical structure and appropriate relationships. The facets and classes were selected based on the most important concepts presented in the concept map (Section 4.2). These concepts were selected to enable the best, holistic overview of the literature findings presented in Chapter 3 on what networked BMI, as a combination of the BM, BMI and VN, entail. Consequently, the hierarchical taxonomy of the networked BMI concepts consists of nine fundamental facets with related classes which aim to integrate the three primary literature bodies, see Figure 4.8 below.

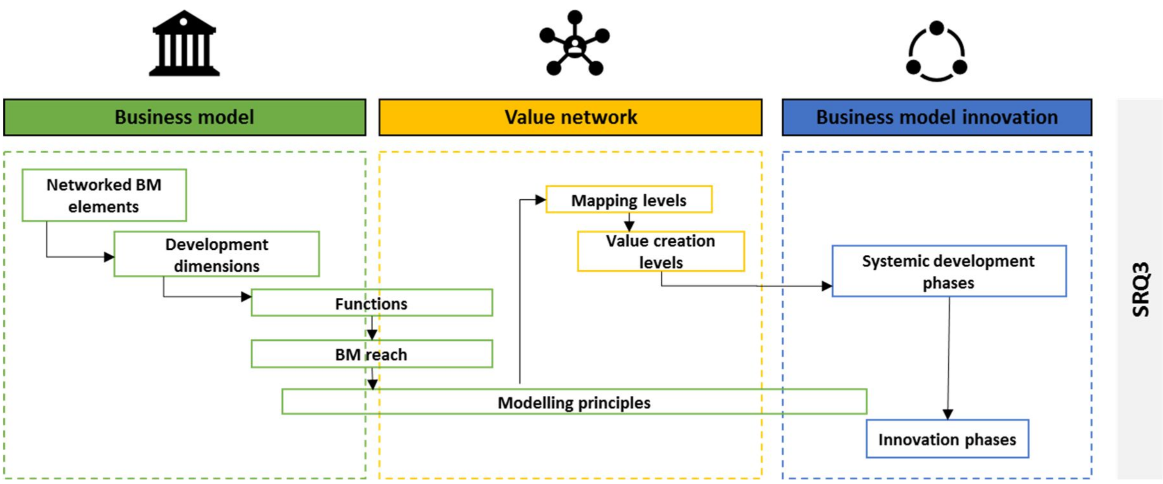


Figure 4.8: The concept taxonomy's facets structured according to the literature bodies (SRQ3)

The first facet, ***Networked BM elements***, identifies the primary four BM dimensions along with their constituent elements, based on the V4 BM structure from Al-Debei and Fitzgerald [7] (discussed in Section 3.3.3). This facet was also included in the BM hierarchical taxonomy presented by Al-Debei and Avison [6] (discussed in Section 3.3.3). The constituent *networked BM elements* were however extended by the researcher using some of the concepts in the concept map, as explained in the previous section (Figure 4.6), to form a more complete structure of the networked BM concept. These elements in each sub-dimension complement each other.

The ***Development dimensions*** facet enables the structured achievement and development of the networked BMI concept through two dimensions, the strategic business net development (originally proposed as business net development) and business opportunity development, as suggested by Palo and Tähtinen [177] (discussed in Section 3.3.5). The third facet, ***Functions,*** explains the functions of the networked BMI concept with a focus on the network perspective and what the networked BM aims to achieve. The functions furthermore provide an explanation of the practical significance of the networked BMI concept in the context of developing and configuring a strategic business net and networked BM. The selected functions furthermore enable the networked BM (first facet) to act as a tool to support strategy execution [42].

The networked ***BM reach*** facet describes the boundaries of the concept, i.e. inter-organisational (extended across a single firm's boundaries to all actors within the network) and on the intermediate layer, therefore being the conceptual link between the network's overall strategy and the firm-level BMs and business processes of the individual actors [6, 173]. The fifth facet is **M*odelling principles***, which is guidelines and features, that cohesively organises the networked BMI concept into an understandable and executable framework, primarily based on the BM hierarchical taxonomy from Al-Debei and Avison [6] (discussed in Section 3.3.3) with some added features which were prominent in the selected literature body.

The next facet explores the different ***Mapping levels*** which are possible within the identified concept, although these mapping levels are on different abstraction levels, they are closely related and depend on one another within the operations of the strategic business net. The first two mapping levels (actors and functions) are based on the ARA model (activities were changed to functions) proposed by Håkansson and Snehota [96] (discussed in Section 3.5.3) with an extra level of capability added to the model, proposed by Biem and Caswell [22] (discussed in Section 3.5.3). The seventh facet concerns the different ***Value creation levels*** as suggested by the synthesised value meta-model from Leviäkangas and Öörni [134] (discussed in Section 3.4.1) which are also in line with the three views on BMs (single-firm view, dyadic-level view, and network-oriented view) proposed by Bankvall *et al.* [20] and presented by Jocevski *et al.* [111] (discussed in Section 3.3.5).

The last two facets specifically relate to the 'innovative' part of the concept. The ***Systemic development phases*** facet is needed as organisations need to transform from one orientation or state to another by means of the dynamic capabilities-based approach as suggested by Teece [219] and Pieroni *et al.* [184] (discussed in Section 3.4.3). The last facet employs the notion of time as the ***Innovation phases*** facet, in line with Palo and Tähtinen [177] (discussed in Section 3.3.5), which were slightly adapted to the research and development phase, the pilot and market phases. This enables the view of the networked BMI concept as a dynamic device in planning an emerging business in a net of actors [177]. Figure 4.9 on the following page provide a summary of the primary theoretical frameworks (identified and discussed in Chapter 3) used to inform each of the classes included in the different facets.

Furthermore, Figure 4.10 below visually depicts the preliminary hierarchical taxonomy of the networked BMI concept, followed by a description of each class with the associated references in Table 4.4.

Figure 4.9: Summary of the theoretical frameworks used in the hierarchical taxonomy

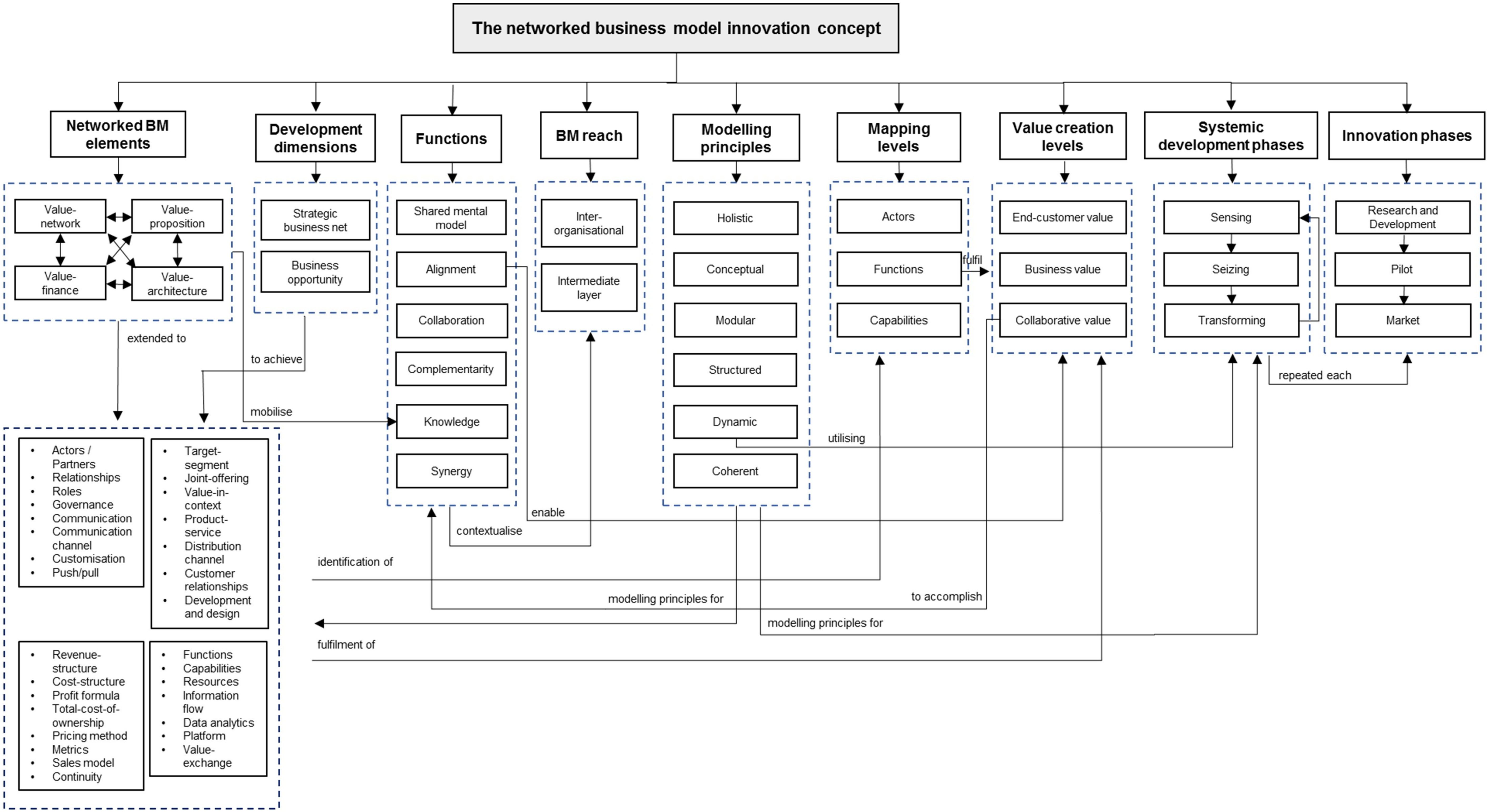


Figure 4.10: Preliminary networked BMI hierarchical taxonomy

Table 4.4: A preliminary hierarchical taxonomy of the networked BMI concept

Facet	Class	Brief description	References
Networked BM elements	(1) Value proposition	A way that demonstrates the business logic of the network in creating value for the end-customer, for each network actor involved, and for the strategic business net in the production and delivering of a joint offering, including an overall synergistic view of the actors' bundle of products, services, and knowledge, to satisfy the needs of their target segments.	[7], [6], [136], [134]
	(2) Value network	A way in which the entrepreneurial actor (or value net integrator) enables value exchanges through coordination and collaboration among the network actors and the customer. It also includes the design, configuration and functioning of the network in the wider business ecosystem.	[7], [6]
	(3) Value architecture	A way that describes the synergistic arrangements of activities and resources that form the architecture of the network, including its technological architecture, organisational infrastructure, value configuration and value exchanges, that enable value co-creation in the provisioning of end-to-end solutions.	[7], [6], [136]
	(4) Value finance	A way in which the network manages the value capture logic related to costing, pricing, and revenue breakdown between strategic business net actors to sustain and improve its creation of revenue. It also includes key metrics to evaluate the network and partners' performance.	[7], [6]
Development dimensions	(5) Strategic business net	A VN that is intentionally formed with a finite set of actors (including the customer) with dedicated roles that aim to gain a competitive advantage through the integration of complementary, but dissimilar, resources and capabilities that can be combined and aggregated to co-create value and to ultimately deliver an innovative joint offering to the end-customer.	[177], [129], [62]
	(6) Business opportunity	A way in which a business opportunity is identified and developed, which can be explained through the value proposition of the joint offering or solution provided by the network of actors.	[177], [129]
Functions	(7) Shared mental model	A way to facilitate the creation of a strategic vision shared by all the strategic business net actors regarding what the network aims to achieve.	[160]
	(8) Alignment	A conceptual way to facilitate alignment to ensure configurational fit between elements, values, and objectives internally and externally through the use of dynamic capabilities. The aim is to fil the gaps between the BM of the strategic business net and the BMs of the network actors.	[6], [85]
	(9) Collaboration	A way to establish inter-organisational collaboration (a process in which entities share information, resources, and responsibilities to jointly achieve a common goal), between all strategic business net actors to enable value co-creation functions and the successful delivery of the joint offering.	[85], [40]
	(10) Complementarity	A way to ensure the strategic business net actor's resources and capabilities are complementarity to each other to enable the co-creation and development of a joint offering. It also includes ensuring the value contributions and offerings of partners are complementary to each other.	[136], [191]
	(11) Knowledge	An intangible and tactical information/ knowledge asset useful in portraying the underlying business logic of the strategic business net and supporting strategic decision-	[113], [6]

Facet	Class	Brief description	References
		making functions, and thus valuable in providing the strategic business net with an enduring competitive advantage.	
	(12) Synergy	A way value and benefits are created together by the network of actors which are greater than the value that can be created by each actor individually (revenue synergies/ cost synergies).	[7], [136]
BM reach	(13) Inter-organisational	The focus is on the interrelationship with all network actors to ensure they have shared values in the co-creation of value for the end-customer.	[111], [184]
	(14) Intermediate layer	An interface or a theoretical intermediate layer between the network (or business) strategy and the business processes performed by each individual actor.	[6], [170], [233]
Modelling principles	(15) Holistic	A holistic (but not exhaustive) way to develop a feasible BM and configure a strategic business net to adequately address the business opportunity by considering internal as well as external factors.	[246], [254], [245]
	(16) Conceptual	A conceptual tool, an abstraction, and a blueprint of the existing business and VN and/or the future planned business and strategic business net.	[6]
	(17) Modular	A modular (or granular) controllable way of designing and evaluating business as the concept is subdivided into manageable elements.	[6]
	(18) Structured	A semi-structured and organised flow of activities (or steps) that need to be matched with specific requirements of the respective BMI initiative, to design and develop the constituent elements.	[245]
	(19) Dynamic	A dynamic concept as BMI is regarded as a dynamic process. Furthermore, the BM and strategic business net configurations and design change over time reflecting adjustments made according to the internal and external environments.	[6], [176], [75]
	(20) Coherent	A coherent way of depicting the logic and operations of a particular strategic business net while entirely taking into consideration the interlinks between its different aspects. This includes the interlinks between aspects within the networked BM, as well as the interlinks between firm-level aspects.	[6]
Mapping levels	(21) Actors	A way to identify the required actors needed to partake in the strategic business net and to analyse their connections (actor bonds), value exchanges and contributions in achieving the value proposition.	[96], [22]
	(22) Functions	A way to identify the required functions (main functions and sub-functions) and how they are connected to each other (links), performed by the various selected actors to deliver the solution or joint offering in addressing the joint offering.	[96]
	(23) Capabilities	A way to identify the required capabilities that actors need to have to perform the identified functions required to deliver the joint offering.	[22]
Value creation levels	(24) End-customer value	A way to address customer needs by creating value, monetary and non-monetary, for the end-user, which is strongly related to the value proposition.	[134]
	(25) Business value	A way to create value for and help individual actors to maximise their own value through the participation in the strategic business net, thus helping them build value for their	[134]

Facet	Class	Brief description	References
		own stakeholders by enhancing the revenue flows, the controlling of costs, or both.	
	(26) Collaborative value	A way to create value for the strategic business net through collaboration, and simultaneously improve the actor's business value. Short-term returns may decrease but long-term returns may increase through proper strategic business net positioning.	[134]
Systemic development phases	(27) Sensing	A way in which threats and opportunities are identified based on internal and external analyses (business, technology, ecosystem, market, customer) and the translation into possible business opportunities ideas and strategies (including the need for a strategic business net and networked BM).	[219], [184], [236]
	(28) Seizing	A way in which relevant business opportunities can be operationalised through the systematic development (feasibility and prototyping) of the networked BM, strategic business net elements and possible joint offerings enabled by emerging technologies	[219], [184]
	(29) Transforming	A way in which selected business opportunities are pursued through adequate decision-making and implementation of the decisions to build new competencies and to implement organisational renewal throughout the strategic business net, as well as the continuous development to ensure sustainability of the networked BM and strategic business net.	[219], [184]
Innovation phases	(30) Research and Development	A way to consider the innovation phase where the emerging technology, service, and product is developed.	[177]
	(31) Pilot	A way to consider the innovation phase where the emerging technology, service, and product is introduced and tested in the market.	[177]
	(32) Market	A way to consider the innovation phase where the emerging technology, service, and product is ready for commercial use in emerging markets.	[177]

4.4 Part C: Concept map of theory

The next step in the systematic development approach, P*art C*, was to design a visual illustration of the networked BMI concept, theoretically described in Section 4.3. Due to the dynamic nature of the concept under investigation, abstraction was used to enable the researcher to ignore some of the details (illustrated in the concept map) and focus on understanding the system at a higher level by keeping only the most important parts. This aimed to answer the following sub-research question: *What is a possible concept map of theory to visually illustrate the networked BMI concept? (SRQ4).*

A conceptual framework *"explains, either graphically or in narrative form, the main things to be studied—the key factors, variables, or constructs—and the presumed relationships among them"* [162]. Conceptual frameworks are the researcher's map of what is being investigated [162]. The framework forces the researcher to be selective and ideally improves and becomes more differentiated and integrated as the study progresses and the researcher's knowledge deepens [150]. It is something that is constructed from ideas that are borrowed from elsewhere [146]. Nevertheless, the structure and overall coherence are built through understanding current phenomena and not something that readily exists. Using this description of a conceptual framework, the concept map of theory can be classified as a graphical conceptual framework as it aims to build and illustrate the networked BMI process that is being studied.

Therefore, the purpose of the concept map of theory was to integrate and synthesise the aspects from the selected theoretical frameworks (identified in the hierarchical taxonomy) into a visual holistic framework. Another purpose was to help the researcher come up with a visual illustration of what is being studied and how the concepts are integrated to enable a brief overview explanation in a more practical manner to a potential user before the use of the management framework or management tool. The selected theoretical frameworks from which concepts and elements were 'borrowed' from to construct the concept map of theory, are illustrated in Figure 4.11.

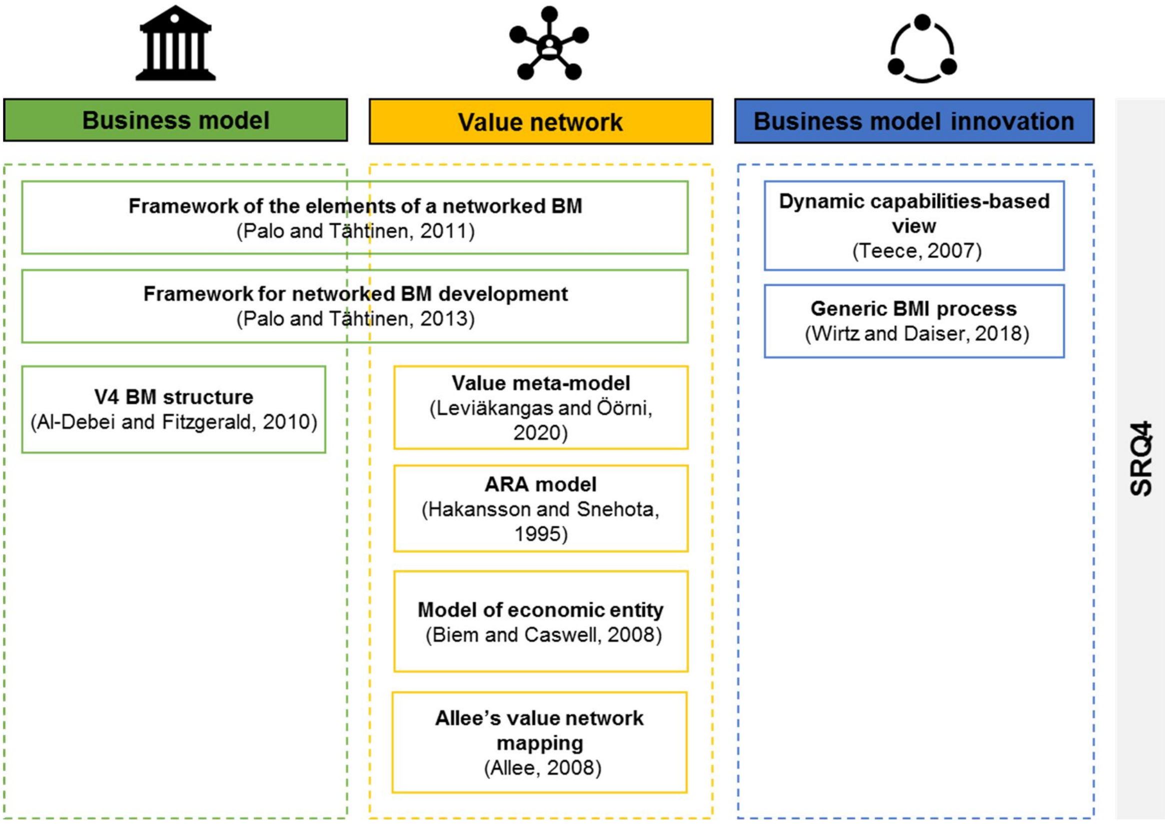


Figure 4.11: Theoretical frameworks used in the concept map of theory (SRQ4)

As stated before, BMs and technological innovations are fundamentally linked [18], creating strong complementarities between these concepts. It is commonly known that often there exists a design-implementation gap during the innovation process (concerning both BMs and technological innovations). Pieroni *et al.* [184] noted that it can happen during different phases because ideas are not followed up, concepts are not implemented or because new BMs may fail in the market. To address this design-implementation gap, organisations need to start the design and development of their networked BM and their strategic business net (intentionally formed VN) as early as in the R&D phase of the technology, to ensure adequate upstream and downstream feedback to the relevant partners or stakeholders. This argument is aligned with the framework of Palo and Tähtinen [177], suggesting networked BM development needs to start during the service development phase, even if that 'construction' is then limited to the actors having a mental picture of it.

Marchese and Sniderman [141] also confirmed this argument within the AM context, by stating that *"AM must be brought into the office to enable complete alignment of the enabling elements* *and value proposition".* Therefore, the networked BMI process needs to be aligned with the technology innovation phases to ensure all concepts are well defined, thought through and adequately addressed to ensure success once the market phase is entered. This will enable timely and accurate feedback leading to proactive actions from all network partners.

The networked BM framework proposed by Palo and Tähtinen [177] is on a high level of abstraction, recognising the three phases of technology and service development as the past state, the pilot phase as the present state and the market phase as the future state. In line with this argument and acknowledging the different stages of the development of emerging technologies, this framework presents the R&D phase as the present and the pilot and market phases as the future. During these three phases, the aspects of the BMI endeavour evolves, instead of merely being the end result of the development [177].

Furthermore, when trying to understand the interactions and links between technology innovation and BMI, it is important to take note of the (nine) technology readiness levels which can be used to estimate the maturity of technologies. Since it is not the focus of this study, it will not be discussed in detail. In the context of this study, it is just important to understand that an emerging technology first needs to reach a certain level of maturity where the technology's applicability can be demonstrated before a potential BM can be developed. Therefore, it is suggested that as soon as a technology reach a certain level of maturity in the R&D phase, the BMI process is initiated. (This entire topic is addressed by another study conducted within the research group, see Burger, Grobbelaar and Sacks [37]).

To align the three phases of technology and service development (categorised within the *Innovation phases* facet in the hierarchical taxonomy) as suggested by Palo and Tähtinen [177], with the networked BMI process, the following relationships are proposed, see Figure 4.12 below. During the R&D phase of the technology, the primary focus is on the sensing phase, consisting of the analysis and ideation sub-phases. During the pilot phase, the focus is on the seizing phase (consisting of the feasibility and prototyping sub-phases) and before the market phase is fully entered, the focus is on the transforming phase (consisting of the decision-making, implementation, and sustainability sub-phases). The simultaneous development process is still an iterative process consisting of various feedback loops to ensure real-life success once introduced into the market.

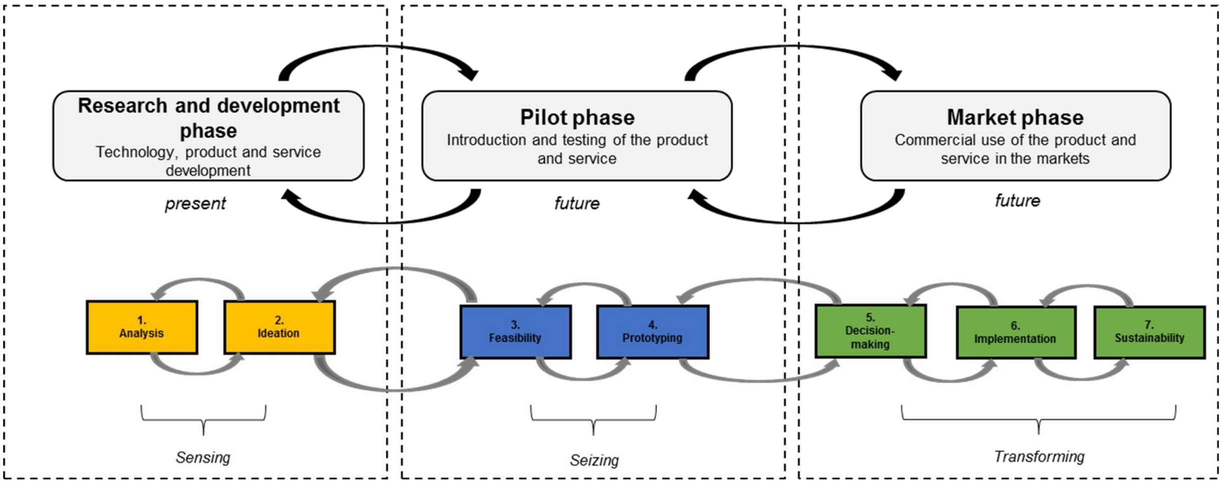


Figure 4.12: Innovation phases and the networked BMI development phases

Reflecting on the context of the current study, the AM technology and related products and services under investigation is still currently in the R&D phase, but application potential has already been demonstrated [175] (reaching an adequate technology readiness level).

Therefore, it can be concluded that the BMI process can be initiated, and stakeholders or role-players already need to start thinking and addressing the necessary business concepts that will result in successful market offerings.

The concept map of theory is illustrated in Figure 4.13 below. It consists of the three systemic development phases namely sensing, seizing and transforming (or reconfiguring) [184, 219], which need to be aligned with each of the innovation development phases [177] as described above with constant feedback and applicable adjustments (not explicitly included as elements in the concept map of theory). Each of these dynamic capability phases is divided into sub-phases from the Generic BMI Process proposed by Wirtz and Daiser [245] (discussed in Section 3.4.3) to make the process more structured and tangible. Thus, the sensing phase consists of analysis and ideation; the seizing phase consists of feasibility and prototyping; and the transforming phase consists of decision-making, implementation, and sustainability.

The networked BM development consists of two development dimensions as proposed by Palo and Tähtinen [177], namely strategic business net development (adapted from strategic net development) which refers to the development of the configuration of the strategic business net on a strategic (value network) and tactical (value architecture) level, and the business opportunity development dimension that refers to the identification and development of possible opportunities to be addressed by the strategic business net and networked BM. Furthermore, there are constant interactions and feedback between the activities and outcomes of each of the dimensions to ensure alignment and successful development.

Possible business opportunities can be identified through analysis and understanding of the external environment. Different types of innovation have a direct impact on the environment and cause different trends and constant changes. The continuous development and improvement of technology is a main driver of innovation, and in the context of this study, enable the introduction of a product-service-system (an integrated combination or bundling of products and services). Furthermore, it is important that any business opportunity identified based on the analysis of the external environment (or based on internal analysis) must be aligned with customer needs.

To realise the business opportunity, a networked BM must be developed that consist of four high-level value dimensions [7] namely, the value network, value proposition, value architecture and value finance with the identified elements selected and illustrated in Section 4.2. Furthermore, because the BM acts as an intermediary between the strategy and business processes, there must be alignment between the networked BM and the strategy of both the strategic network, as well as the strategies and business processes of the individual network actors.

The business opportunity can however not be pursued and delivered by the focal (or entrepreneurial) actor alone, but a collaborative effort from various actors or partners is needed. Therefore, a strategic business net is required which is intentionally formed. Within this strategic business net, the entrepreneur actor(s) can act as facilitators within the network, as they identify and create business opportunities [177]. The design and configuration of the strategic net need to be mapped on the strategic level (associated with the value network dimension) using the three identified mapping levels (actors, functions, and capabilities) [12, 22]. Actors fulfil specific roles in the strategic business net and therefore there is constant interaction between actors and roles. Functions are used on a higher abstraction level but consist of various activities; and then lastly capabilities that actors must have to fulfil the functions, are associated with tangible and intangible resources.

To better enable the visualisation and understanding of how value is co-created between the focal (entrepreneurial) actor, the customer and other network actors, a lower (tactical) level of visualisation is needed. This visualisation effort is associated with the value architecture dimension and refer to the mapping of the different tangible and intangible values that are exchanged between the network actors to fulfil each function. Tangible values include products, materials, natural resources, and money. Intangible values include knowledge, information, services, skills, and competencies. The successful development and implementation of a networked BM, as well as a strategic business net, will enable the production of an end-to-end solution. The end-to-end solution forms part of the joint offering provided by the strategic business net and include offerings such as flexibility, quality, and accessibility in addition to the product and service. Visualising and mapping the strategic business net on the strategic (value network) level as well as the tactical (value architecture) level, together forms the strategic business net. In Section 4.5 a development process is proposed to help users perform this mapping.

The functions fulfilled by the actors to create the joint offering and the value exchanges between the different actors must create value, otherwise, it is nullified. Therefore, the perceived value must be evaluated. The value perceived can be located in different levels for different actors namely business value (for an individual actor), collaborative value (for the network) and end-customer value (for the customer) [134]. Value conversion is only completed when the value offered by any role on any level is accepted or validated by another role in the VN [12], therefore the importance to evaluate the perceived value at the end to ensure value conversion was successful.

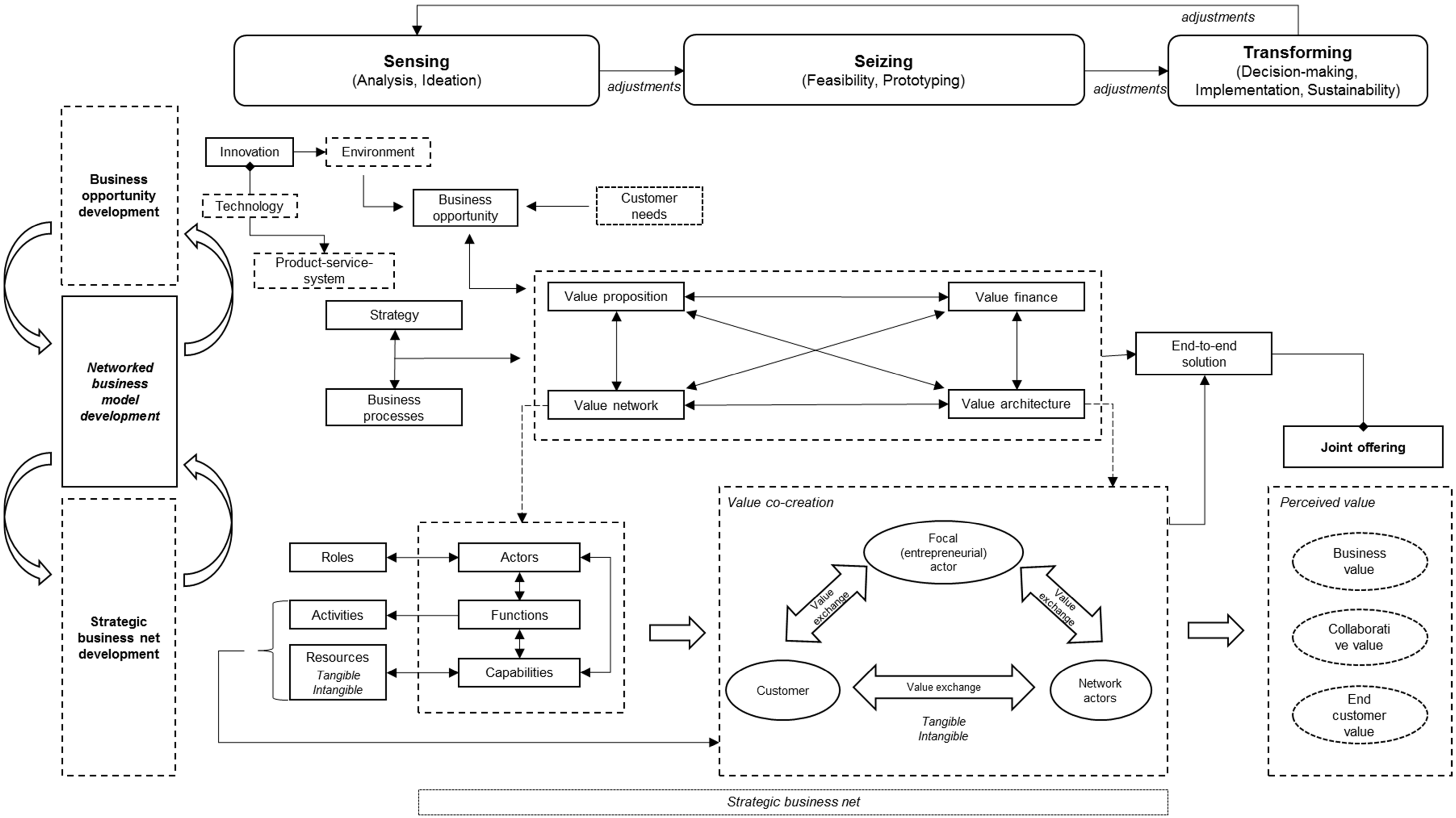


Figure 4.13: Preliminary concept map of theory

The concept map of theory aimed to visually present the facets proposed in the hierarchical taxonomy developed in Section 4.3. Most of the facets were explicitly addressed and illustrated (see Figure 4.14), except for the ninth facet, *Innovation phases*, which were explained previously. Furthermore, the specific *Function* classes could also not be clearly illustrated in the concept map of theory but are rather seen as guidance on what the successful implementation of the other facets will ultimately achieve (addressed in the management framework). All *Modelling principles* identified in the taxonomy, were followed on an abstract level in the presented framework. The principles were addressed in the following manner:

- **Holistic:** The internal (strategy and business processes) as well as the external environment are acknowledged.
- **Conceptual:** Only the main concepts from the initial research artefacts are included.
- **Modular:** Each concept exists as a module, forming part of the bigger picture.
- **Structured:** A structured process is proposed with development phases, dimensions, and concepts.
- **Dynamic:** The use of different phases, sub-phases, and feedback loops illustrate it is a dynamic process.
- **Coherent:** The included concepts form a coherent and logical understanding of what the networked BMI concept entails, as described above.

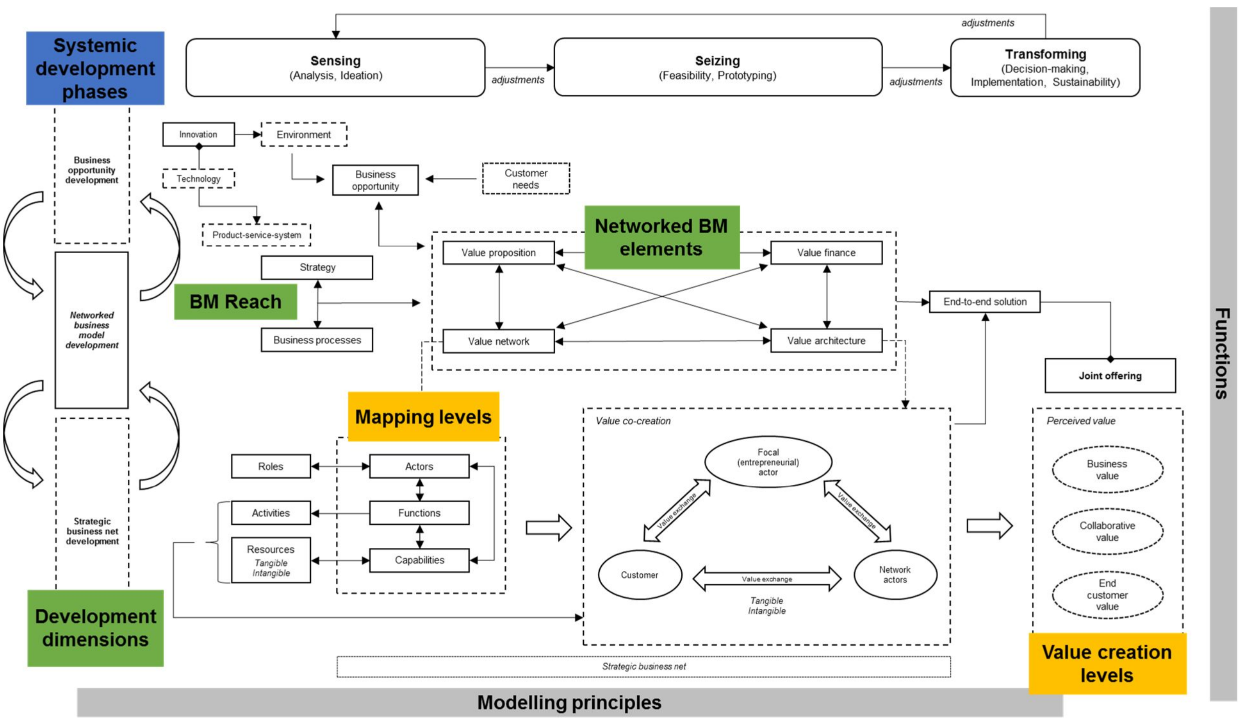


Figure 4.14: Identified facets incorporated into the concept map of theory

As described earlier, during the development of the concept map of theory, various ideas were 'borrowed' from existing theoretical frameworks, identified in Chapter 3. Figure 4.15 illustrates the different theoretical frameworks from the BM, BMI, and VN literature bodies, and which concepts or ideas were borrowed and integrated within the concept map of theory. To illustrate where and how each theoretical framework was used, see Figure 4.16.

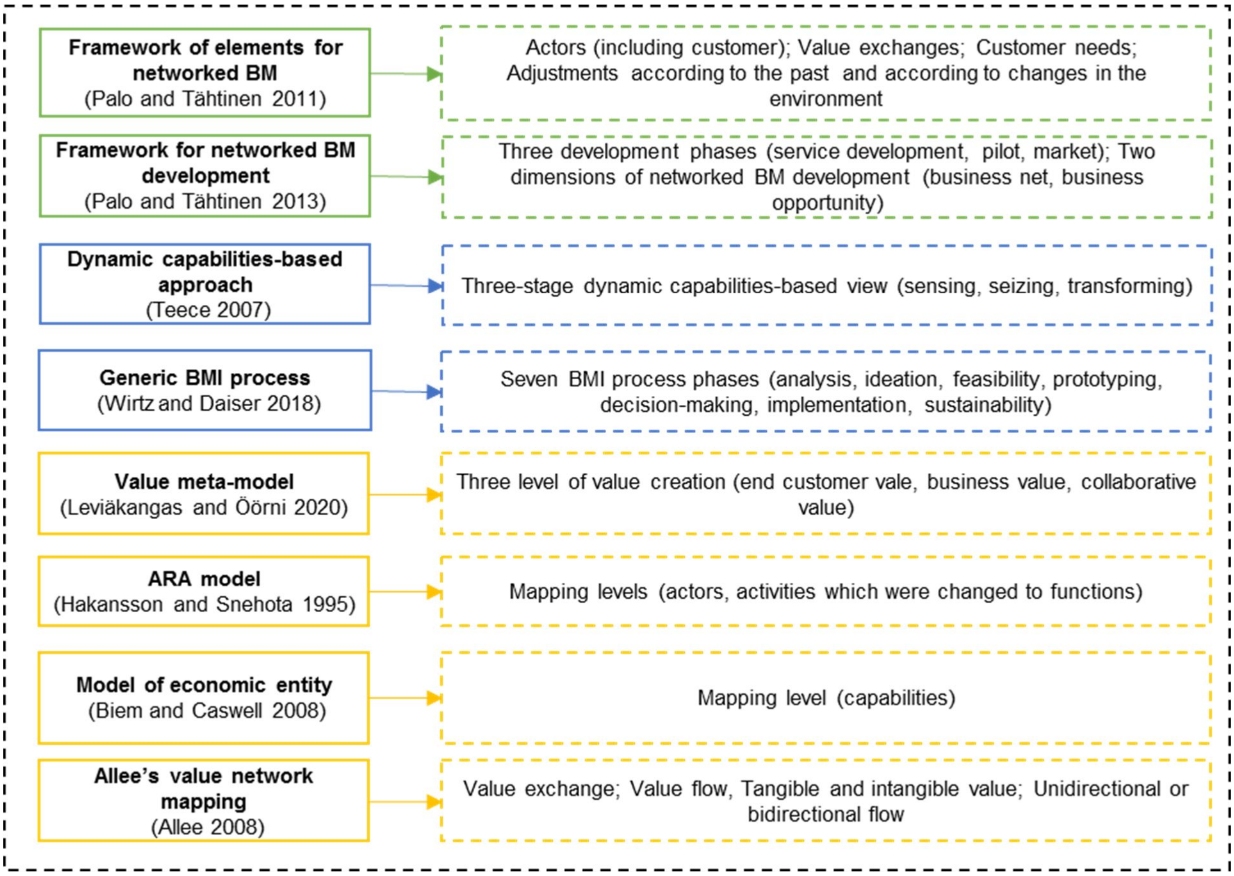


Figure 4.15: Theoretical frameworks used to inform the concept map of theory

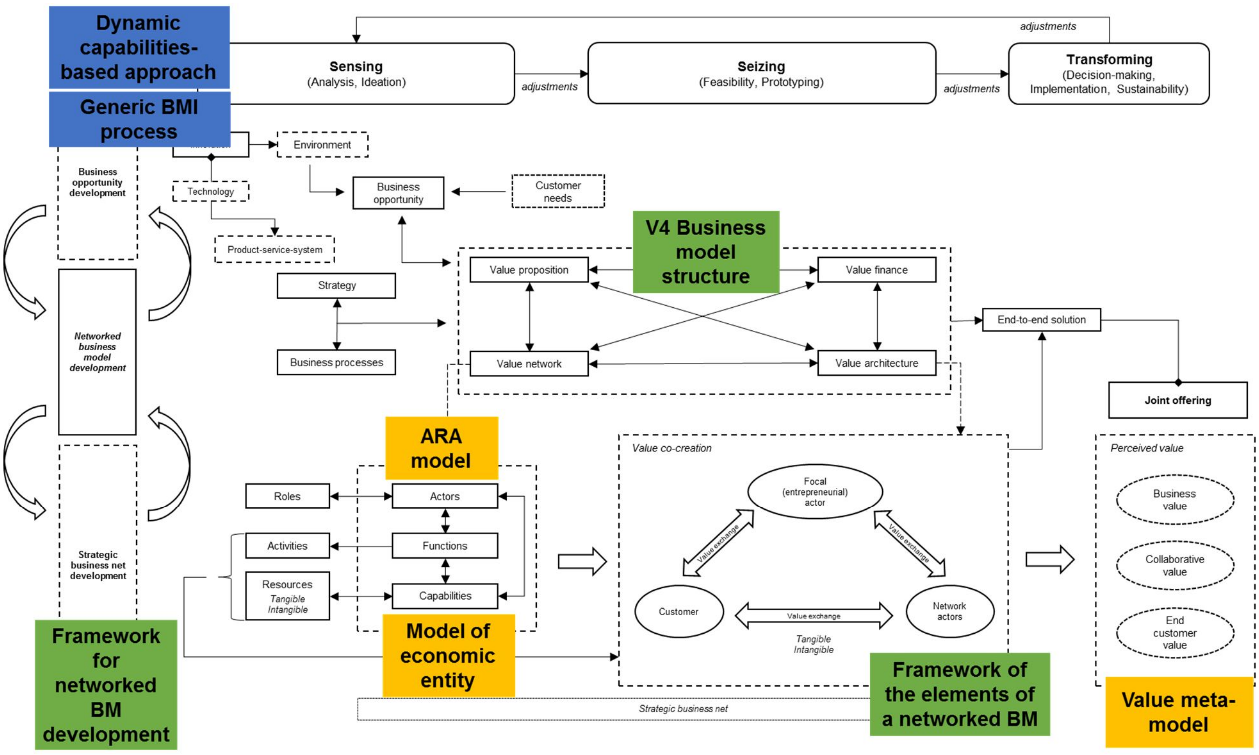


Figure 4.16: Theoretical frameworks incorporated into the concept map of theory

4.5 Part D-1: Strategic business net configuration process

Part D, illustrated in Figure 4.1, consists of two sections. The first section is describing the development approach of the SBN configuration process that plays an integral part in the conceptual framework, developed in section two, as well as the management framework developed in Chapter 6.

As explained above, it is proposed that the strategic business net need to be mapped on the strategic level (value network) as well as on the tactical level (value architecture), to enable the visualisation of the configuration of the net as well as the value co-creation (Figure 4.17). This visualisation and mapping are therefore of utmost importance as it forms an integral part of the networked BMI concept under investigation.

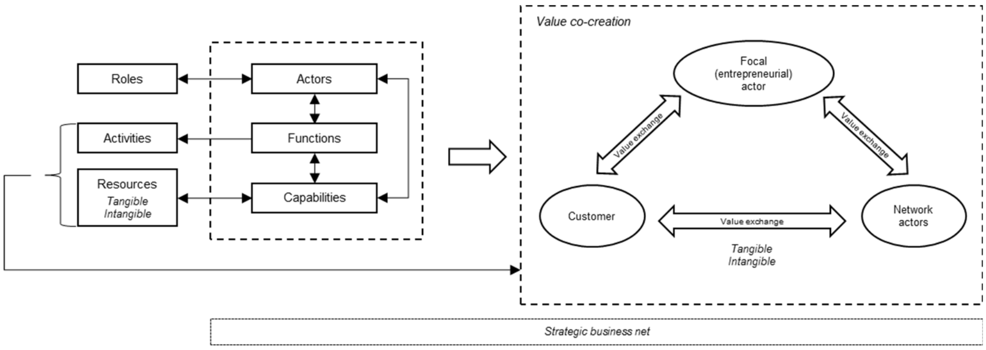


Figure 4.17: Snippet of concept map of theory

The VN literature body contains various methodologies or frameworks to analyse, design and develop VNs as identified in Section 3.5.3. However, these methodologies or frameworks are highly aggregated or too detailed which can lead to confusion and uncertainty during network development or analysis. Furthermore, none of these methodologies or frameworks provides a comprehensive approach to develop a VN from a strategic and tactical perspective. Therefore, a gap in the literature was identified for a process (including visual maps) to develop the strategic business net in a structured, logical, and self-explanatory way to enable the visualisation of value co-creation. Figure 4.18 below provides a brief overview of which aspects from the existing theories and frameworks (discussed in Section 3.5.3) were used, together with the researcher's intuition and understanding, to propose the new process. The following section describes the logical approach taken to design and develop the process.

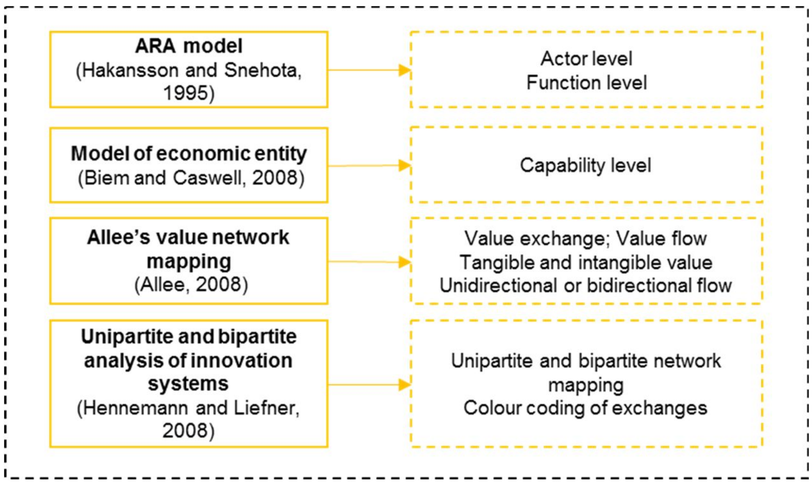


Figure 4.18: Theoretical frameworks used in the SBN configuration process

4.5.1 Development approach

Although it is acknowledged that VNs are complex and not structured in a linear manner, some network mappings may be confusing as it is difficult to determine where to start 'reading' the map. Therefore, to ensure easy visualisation and structured analysis of prototype scenarios of the strategic business net, a linear structure is proposed. To address the need for a more aggregated level of development from a strategic perspective (in addition to the tactical perspective/ level), as well as the need to distinguish between the different tangible and intangible flows that can happen between actors, the combination of Allee's VN model [12] and the unipartite and bipartite network analysis approach from Hennemann and Liefner [101] which was built on graph theory, were used.

Applying the same logic as Hennemann and Liefner [101], one can argue that any system can be divided into activities, transactions, or functions (representing the top-nodes), and different actors or roles (bottom nodes) are involved in the execution of the different functions. Figure 4.19 illustrates the unipartite strategic VN model, which also addresses two mapping levels from the ARA model [96], namely the activity and actor levels. Although the ARA model is often used as a reference framework, there is no guidance regarding the practical application of the different mapping levels.

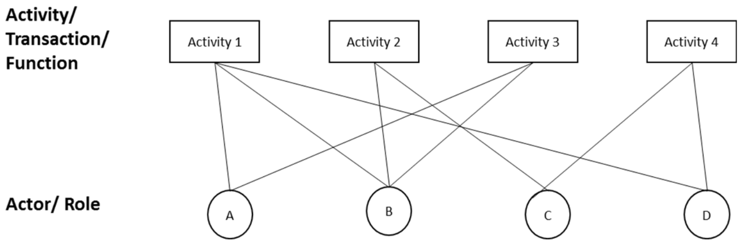


Figure 4.19: Unipartite VN modelling: activity-actor

As a next step, the missing mapping level from the ARA model [96], namely resources, was added to the model. This level is associated with the resources needed to execute each activity, transaction, or function, see Figure 4.20.

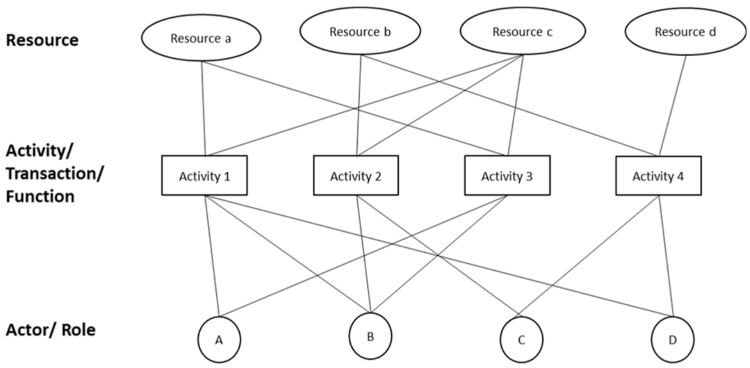


Figure 4.20: Unipartite value network modelling: activity-resource-actor

The hierarchical taxonomy of the networked BMI concept (Section 4.3), also included the capability level, proposed by Biem and Caswell [22]. Therefore, the level was also added, see Figure 4.21. However, having four mapping levels turned out to be too many as it may result in confusion and too much detail from a strategic perspective.

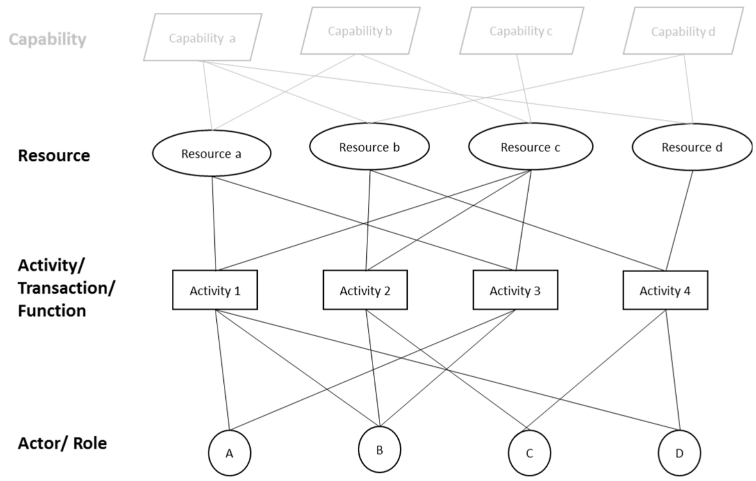


Figure 4.21: Unipartite value network modelling: activity-resource-actor-capability

When developing a new VN, it is easier to identify the required capabilities for each activity or function, before considering the resources required on the company level. Therefore, to ensure simplicity, it was decided to keep only three mapping levels, namely activities (or functions), actors (or roles), and capabilities, see Figure 4.22. Furthermore, the mapping levels were switched around since it is more logical to first see the actors or roles, followed by the functions or activities. This concludes the development of the strategic view of the strategic business net, also referred to as the 'value network' map.

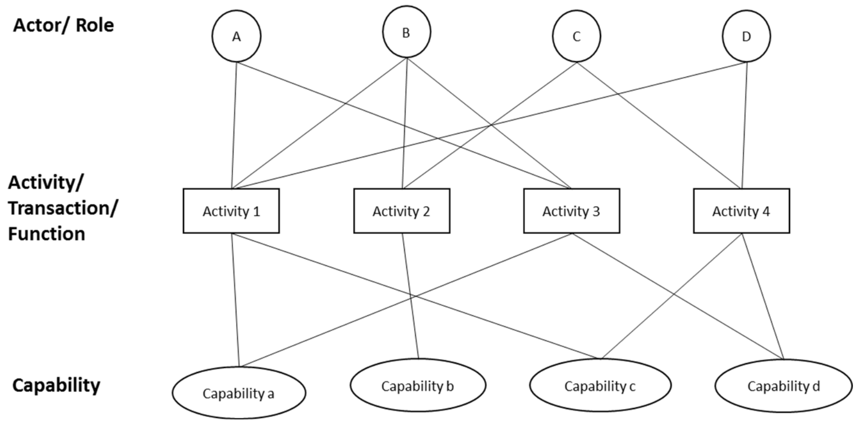


Figure 4.22: Unipartite value network modelling: actor-activity-capability

For the 'value architecture' map, which refers to the tactical view of the strategic business net, the proposed tangible, and intangible flows from Allee's model [12] were used as the theoretical foundation, see Figure 4.23.

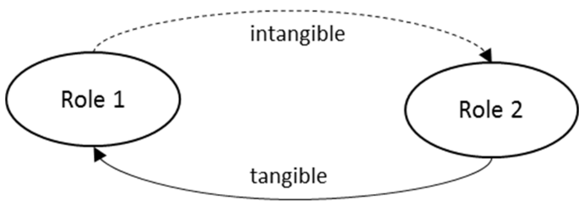


Figure 4.23: Value network mapping [12]

However, this model lacks the ability to easily distinguish between the types of intangible flows or the types of tangible flows. Hennemann and Liefner [101] used different colours to distinguish between the involvement of different actors in the different innovation phases. This logic can however be used (although not directly linked to their argument) to distinguish between the different tangible and intangible flows that can happen in the VN, addressing the lack in the method proposed by Allee [12].

Furthermore, the network map from Allee [12] lacks the ability to clearly distinguish which actors or roles are involved in each transaction, activity, or function as the method combines the flow of transactions with deliverables. Therefore, developing and analysing each activity, function or transaction individually is proposed, distinguishing between the different types of tangible and intangible flows, see Figure 4.24. This enables individual activity, transaction or functional analysis on a lower level and enable the value exchanges to be mapped, as proposed by Allee [12].

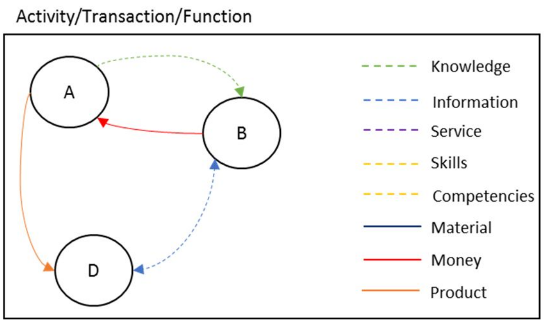


Figure 4.24: Value flows per activity/transaction/function

To enable the visualisation of value flow and exchange between the different activities, transactions, or activities, principles from the bipartite VN analysis from Hennemann and Liefner [101] were used, see Figure 4.25. Therefore, adding value flow and exchange that occur between the different activities, to specific actors (emphasising the interconnectedness and interdependence of the activities and actors within the strategic business net). This concludes the tactical view of the strategic business net, also referred to as the 'value architecture' map.

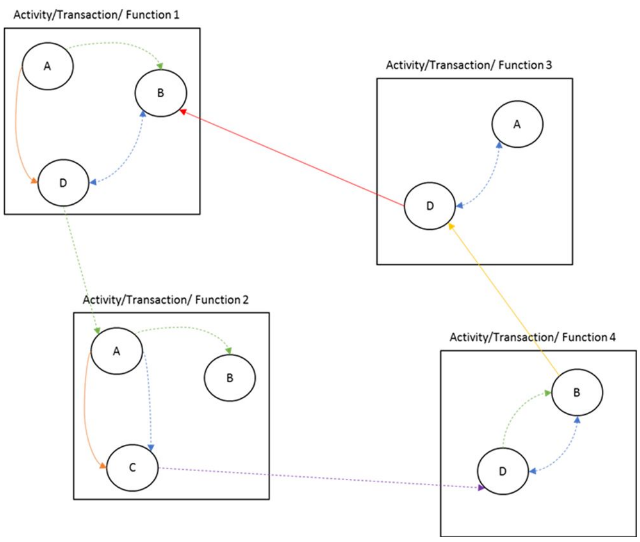


Figure 4.25: Bipartite value network mapping

After value mapping on the tactical level are performed per individual activity, function, or transaction, users can identify the required resources needed by the different actors to enable the value flow and to complete the activity, function, or transaction. For simplicity reasons, the term ‘function’ will be used, but it can be used interchangeably with the term activity or transaction, whichever is the most applicable to the business case.

To just jump in and start mapping the strategic business net on a strategic or tactical level can waste time, therefore it is suggested to make use of matrixes or tables to do the initial strategic, or value network thinking and identification, before drawing and mapping it. See the tables below for illustration purposes.

Table A: Function - Capability

	Function 1	Function 2	Function 3	Function 4
Capability a				
Capability b				
Capability c				
Capability d				

Table B: Actor – Function

	Actor A	Actor B	Actor C	Actor D
Function 1				
Function 2				
Function 3				
Function 4				

4.5.2 Preliminary SBN configuration process

Since the networked BM is viewed as a set of linked activities or functions, to explain value creation and value capture [255] for the strategic business net, viewed as an intentionally formed VN with a finite set of parties that can be partially managed and controlled to be efficient [154], that aim to collaborate to achieve joint goals, it is important to enable users to easily link these two concepts through a VN visualisation tool. Therefore, the SBN configuration process is developed to fulfil this role, and to address the identified gap in the literature body regarding network visualisation on a strategic and tactical levels.

The preliminary SBN configuration process consists of 10 development steps, see Figure 4.26. It furthermore consists of two levels of development and mapping, see Figure 4.27. The value network (strategic) level (Step 1-6) and the value architecture (tactical) level (Step 7-10) - which were identified as two of the value dimensions within the *Networked BM elements* facet in the hierarchical taxonomy.

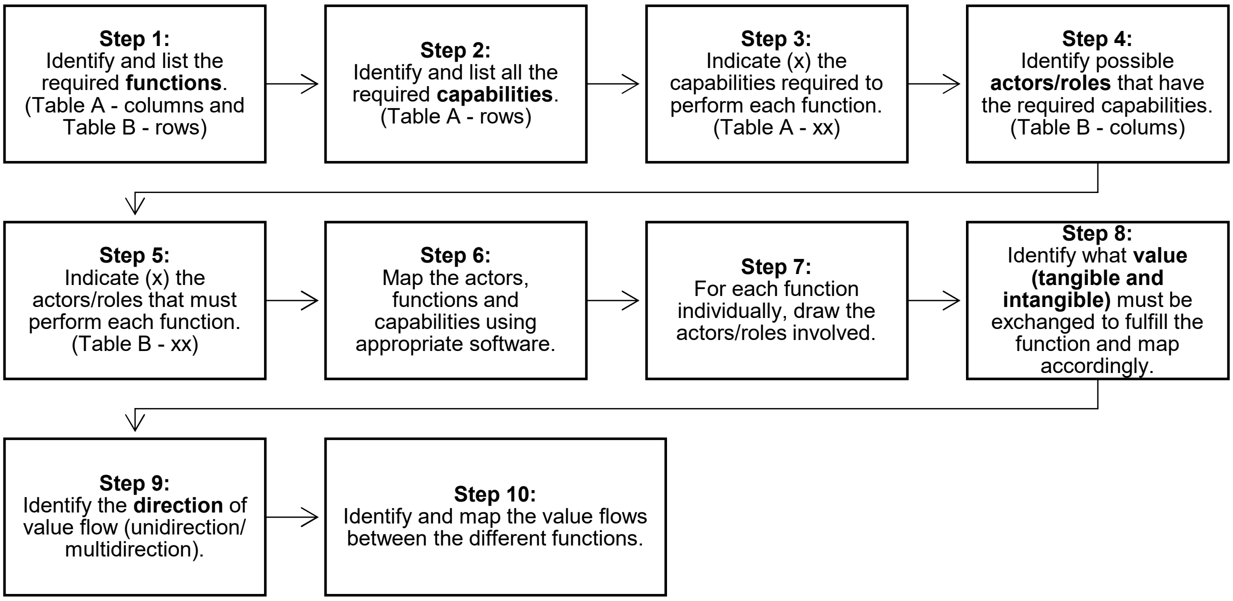


Figure 4.26: Preliminary SBN configuration process

	Function 1	Function 2	Function 3	Function 4
Capability a	x	x		
Capability b	x	x	x	
Capability c	x			x
Capability d			x	x

	Actor A	Actor B	Actor C	Actor D
Function 1	x	x		x
Function 2		x	x	
Function 3	x	x		
Function 4			x	x

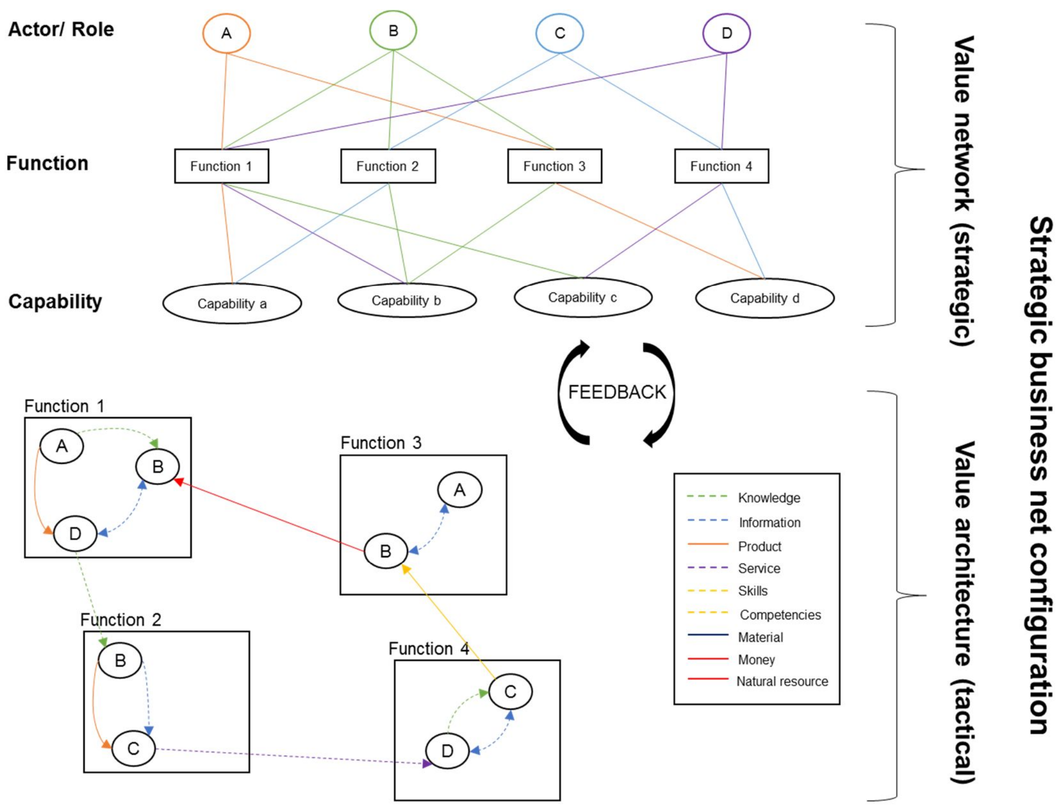


Figure 4.27: Example of SBN configuration process application

To adequately address the identified gap in the literature, the process enables strategic and tactical value mapping and enable the creation of operational plans on the lowest company level. It provides an overview of the network in a structured and organised manner so that everyone in the SMME can understand the operation and configuration of the network. It furthermore allows everyone to partake in the development and changes and adjustments can easily be made and value exchanges and flows can be re-evaluated in a 'safe' cost-free environment before prototyping and implementation.

Before applying this process in the R&D phase, several assumptions must be made and documented to enable the creation of different scenarios. These assumptions must be reviewed as time progress and the required changes need to be assessed, prioritised, and then implemented.

Reflecting on the context of the study, the adoption of AM will potentially change the way the VN operates, and companies will need to decide whether they will adopt centralised or decentralised VNs. Furthermore, the configuration of this new VN remains a challenge as AM allow organisations to move upstream and downstream along their supply chains [192]. Using this strategic business net mapping as part of the conceptual framework and management tool, will enable users to come up with different scenarios on how to configure and develop the VN, and different prototype configurations can be compared and weighed against each other.

This approach will also help organisations to create scenarios and think through the entire process from beginning to end, to identify missing links or things not thought about before. The configuration process will furthermore enable users to establish how adaptive or modular their BMs need to be, in terms of market reach and the fulfilment of supply chain activities [192] (discussed in Section 3.6.4). It will furthermore help with the identification of next steps (including the identification of resources) as well as the drafting of road maps and action plans to improve the technology, product, and service development.

4.6 Part D-2: Conceptual framework

4.6.1 Development approach

The approach, logic, and reasoning to develop the conceptual framework are discussed within this section. Whereafter the preliminary design of the framework is presented, to conclude the first design cycle iteration as well as section two of *Part D* presented in Figure 4.1. Subsequently, this section aims to answer the following sub-research question*: What are the key conceptual findings that need to be integrated into a conceptual framework? (SRQ5).*

Parallel to the interpretation of the BM on a network-level is that of the concept of ecosystem BMs for the IoT [111]. These perspectives suggest value creation and exchange requires active involvement from relevant stakeholders and a common understanding across the network of actors [128]. The VN or ecosystem is co-evolving and the concept of a BM connects the firm with its environment and customers (and society as a whole) for joint utilisation of complementary capabilities [110]. It is used to enable one to understand value drivers at both the firm and the overarching ecosystem or network-level. These value drivers are assumed to be closely linked, changeable over time and influence whether an actor stays in the ecosystem or VN. They furthermore suggest that the alignment of firms' roles within the ecosystem (in terms of resources, knowledge and complementarities) and firm-level BMs with a network-oriented BM may lead the ecosystem to prevail over its disintegration [111]. This co-evolving ecosystem or VN perspective is applied throughout the development of the conceptual framework and subsequent management framework in Chapter 6.

Visioning the BM may be challenging because there are only vague ideas about its future business potential. However, according to the study conducted by Palo and Tähtinen [177], managers stressed that the development of the BM was central to developing and producing services after the research project ended. It is furthermore noted that it is essential to resolve issues around the offering and the technology itself in the BM. The value configuration is dependent on the technology and the service. The content of the services (and products) should steer the technological development rather than the other way around. One of their study's participants noted the following: *"The starting point should be different; the technology comes only after the customer needs and other things have been [determined]."* The managers recognised customer needs and the value of the services as the cornerstone of BMs [177]. Based on this perspective and background, the framework is qualitatively developed spanning boundaries across firm-level to be inter-organisational (allowing partners to join in the process).

The conceptual framework is divided into the primary three dynamic capabilities phases, namely sensing, seizing, and transforming [219]. With sub-phases proposed by the Generic BMI Process suggested by Wirtz and Daiser [245]. Although the networked BM framework proposed by Palo and Tähtinen [177] is on a highly-aggregated level of abstraction, it still formed part of the theoretical foundation. The framework contains the two dimensions of development, namely the business net development and the business opportunity development, but what needs to be done during each of the phases (service development, pilot, and market) contained within the model is just briefly described. Their framework, therefore, lacks the inclusion of exact activities, guidelines, or tools on how a company or organisation need to go about developing the networked BM as time progresses within each of the phases.

Therefore, the conceptual framework aimed to adopt a lower level of abstraction, thus a moderately-aggregated to a detailed level, by adding the necessary steps contained within each BMI phase, as well as assigning specific steps to develop the networked BM in both dimensions. After the steps were identified to create a holistic networked BMI process, the fundamental concepts (part of the concept taxonomy) addressed within each step were added. The concept map presented in Section 4.2 was used as 'checklist' to ensure all the identified concepts were addressed within the framework.

The conceptual and management frameworks aim to first create an 'as-is' state of the business and VN (if the user is already an established organisation) and then guide the user to iteratively create a potential 'to-be' state through collaboration once the technology, products and services are ready to be introduced into the market and the identified business opportunity has potential to be successfully pursued by the strategic business net.

It can be concluded that the conceptual framework consists of phases, sub-phases, steps, and fundamental concepts addressed within each step. The management framework is an upgraded version of the conceptual framework with some added activities, details, tools, guidelines, and considerations. The SBN configuration process presented in Section 4.5 forms an integral part of both frameworks and the application of the specific process steps are presented in the management framework.

4.6.2 Conceptual framework

The conceptual framework was mainly developed from a business perspective, as it is based on the fundamental concepts identified in Section 4.2. For this study, the BMI endeavour is viewed from a dynamic perspective [75] (discussed in Section 3.4.1), and the definition provided by Foss and Saebi [75] is adopted, regarding BMI as a process, being a combination of BM design and BM reconfiguration, or in other words the process of developing the BM on a network-level (discussed in Section 3.4.2).

The steps included in the framework were based on the activities suggested by the Generic BMI Process from Wirtz and Daiser [245] as well as other important aspects identified in the literature bodies. The *technology analysis* step provides an overview of the analysis of the introduction of AM into the business, but more AM specific steps and guidelines were added after the management framework was evaluated by business experts. Figure 4.28 below provides a brief summary of each of the three main phases of the framework (adapted from the descriptions provided by Teece [219]). Figure 4.29 provides a brief summary of the seven sub-phases of the framework (adapted from the descriptions provided by Wirtz and Daiser [245]).

Figure 4.28: Overview of the phases of the conceptual framework

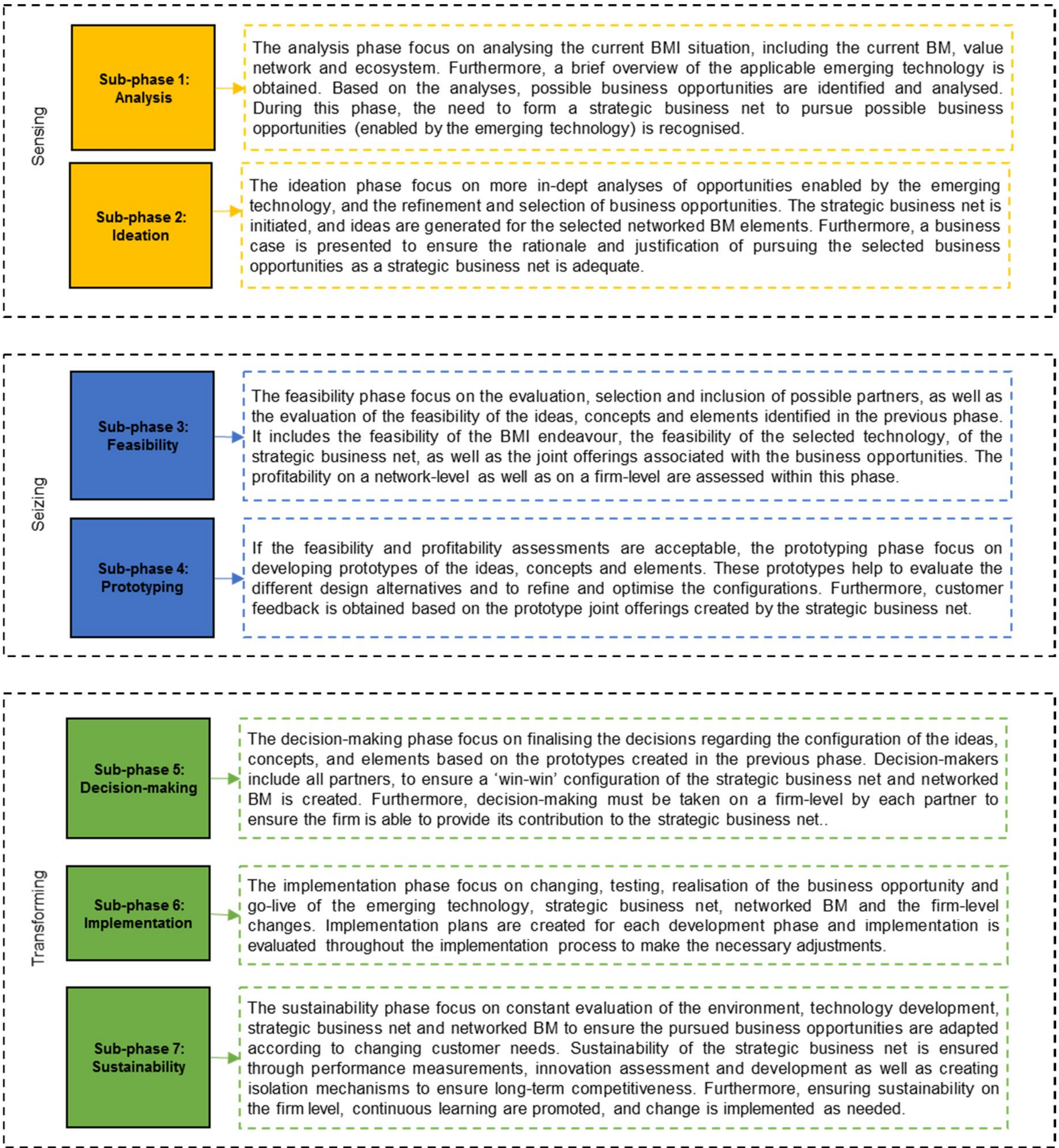


Figure 4.29: Overview of the sub-phases of the conceptual framework

During the design and development of the conceptual framework, it was realised that a semi-structured, lower-level approach was required regarding the allocation of the steps. The hierarchical taxonomy developed in Section 4.3, originally identified two development dimensions for the networked BM, namely the strategic business net development (originally proposed as business net development) and business opportunity development [177]. However, during the logical allocation of steps within the different sub-phases of the framework, the need for more development dimensions was recognised to ensure structure to the process. Therefore, an additional four development dimensions were added, including the 'Networked BM' as a separate dimension. The other dimensions included, were all identified as elements in the concept map of theory, see Figure 4.30 below.

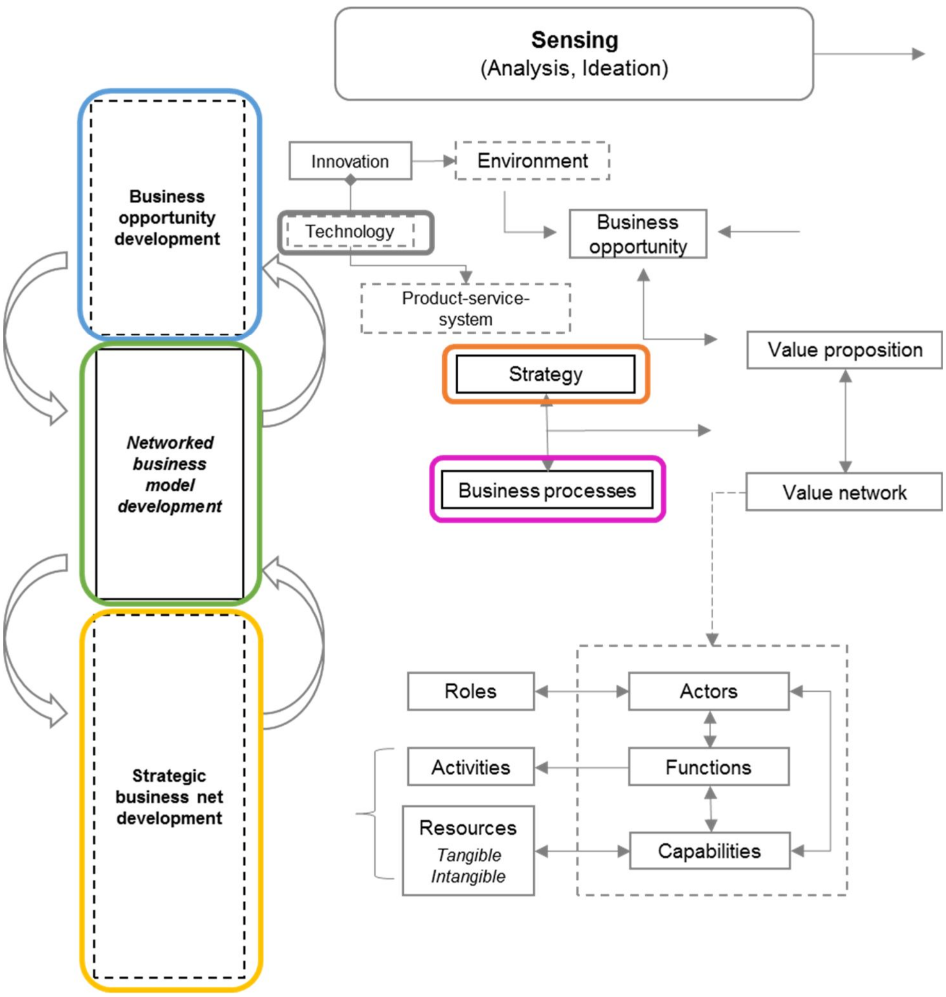


Figure 4.30: Development dimensions within concept map of theory

Although the focus of this study was on the tactical level where the BM is typically located (hence the development of the networked BM and strategic business net configuration process), a management framework will not be deemed comprehensive without the inclusion of the higher and lower levels. Throughout the literature review, the importance of alignment has been highlighted by several authors (as discussed in Section 3.3.1), the division of the steps according to these development dimensions will improve the alignment between all aspects within the framework (including the adoption of AM). This alignment aims to include internal firm-level alignment, referring to the alignment of the strategy, BM, business process and IT [6, 59], internal network-level alignment, referring to the alignment between the network-level BM and firm-level BMs and between all the firm-level BMs [59], and external alignment, referring to alignment with the customer needs, stakeholder priorities, and the external environment [209, 216].

Furthermore, the inclusion of these development dimensions enables a complete view of the networked BMI concept from a strategic, tactical, and operational view (the concept of using these three levels to develop a VN was proposed by Schneider *et al.* [201], discussed in Section 3.5.3), see Figure 4.31. Table 4.5 below provides a summary of each of the development dimensions regarding what it entails.

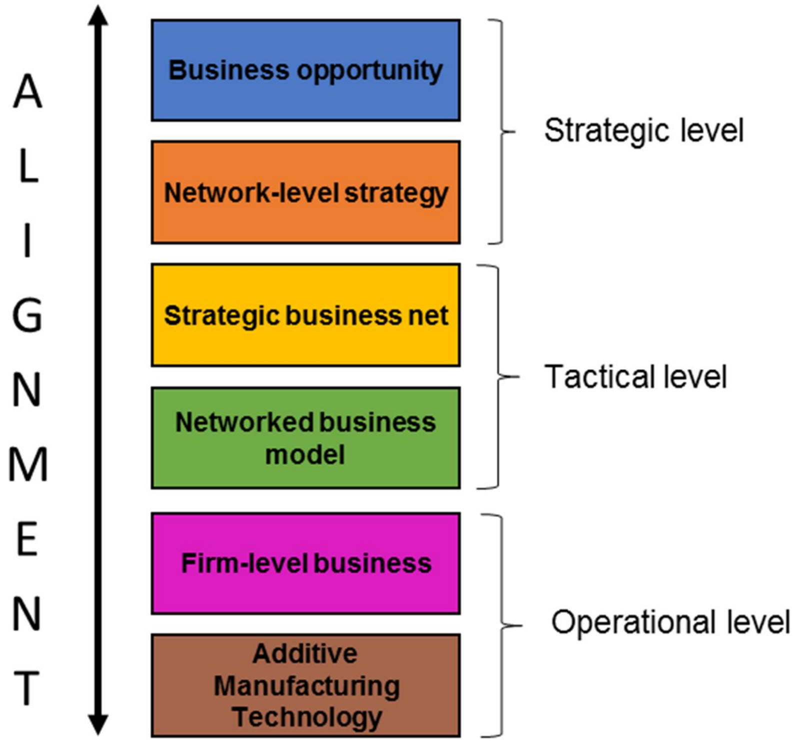


Figure 4.31: Development dimensions from a value network perspective

Table 4.5: Development dimensions descriptions

Development dimension	Description
(1) Business opportunity	A way to identify possible business opportunities to be pursued by the strategic business net, the development thereof, as well as the selection and prioritisation for short, medium, and long-term realisation.
(2) Network-level strategy	A way to guide the strategic decision-making process regarding the strategic business net's strategy and the alignment thereof with the configuration of the strategic business net, networked BM, and other aspects.
(3) Strategic business net	A way to systematically develop and design the strategic business net regarding its configuration, features, value creation levels and performance (including the performance of individual partners).
(4) Networked BM	A way to systematically consider and develop the identified networked BM elements, categorised into the four value dimensions, and ensuring the alignment thereof with the configuration of the strategic business net, as well as the firm-level business processes.
(5) Firm-level business	A way to consider high-level aspects pertaining to processes that must happen on the firm-level (either applied to the focal actor or other network partners), although not detailed, it emphasises the connection and alignment of the network-level with the firm-level.
(6) (Additive Manufacturing) Technology	A way to systematically consider the development of an emerging technology (in this case AM technology) in line with the development of the networked BM and the strategic business net's configuration to ensure alignment and successful implementation when the technology is commercially ready.

The use of multiple development dimensions that progress and evolve within each of the sub-phases of the framework is also in line with the DSR logic used to conduct this study. As the elements, features, or concepts contained within each phase, under each development dimension, progress and evolve with time, as the user progress with the BMI initiative.

However, since the development dimensions are fundamentally linked with close interrelationships, there might sometimes be overlaps among some of the elements, for example, a networked BM element might be defined within another development dimension than *Networked BM* that makes more practical and logical sense. These changes to the *Development dimension* facet in the hierarchical taxonomy as well as the visual presentation in the concept map of theory, are illustrated in the final frameworks in Chapter 8. These improved designs were evaluated by the business management experts in Chapter 6.

The conceptual framework, containing the phases, sub-phases and steps are illustrated below. Furthermore, the framework indicates which concepts illustrated in the concept map in Section 4.2 are addressed within each step.

Phases		Steps		Fundamental concepts
Sensing	1. Analysis	1.1 Business analysis *(if existing manufacturer)*	1.1.1 Internal business analysis	Entrepreneurial/ focal actor, Value network, Value proposition, Value architecture, Value finance, Strategy
			1.1.2 Value network analysis	Value network, Actors, Partner, Functions, Competencies
		1.2 Technology analysis	1.2.1 Technology analysis	Emerging technology, AM
		1.3 Ecosystem analysis	1.3.1 External environment analysis	Ecosystem, External environment, Trends and drivers, Innovation
			1.3.2 Operating environment analysis	SA, SMME
		1.4 Business opportunity identification and analysis	1.4.1 Customer profile	Target-segment, Customer, Customer needs, Offering, Distribution channel, Customer relationships, Communication channel, Value co-creation
			1.4.2 Industry and market analysis	Competitors, Market, Demand
			1.4.3 Business opportunity identification	Business opportunity, Joint offering, Value-in-context, Complementarity
			1.4.4 Realisation requirements/ enablers	Product-service, End-to-end solution, Emerging technology, Strategy, Business processes
			1.4.5 Strategy formulation	Strategy, Strategic choices, Alignment
		1.5 Strategic business net establishment	1.5.1 Strategic business net need	Strategic business net, Intent, Mode
			1.5.2 Objectives	Strategic business net, Objective, Customer
			1.5.3 Boundaries	Boundaries, Stakeholders, Actors, Ecosystem

Phases		Steps		Fundamental concepts
Sensing	2. Ideation	2.1 Business opportunity development	2.1.1 Refinement	Business opportunity, Value-in-context, Joint offering
			2.1.2 Selection and prioritisation	Business opportunity, Value-in-context, Joint offering
			2.1.3 Risk management	Risks, SMMEs, Innovation, Emerging technology, Investment and financing, Business opportunity
		2.2 Strategic business net development and configuration	2.2.1 Initiation features	Innovation, Intermediary, Integration
			2.2.2 Strategic business net configuration	Roles, Actors, Functions, Capabilities, Configuration, Value creation system, Strategic business net
			2.2.3 Key success factors	Key success factors
		2.3 Networked BM development	2.3.1 Value network elements	Governance, Management, Control, Collaboration, Communication, Communication channel, Customisation, Push/pull
			2.3.2 Value proposition elements	Development and design, Contact
			2.3.3 Value architecture elements	Infrastructure/ Assets, Information, Data analytics, Platform
			2.3.4 Value finance elements	Pricing method, Cost-structure, Revenue-structure, Profit formula, Total-cost of ownership, Sales model, Continuity
		2.4 Business case rationale	2.4.1 Customer profile	Customer, Customer needs, Target segment, Distribution channel, Relationship, Value co-creation
			2.4.2 Network completion	End-to-end solution, Customer, Customer needs
			2.4.3 Business case	Business opportunity, Joint offering

Phases		Steps		Fundamental concepts
Seizing	3. Feasibility	3.1 Strategic development	3.1.1 Business environment assumptions	Emerging technology, Business opportunity, Innovation
			3.1.2 Strategic roadmaps development	Strategy, Emerging technology, SMMEs, Strategic decisions, Innovation
		3.2 Strategic business net development and configuration	3.2.1 Partner evaluation and selection	Partner, Actors, Perceived advantages, Perceived disadvantages, Benefits, Value driver, Key Success Factors, Shared values, Synergy, Culture, Relationship, Complementary, Partnership, Alliance
			3.2.2 Partner involvement	Partner, Value opportunity, Business opportunity, Information, Integration
			3.2.3 Strategic business net features development	Co-operation, Coordination, Trust, Integration, Power, Control points
			3.2.4 Strategic business net configuration	Actors, Functions, Capabilities, Configuration, Value creation system, Link, Flow
			3.2.5 Performance measurements	Metrics, Strategic business net, Partners
		3.3 Networked BM development	3.3.1 Value network elements	Governance, Management, Control, Collaboration, Communication, Communication channel, Customisation, Push/pull
			3.3.2 Value proposition elements	Development and design, Contact
			3.3.3 Value architecture elements	Infrastructure/ Assets, Information, Data analytics, Platform
			3.3.4 Value finance elements	Pricing method, Cost-structure, Revenue-structure, Profit formula, Total-cost of ownership, Sales model, Continuity
		3.4 Firm-level feasibility	3.4.1 Feasibility and profitability assessment	Partner, Actor, Business processes, Strategy
			3.4.2 Customer feedback	Partner, Actor, Customer

Phases		Steps		Fundamental concepts
Seizing	4. Prototyping	4.1 Strategic business net development and configuration	4.4.1 Strategic business net configuration	Value co-creation, Actors, Value exchange, Value flow, Joint value creation, Knowledge, Value-configuration, Value creation system, Link, Flow
			4.1.2 Functional interdependence assessment	Functions, Value-configuration, Value creation system, Link, Flow
			4.1.3 Strategic business net features prototyping	Shared values, Synergies, Complementary, Control points, Power, Culture, Co-operation, Coordination, Trust, Integration
		4.2 Networked BM prototyping	4.2.1 Networked BM prototyping	Value proposition, Value network, Value architecture, Value finance, Intermediary
			4.2.2 Alignment	Alignment, Strategy, Business processes, Environment, Dynamic capabilities
		4.3 Strategic development	4.3.1 Strategic roadmaps development	Strategy, Emerging technology, SMMEs, Strategic decisions, Innovation
			4.3.2 Marketing plan development	Market, Customer needs Target segment, Customer, Joint offering, End-to-end solution, Demand, Strategy, Strategic choices
			4.3.3 Action plan development	Actors, Activities, Resources, Tangible (operand) resources, Intangible (operant resources)
		4.4 Firm-level prototyping	4.4.1 Action plan development	Actors, Activities, Resources, Tangible (operand) resources, Intangible (operant resources)
			4.4.2 Firm-level prototyping	Business processes, Offering, Activities, Infrastructure, Resources

Phases		Steps		Fundamental concepts
Transforming	5. Decision-making	5.1 Business opportunity decision-making.	5.1.1 Shared mental model	End-to-end solution, Joint offering, Decision-making, Strategy, Strategic choices, Perceived value, Shared mental model
			5.1.2 Technology	Emerging technology, Infrastructure, Investment and financing
			5.1.3 Risk management	Risks, SMMEs, Innovation, Emerging technology, Investment and financing, Business opportunity
			5.1. 4 Customer's perceived value	Customer, Perceived value, Joint offering, Business opportunity
		5.2 Strategic business net development and configuration	5.2.1 Strategic business net operation	Value creation system, Value network, Value architecture, Strategic business net
			5.2.2 Strategic business net features decision-making.	Shared values, Synergies, Complementary, Control points, Power, Culture, Co-operation, Coordination, Trust, Integration
			5.2.3 Harmonisation of features	Shared values, Synergies, Complementary, Control points, Power, Culture, Co-operation, Coordination, Trust, Integration, Alignment
			5.2.4 Value creation levels	Business value, Collaborative value, End-customer value, Intended value element, Perceived value
			5.2.5 Performance measurements	Strategic business net, Partners, Metrics
		5.3 Networked BM development	5.3.1 Networked BM elements decision-making	Value proposition, Value network, Value architecture, Value finance
			5.3.2 Harmonisation of elements	Value proposition, Value network, Value architecture, Value finance, Alignment
		5.4 Strategic decision-making	5.4.1 Marketing plan finalisation	Market, Customer needs, Customer, Joint offering, End-to-end solution, Demand, Strategy
			5.4.2 Strategic roadmaps finalisation	Strategy, Emerging technology, SMMEs, Strategic decisions, Innovation
		5.5 Firm-level decision-making	5.5.1 Action plan development	Actors, Activities, Resources, Tangible (operand) resources, Intangible (operant resources)
			5.5.2 Change management plan development	Actors, Capabilities, Competencies, Dynamic capabilities, Infrastructure, Business processes
			5.5.3 Training plan development	Actors, Capabilities, Business processes

Phases		Steps		Fundamental concepts
Transforming	6. Implementation	6.1 Strategic implementation	6.1.1. Feedback and progress reporting	Actors, Capabilities, End-to-end solution, Joint offering
			6.1.2 Implementation plan	Value proposition, Value network, Value architecture, Value finance, Business opportunity, Joint offering, End-to-end solution, Customer, Business processes
			6.1.3 Communicate with network partners	Actors, Partners, Communication, Communication channel, Collaboration, Coordination, Co-operation
		6.2 Firm-level implementation	6.2.1 Implementation plan	Business processes, Focal actor, Partners, Activities, Functions, Resources, Infrastructure
			6.2.2 Change management implementation	
			6.2.3 Evaluate and adjust	
		6. 3 Networked BM implementation	6.3.1 Implementation plan	Value proposition, Value network, Value architecture, Value finance
			6.3.2 Networked BM implementation	
			6.3.3 Evaluate and adjust	
		6.4 Strategic business net implementation	6.4.1 Implementation plan	Strategic business net, Business opportunity, Business processes, Configuration
			6.4.2 Strategic business net implementation	
			6.4.3 Evaluate and adjust	
		6.5 Business opportunity assessment	6.5.1 Monitor and evaluate	Actors, Partners, Strategic business net, Metrics, Objective
			6.5.2 Partner feedback and reporting	Actors, Partners, Communication, Metrics, Business processes
			6.5.3 Risk management	Risks, SMMEs, Innovation, Emerging technology, Investment and financing, Business opportunity
			6.5.4 Re-evaluate and adjust	Business opportunity, Environment, Emerging technology, Value proposition, Value network, Value architecture, Value finance, End-to-end solution

Phases		Steps		Fundamental concepts
Transforming	7. Sustainability	7.1 Business opportunity evaluation	7.1.1 Customer feedback	Customer, Target segment, Communication, Customer relationship
			7.1.2 Evaluate and adjust	Business opportunity, Strategic business net, BM, Configuration
		7.2 Strategic business net evaluation	7.2.1 Strategic business net performance	Innovation, Metrics, Strategic business net
			7.2.2 Partner performance	Innovation, Metrics, Actors, Partners
			7.2.3 Evaluate and adjust	Metrics, Value proposition, Value network, Value architecture, Value finance, Joint offering, End-to-end solution, Joint value proposition
		7.3 Networked BM evaluation	7.3.1 Networked BM elements performance	Value proposition, Value network, Value architecture, Value finance,
			7.3.2 Evaluate and adjust	
		7.4 Strategic sustainability	7.4.1 Ecosystem scanning	Ecosystem, Market, Competitors
			7.4.2 Innovation assessment and development	Innovation, Emerging technologies, Strategic business net, External environment, Market, Customer
			7.4.3 Isolation mechanisms	Innovation, Emerging technologies, Competitors, Strategy, Strategic choices
			7.4.4 Long-term competitiveness	Innovation, Emerging technologies, Competitors, Strategy, Strategic choices
			7.4.5 Communicate with network partners	Collaboration, Communication, Communication channel, Actors, Partners
		7.5 Firm-level sustainability	7.5.1 Continuous learning	Actors, Partners, Capabilities, Dynamic capabilities, Innovation, Strategic business net
			7.5.2 Change management plan development	Actors, Partners, Capabilities, Dynamic capabilities, Strategic business net, Business processes
			7.5.3 Training plan development	Dynamic capabilities, Competencies, Actors, Activities, Business processes, Resources

4.7 Conclusion: Chapter 4

Due to the complex nature of the networked BMI framework, this study aims to develop, a structured and systematic process needed to be followed. In this chapter, the first few steps were executed up until the development of the conceptual framework, to conclude the first design cycle iteration. During the design of the conceptual framework, it was found that a few changes needed to be made to the hierarchical taxonomy and concept map of theory regarding the development dimensions. These changes reflect in the final frameworks presented in Chapter 8.

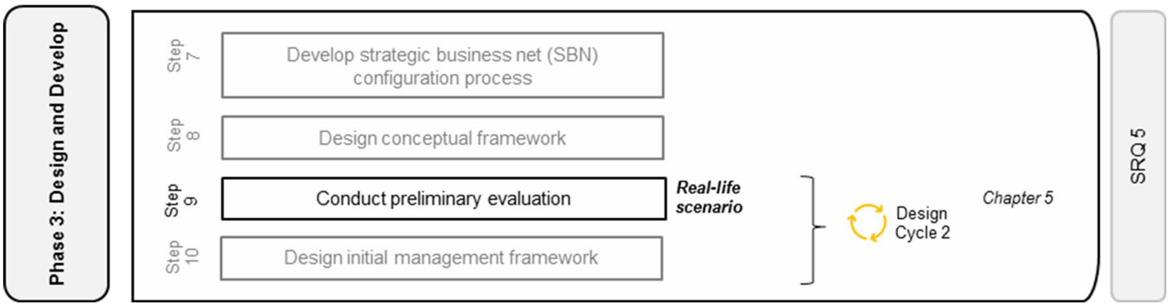
To ensure the research artefacts presented in this chapter, namely the SBN configuration process, as well as the conceptual framework, is relevant and rigorous, the results from the preliminary evaluation conducted, are presented in the next chapter.

Chapter 5: Preliminary evaluation

As part of the second design cycle iteration, Chapter 5 aims to evaluate the SBN configuration process and conceptual framework proposed in Chapter 4. The SBN configuration process is evaluated using a real-life scenario and adjustments to the process was made according to the findings. The conceptual framework is internally evaluated using the proposed hierarchical taxonomy of the networked BMI concept, as it is regarded as a set of requirements for approaching networked BMI.

Chapter 5 key objectives:

- Discuss the evaluation of the SBN configuration process (Section 5.1).
- Present the proposed SBN configuration process (Section 5.2).
- Discuss the internal evaluation of the conceptual framework (Section 5.3).



5.1 Evaluation of the SBN configuration process

The design and development of the SBN configuration process aimed to address the gap in the VN literature body regarding a structured approach to enable the visualisation and mapping of a VN on both the strategic and tactical levels. The proposed process steps are included in the management framework, developed in Chapter 6. Since it is the only tool to be included in the management framework that was not previously evaluated and tested within literature or practice, it was needed to evaluate the process before applying it to the contextual application domain. The aim of the evaluation was to ensure the process makes practical sense and has a logical flow, and therefore the outcomes were not specifically reflected upon in this chapter. This evaluation was conducted from a business perspective as the selected scenario does not specifically fall within the context of this study. However, within Chapter 7, evaluation was done from a manufacturing perspective within the context of this study. Therefore, both the management framework and the SBN configuration process are evaluated from both a business and manufacturing perspective.

Therefore, to ensure the SBN configuration process is indeed applicable and feasible, a real-life scenario was used as the first evaluation step. A real-life scenario is closely associated with a case study but does not follow a strict and formal process with facts, figures, and data as in the instance of conducting a case study, it is furthermore usually shorter and may contain fictionalised elements [109]. Strict confidentiality was exercised during the data gathering process and the reporting to comply with the conditions for ethical research. After the process was applied, relevant modifications were made to the SBN configuration process.

5.1.1 Scenario selection

The appropriate scenario would present the opportunity to investigate the process's suitability as a management tool for guiding SMMEs in the process of strategic net development as well as the visualisation of value co-creation and the configuration of strategic business nets (or VNs). Therefore, the following process requirements for the appropriate scenario were formulated:

- The company must be a SME/SMME.
- The company must be based in South Africa.
- The company's business must be based on a technology.
- The company's BM must currently be on the firm-level, with possible opportunities to expand it to the network-level.
- The company must provide or deliver a product and service.
- The company must have available and willing participants.

The selected company, Company A, met all the specific requirements for the application of the process. What made the case even more attractive, was the fact that Company A was faced with expansion opportunities at the time, making the application of the process one of its top priorities. Due to time restrictions, the owner of the company could not participate throughout the application, but he attended the briefing session and gave his approval to proceed and agreed to evaluate and confirm the outputs from the process. The owner did however dedicate the company's senior business analyst to participate in the study.

5.1.2 Scenario background

Company A considered within this scenario operates in the IT industry. The company is an SMME with six employees, based in South Africa with operations throughout Africa. In the past, the company's business focused on document and record management with a service-oriented approach, using an open-source product. Due to the price of the product and competitiveness within South Africa of existing open-source products, Company A was forced to innovate their BM to survive. Therefore, Company A decided to focus only on one of the components of the document and record management process. Consequently, they developed a product to perform the scanning and digital imaging of documents. This product innovation changed the focus of the company to a product-oriented company with services (installation, support, customisation, continuous improvement) associated with their product, which is regarded as cutting-edge technology within this industry.

Company A focuses on enabling organisations to focus on their core business processes through the smart classification of documents and extraction of meaningful information from such documents. They aim to remove the overhead costs involved in manually identifying documents and extracting relevant information for line of business processes and applications. Their customers include any company, organisation, or service bureau that need to handle big volumes of paper documents such as invoices, customer files or historical transactional data.

At the moment, Company A does everything related to their product and service development in-house with their six employees. Including the technical development, functional support, installation, and training of their clients. However, to enable growth, Company A realised they require partners as they do not have the capacity to enable any further growth if they want to remain primarily focused on their product. To successfully form partnerships and expand further into Africa, changes to the BM and operations of Company A are required. These partnerships will therefore force Company A to innovate its BM from the firm-level to the network-level to enable success.

Company A was recently approached by another organisation for a possible partnership, as they want to sell the company's smart imaging product together with the organisation's scanners. This made the company realise that the opportunity to grow must now be pursued, using this organisation as a first test case on how to implement partnerships. However, the company acknowledges that business knowledge is not available in-house to move to the BM to the network-level as they are more product and technology focused.

5.1.3 SBN configuration process application

For Company A, the aim of the application of the process was to clarify what the VN (or strategic business net) and the formation of partnerships will possibly entail. The process aimed to help the company's participant to think through the business processes and to identify what must be in place before pursuing the expansion opportunity. It was already decided that the opportunity of expanding through partnerships will be pursued. The outputs produced from the process aimed to form a prototype of a strategic business net configuration that will be tested with the organisation that approached Company A before other partners will be included.

The proposed future strategic business net, illustrated in Figure 5.3, provides a baseline or blueprint for Company A to build upon once they need to develop requirements and roles for potential partners to form part of their network, as well as the functioning of the potential network. Whereas the few functions that were mapped on the tactical level, illustrated in Figure 5.4, provide an example of how Company A can analyse their network to identify gaps, outstanding work, as well as capabilities and resources required for the successful operation of their potential future network.

Before the applicable data were gathered, an overview of the entire research study was provided to the participants (the owner and the business analyst), see the applicable slides in Appendix C. The briefing session provided a clear understanding of the research study's objectives and where exactly the process fits in. During the overview, there were strong indications that the process of applying the SBN configuration process had the potential to provide valuable feedback to both the company and the researcher. The data was gathered through online interviews with the research participant (which ended up being workshop-like as the researcher prompted the interviewee based on answers provided). The tables completed as part of the process are presented in Appendix C, but the visualisation of the strategic business net on the strategic level is presented below, together with the visualisation of a few functions on the tactical level (due to time constraints only five functions were mapped).

During the application of each step contained in the SBN configuration process, the following observations and notes were made:

- **Step 1: Identify and list the required functions.**

  Although the term 'function' was included in the initial process, the identification of activities and transactions were also considered. It however turned out that functions are an appropriate level of analysis. It was furthermore found that it is required to divide the functions into two categories, namely, main functions and sub-functions. The main functions were used to group the sub-functions into appropriate business categories, and further analysis was done using the identified sub-functions. Unfortunately, due to time constraints, the current VN could not be fully mapped, but current operations were used to initially identify functions, whereafter more functions were added to realise the identified business opportunity.

- **Step 2: Identify and list all the required capabilities.**

  As noted above, the as-is state of the current VN could not be mapped, however, to identify the required capabilities for the future strategic business net, current competencies were first listed. This confirmed the need and applicability to first identify and map an as-is state before the future business net is developed (if it is an existing company or organisation). In this scenario, the current internal company competencies were capabilities required by potential partners that want to deliver the service. Furthermore, additional capabilities were identified on technical and functional levels of the company as it is used to distinguish between different operations within their business.

- **Step 3: Select (x) the capabilities required to perform each function.**

  To identify capabilities required for each function, the current competencies used to perform each function was first selected, whereafter the additional capabilities identified, were allocated to the relevant functions.

- **Step 4: Identify possible actors/roles that have the required capabilities.**

  During the execution of this step, it was realised that the most appropriate approach for this scenario was to first identify the different roles within the strategic business net, as different types of partners would have different capabilities. However, the partners go through different levels (or roles), where the capabilities build on one another. Therefore, the second level 'role' require all the capabilities of the first 'role', with a few additional capabilities. These different roles can be fulfilled by different companies as the strategic business net grows.

- **Step 5: Select (x) the actors/roles that must perform each function.**

  The execution of this step enabled the research participant to carefully go through the logic of how to distinguish between the different roles that partners can potentially fulfil. This distinction between the different roles and partner levels enabled the participant to draft a list of additional requirements partners must have. To ensure the visualisation remains simple and easy to understand, only the additional functions for each role were selected and mapped, with the assumption that the other functions of the lower-level partners are also applicable.

- **Step 6: Map the actors, functions and capabilities using appropriate software.**

  For this scenario, draw.io was selected to perform the mapping as it is free to use and enabled collaboration between the researcher and the research participant. It proved to be valuable to use a different colour for each role, and to use that colour to indicate which capabilities are associated with that role for every function. The capabilities were however depicted more than once on the map to ensure easy interpretation and readability of the map. See Figure 5.1 below for the visualisation.

- **Step 7: For each function individually, draw the actors/roles involved.**

  Within this step, additional actors were identified that need to provide information or knowledge, illustrating the need for continuous feedback between the tactical level and strategic level.

- **Step 8: Identify what value (tangible and intangible) must be exchanged to fulfil the function and map accordingly.**

  During the identification of values to be exchanged, it was noted that it is very valuable to first identify the required values to be exchanged for the specific business scenario and to allocate appropriate colours before the mapping is commenced. This step proved to be valuable to create potential scenarios for the function and to follow the logic which helped to successfully complete the value mapping for each function.

- **Step 9: Identify the direction of value flow (unidirectional/ multi-directional).**

  The direction of flow was easy to map, and no additional observations were made.

- **Step 10: Identify and map the value flows between the different functions.**

  The flow between functions helped to identify the potential outputs from each function, delivered by which actor. The need to identify precedence was identified as some functions can only be performed after another function is completed. Furthermore, other observations made, included the need to identify which actor within the function is the main responsible actor or 'owner' of the function, as well as the need to identify functions that are interrelated and not necessary executed independently. See Figure 5.2 below for the visualisation.

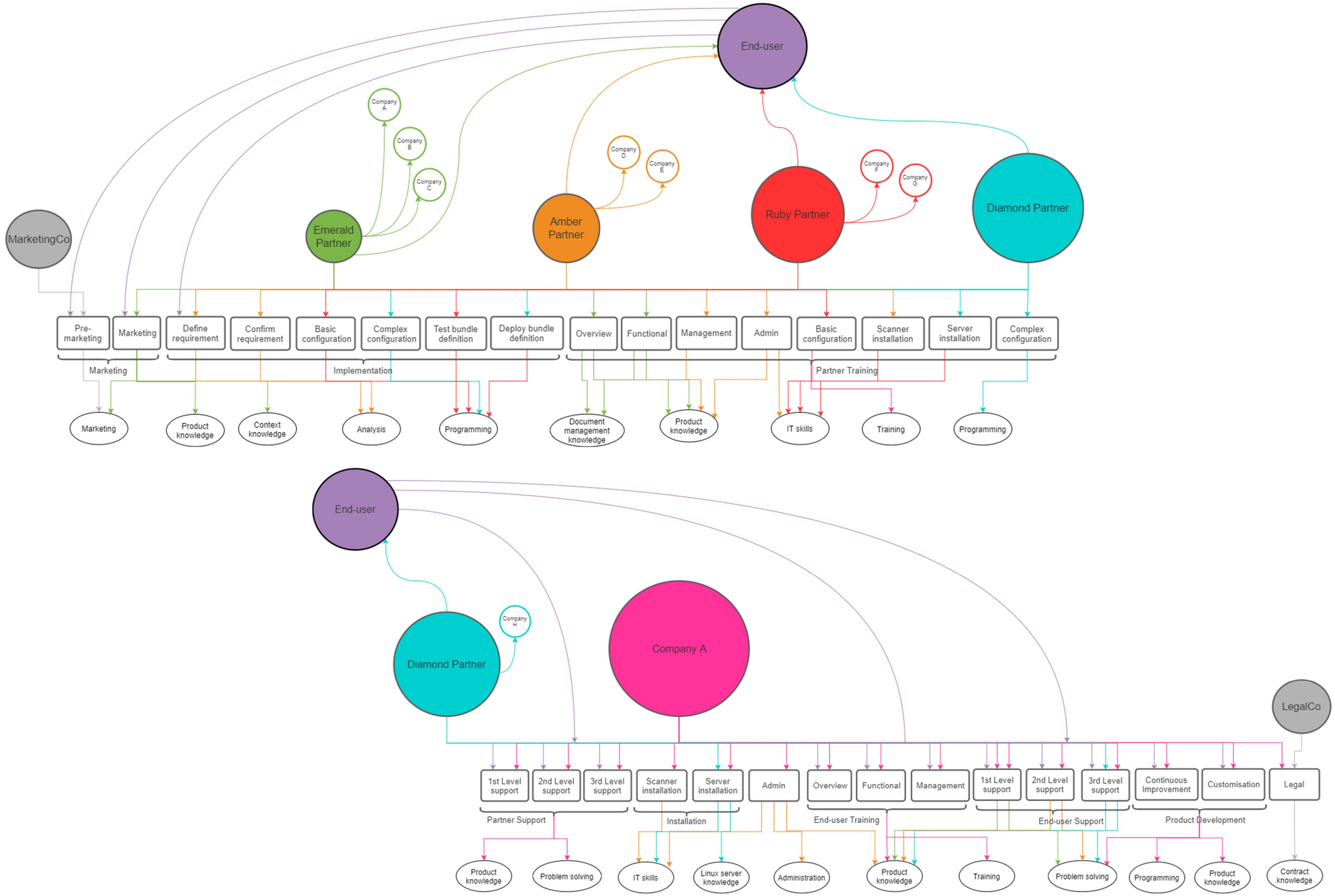


Figure 5.1: Real-life scenario strategic business net (strategic level)

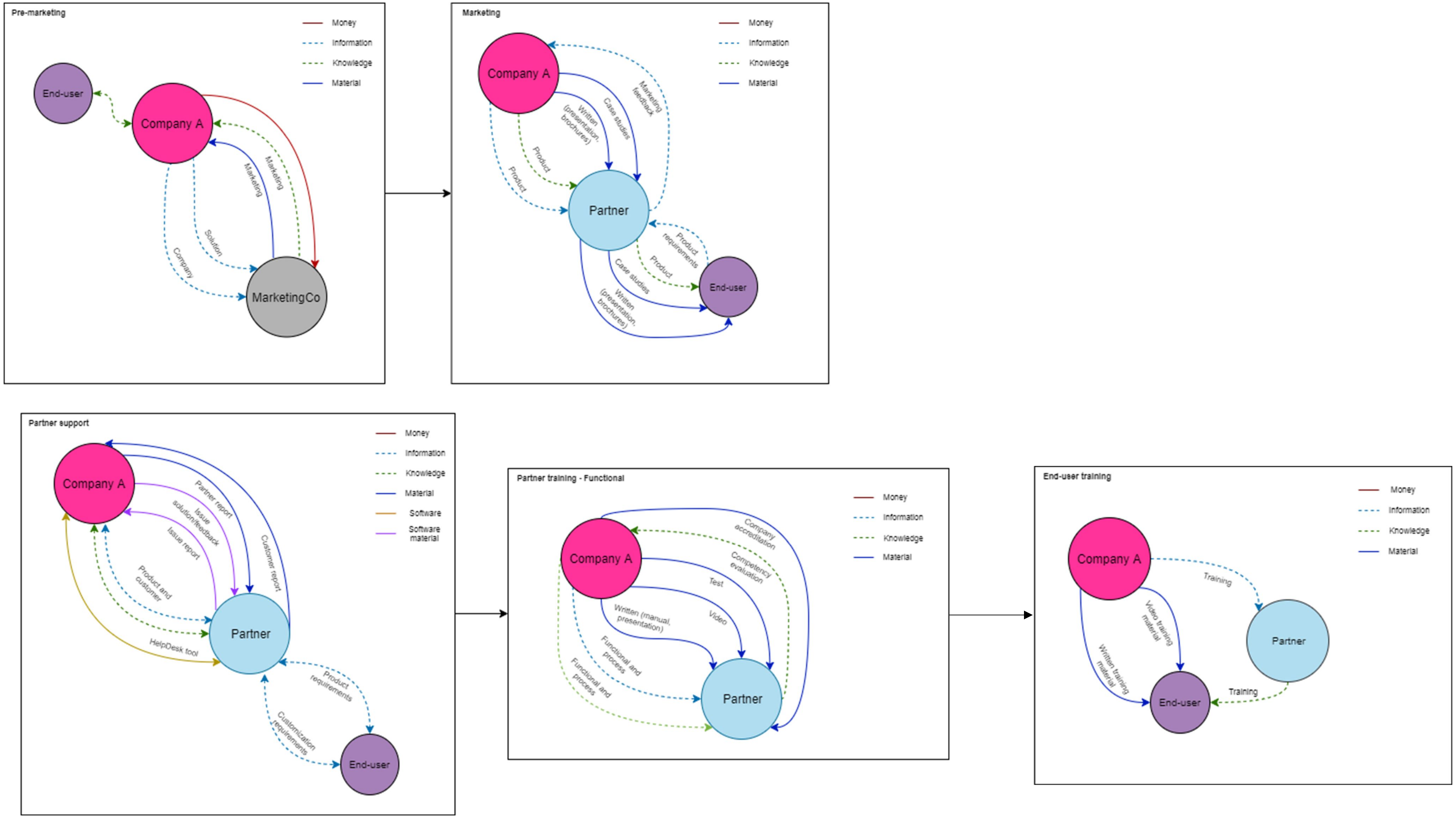


Figure 5.2: Real-life scenario strategic business net (tactical level)

5.1.4 Outcomes of the scenario

The outcomes and findings of the application of the SBN configuration process using a real-life scenario have been divided into three sub-categories. The first category highlights where the findings are aligned with the content and logic of the research artefact. The second category contains the additions to the research artefact based on the findings made during the process's application. The third category summarises where the findings result in required modifications to the research artefact. Some of the findings and outcomes are based on the researcher's observations described in the section above and others are based on feedback received from the research participant during and after the process application.

Table 5.1: Outcomes of the real-life scenario

	Aspect	Description
Validations	Relevance/ applicability	The application enabled the research participant to think about the company's existing processes and re-assess the functions and their sequence, not just assuming current operations are the most effective and efficient.
		The application enabled the identification of firm-level shortcomings and problems not previously known.
		The process enabled a structured process on how to think about the transformation process from the firm-level to the network-level.
		The application of the process enabled the research participant to stand back from only the technology development and see the bigger picture regarding what firm-level business changes are required if partners are to be included in the company's BM and business structure. Therefore, validating that SMMEs that mainly focus on technical and technological aspects do some need guidance regarding business development.
		The application confirmed the need that input from various employees are needed to transform the BM and structure of SMMEs as each employee has valuable contributions and experience in different functions.
	Logic	The alignment of functions and capabilities throughout the process helped to better structure the configuration of the network and understanding the implications.
		The application confirmed the need and value to first analyse the as-is value chain or VN structure of an SMME, before configuring a possible future state.
		The real-life scenario confirmed the value and applicability of the three main concepts included in the process, namely functions, capabilities, and actors/roles.
		The real-life scenario confirmed the logical sequence of the steps as well as the applicability and relevance thereof to address real-life problems of SMMEs.
		The real-life scenario confirmed that mapping the strategic business net on both the strategic and tactical level provides valuable insights to the user and illustrated the constant feedback required between the two levels as they are closely related.
Additions	SBN configuration process	During the application, the need to include functional owners was recognised and therefore Step 10 was added (see below).
		During the application, the need to indicate preceding and interrelated functions was recognised and therefore Step 12 was added (see below).
Modifications	SBN configuration process	During the application, it was recognised that roles are known before specific actors, therefore changing 'actor/role' to 'role (actor)'.

5.2 Proposed SBN configuration process

Based on the findings and observations made during the application of the SBN configuration process to a real-life scenario, a few changes and additions were made to the process. Figure 5.3 below propose the new SBN configuration process which was evaluated by the subject-matter experts in Chapter 6. Figure 5.4 provide a basic illustration of the results of the application of the proposed process steps. The visualisation example consists of the two tables that indicate the relationships between the functions, capabilities, and roles (actors), and the visualisation of the information on the strategic and tactical levels. The final SBN configuration process is presented in Chapter 8.

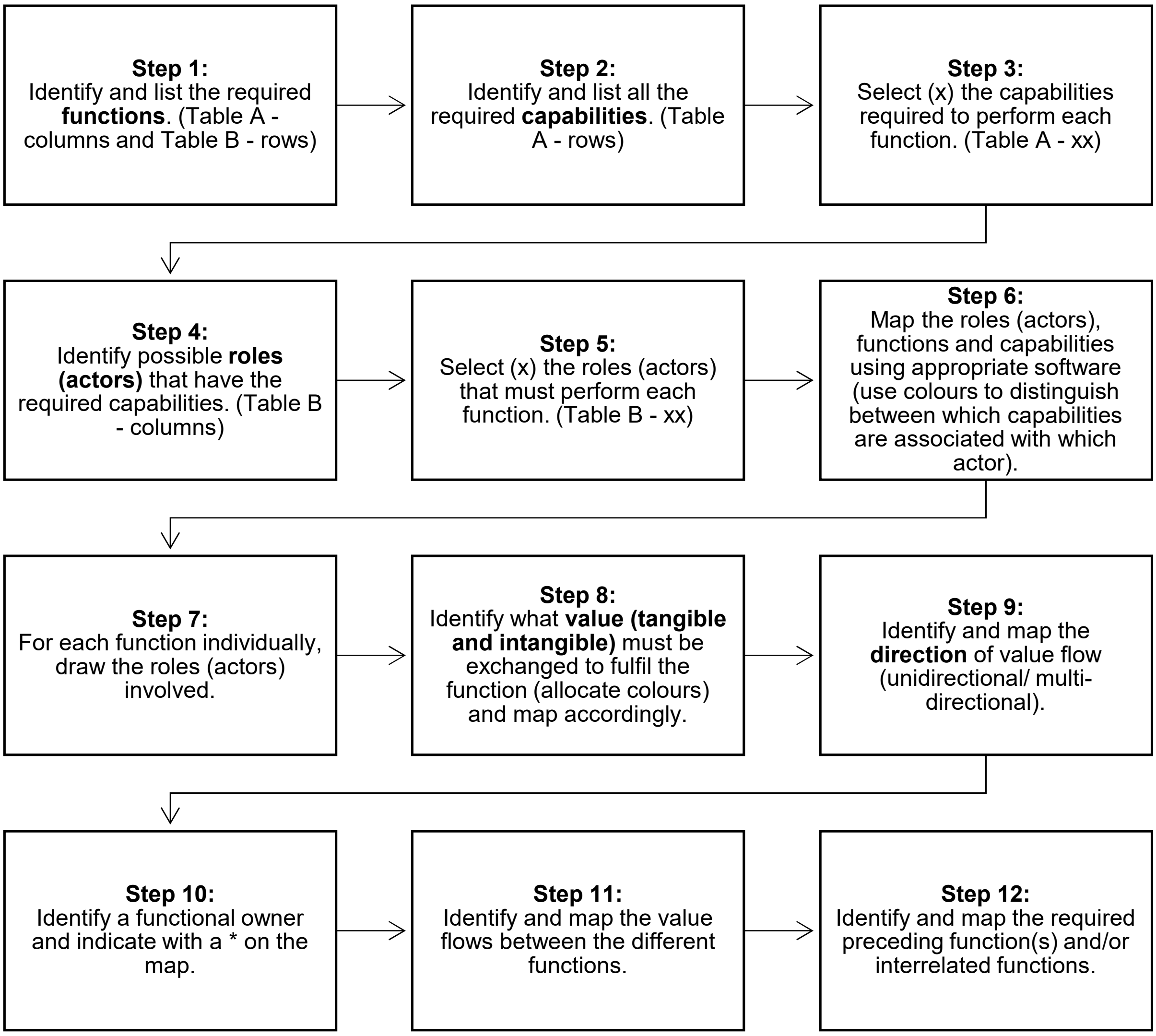


Figure 5.3: Proposed SBN configuration process

· **Table A: Function-Capability**

	Function 1	Function 2	Function 3	Function 4
Capability a	x	x		
Capability b	x	x	x	
Capability c	x			x
Capability d			x	x

Table B: Role (Actor) -Function

	Role (Actor A)	Role (Actor B)	Role (Actor C)	Role (Actor D)
Function 1	x	x		x
Function 2		x	x	
Function 3	x	x		
Function 4			x	x

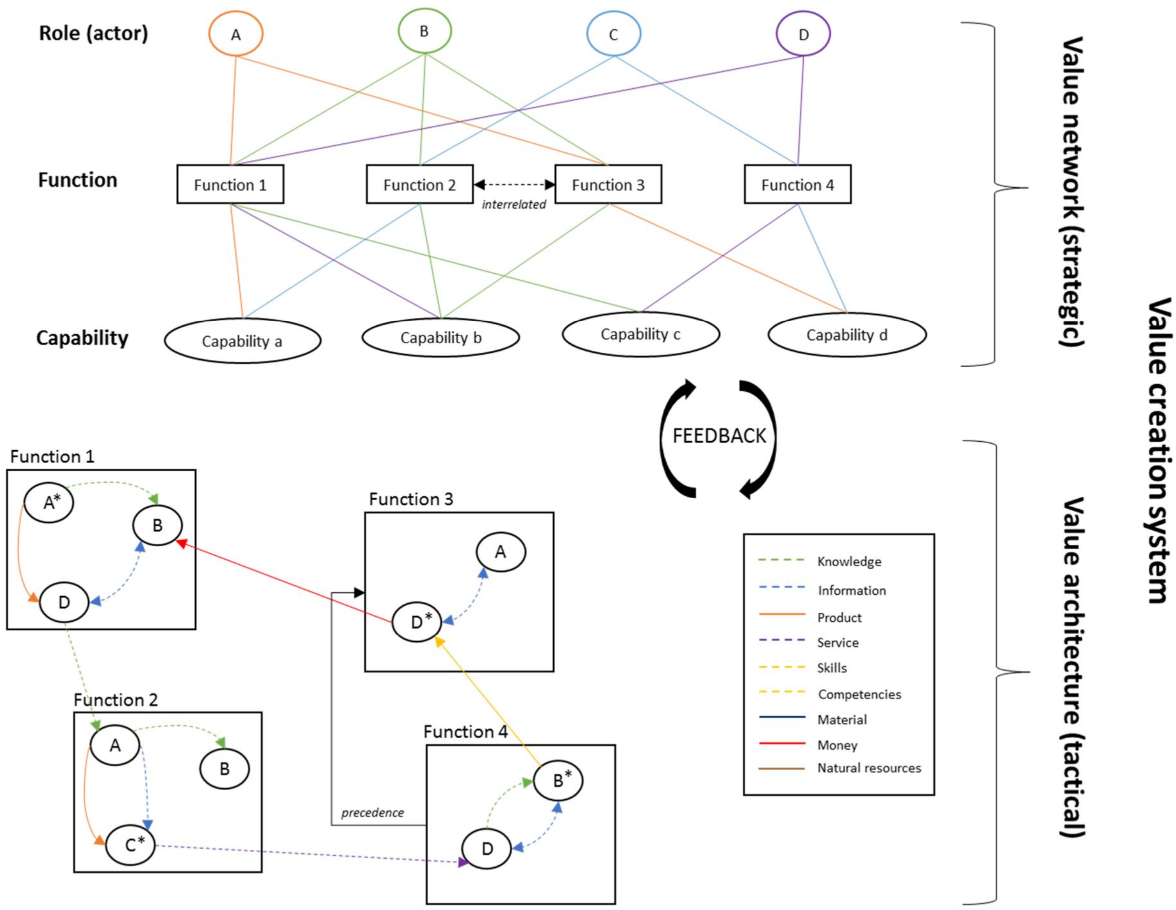


Figure 5.4: Example of SBN configuration process application

5.3 Internal evaluation of the conceptual framework

The internal evaluation of the initial conceptual framework was the first framework evaluation step conducted in this study. This evaluation was done based on a previously developed research artefact, namely, the hierarchical taxonomy of the networked BMI concept which aimed to provide a set of requirements on how to approach the networked BMI concept. The reason for conducting internal evaluation (self-reflecting on the previously stated requirements) was to ensure that subsequent management framework designs based on the conceptual framework are adequately grounded on the theoretical findings made up to this point. Therefore, the hierarchical taxonomy of the networked BMI concept (Section 4.3) was used to evaluate the conceptual framework. The additional four development dimensions (discussed in Section 4.6.1) were also included.

Table 5.2 below contains the facets and classes of the hierarchical taxonomy, together with a brief description of how each class was implemented or addressed within the initial conceptual framework. The descriptions of each class presented in Section 4.3 were used to guide the researcher in performing the evaluation regarding the implementation of the specific class within the initial conceptual framework.

Table 5.2: Internal conceptual framework evaluation based on the hierarchical taxonomy

Facet	Class	Implementation within framework	
Networked BM elements	(1) Value proposition	√	The selected networked BM elements from each of the four value dimensions are systematically developed throughout the phases of the conceptual framework – all categorised under the *Networked BM* development dimension. Within the ideation phase, different ideas for the configurations of the different elements are proposed. Within the feasibility phase, the feasibility of the proposed ideas and configurations are investigated, and prototypes of the elements are created in the prototyping phase. Based on the different prototypes, final configurations and definitions are selected in the decision-making phase and are implemented in the implementation phase. During implementation, and throughout the sustainability phase, the performance of these configurations is measured, evaluated and the necessary adjustments are implemented to ensure successful operation and alignment of the networked BM.
	(2) Value network	√	
	(3) Value architecture	√	
	(4) Value finance	√	
Development dimensions	(5) Business opportunity	√	Potential business opportunities are identified, developed, prototyped, and the selected opportunities are implemented throughout the framework – categorised under the *business opportunity* development dimension. These potential business opportunities can however not be pursued by a single actor, and therefore initiate the development and formation of a potential strategic business net to produce a joint offering to the customer.
	(6) Network-level strategy	√	Within the analysis phase, the ecosystem is analysed to inform the direction of the strategic business net. During the feasibility phase a strategy for the network is developed to provide strategic guidance on how the business opportunity can be pursued. Within the prototyping stage, more details are added on how the network will produce the joint offering on a strategic level, as well as how the market will be approached. Within the decision-making phase, strategic plans, applicable to the entire network, are finalised and implemented within the implementation phase.
	(7) Strategic business net	√	Within the analysis phase, the need for the formation of a strategic business net to address potential business opportunities are recognised and consequently developed throughout the framework under the *strategic business net* development dimension. The importance of the configuration of the net is stressed by the development of the SBN configuration process that is implemented in a stepwise manner throughout the framework phases. Furthermore, specific strategic business net features were identified (in addition to the value network elements that form part of the networked BM) which are also specifically considered throughout the framework phases.
	(8) Networked BM	√	The networked BM elements contained within this development dimension is discussed under the *Networked BM elements* facet. Furthermore, within the prototyping phase, the alignment of the elements is addressed, and within the decision-making phase, the harmonisation of the elements is included.
	(9) Firm-level business	√	Within the framework, the steps categorised within this development dimension, touches on what needs to happen on the firm-level during the BMI endeavour. These steps are not comprehensive but aim to provide a bit of guidance and ensure the framework is comprehensive.

Facet	Class	Implementation within framework	
	(10) (Additive Manufacturing) Technology	√	Within the framework, the steps categorised within this development dimension, touches on what needs to happen on the firm-level during the BMI endeavour regarding the AM technology. Although the conceptual framework only contains one step regarding this development dimension, more steps will be added during the development of the management framework in Chapter 6.
Functions	(11) Shared mental model	√	The use of the SBN configuration process throughout the framework (associated with all the strategic business net configurations steps) ensures that a shared mental model on the operation of the strategic business net is created. Furthermore, the involvement of partners at an early stage ensures everyone is on the same page regarding the objectives of the strategic business net. Since a future state strategic business net and networked BM are developed, a shared mental model is important although many unknowns and assumptions might still be present.
	(12) Alignment	√	Throughout the framework, alignment is addressed to ensure the networked BM, strategies, and the strategic business net is aligned internally on the network-level, as well as ensuring alignment on the firm-level and with the external environment (as discussed in Section 3.3.1). The alignment is also addressed through the use of the different development dimensions, categorised into the strategic, tactical, and operational views of the network.
	(13) Collaboration	√	The framework sets out to promote collaboration among network partners, through the formation of a strategic business net, working together to create a joint offering and pursue the identified business opportunities.
	(14) Complementarity	√	During the feasibility phase of the framework, potential partners are evaluated based on a predetermined criterion, including the evaluation and identification and evaluation of complementary capabilities and resources.
	(15) Knowledge	√	Throughout the framework, different aspects, features, and elements are developed, analysed, and assessed to ensure knowledge is created and shared between the partners regarding the operation of the strategic business net in providing the joint offering.
	(16) Synergy	√	As part of the partner selection process in the feasibility phase, synergies are assessed to ensure each partner bring value to the network and in combination, the bigger value will be able to be created during the value co-creating process.
BM reach	(17) Inter-organisational	√	Due to the nature of the business opportunity, a single actor is not able to realise the business opportunity, and therefore it is required to form a strategic business net, implying different actors or partners from other organisations are included.
	(18) Intermediate layer	√	The networked BM is located on the intermediate layer of the network, and consequently developed and implemented on a detailed level throughout the framework's phases. However, to ensure alignment and coherence between the strategic and organisational layers of the network, the *network-level strategy* and *firm-level business* development dimensions are also included and developed throughout the framework. No details of these layers are included, but to ensure the BMI process is successfully executed and alignment is achieved with the networked BM and strategic business net, it could not simply be excluded from the framework.
Modelling principles	(19) Holistic	√	The framework is holistic as it addresses all the phases of BMI (as identified in Section 3.4.3) and includes all the required levels of development throughout each of the phases.
	(20) Conceptual	√	The framework is conceptual as it provides guidance regarding what concepts (including elements, features) need to be addressed when

Facet	Class	Implementation within framework	
			throughout the BMI endeavour. The framework is not predictive or prescriptive in nature, therefore it adopts a conceptual structure.
	(21) Modular	√	A modular approach to the networked BMI concept is achieved using phases, sub-phases and different development dimensions throughout the framework. Within each main step (associated with the different development dimensions), different sub-steps are proposed, giving it a modular structure.
	(22) Structured	√	The framework is semi-structured, as phases and steps are proposed to be executed in order, however, the steps can be altered, adapted, and executed to fit the specific business requirements and BMI scope.
	(23) Dynamic	√	The framework is dynamic as it progresses through different steps where different elements, concepts and aspects are developed and tested before implementation to ensure necessary adjustments are made according to changes that happen internally or externally. Furthermore, it is proposed that after each sub-phase is executed, feedback loops need to be in place to ensure necessary adjustments are made in previous steps when needed.
	(24) Coherent	√	Coherence is established throughout the framework as the links and relationships between the different development levels are constantly considered.
Mapping levels	(25) Actors	√	The strategic configuration of the strategic business net, developed throughout the framework, is based on the actors, functions, and capabilities identified (discussed and developed in Section 4.5). (The main components of the SBN configuration process).
	(26) Functions	√	
	(27) Capabilities	√	
Value creation levels	(28) End-customer value	√	Within the decision-making phase, each function that forms part of the strategic business net is evaluated to determine if it creates value and on which level (discussed in Section 3.5.1). If no value is created by a function, or through an exchange or flow within a function, it must be re-evaluated or removed.
	(29) Business value	√	
	(30) Collaborative value	√	
Systemic development phases	(31) Sensing	√	It is one of the primary phases of the framework; divided into the following sub-phases: analysis and ideation.
	(32) Seizing	√	It is one of the primary phases of the framework; divided into the following sub-phases: feasibility and prototyping.
	(33) Transforming	√	It is one of the primary phases of the framework; divided into the following sub-phases: decision-making, implementation, and sustainability.
Innovation phase	(34) Research and Development	√	The three innovation phases of the emerging technology development are briefly addressed within the conceptual framework but will however be addressed and included in more detail during the development of the management framework. The innovation phases are however closely associated with the *AM technology* development dimension.
	(35) Pilot	√	
	(36) Market	√	

5.4 Conclusion: Chapter 5

This chapter presented the results from the preliminary evaluation of the SBN configuration process, using a real-life scenario, as well as the initial conceptual framework, using the developed hierarchical taxonomy. Although the real-life scenario only focused on the application and demonstration of the SBN configuration process as a management tool, the interaction with employees from an SMME that operates within the South African environment confirmed the need for a strategic management tool to guide SMMEs during their transformation process from firm-level to network-level. Company A focused on technical aspects and therefore lacked business and management skills in-house, confirming the statements made in Section 1.4, which are ultimately the gap that needs to be addressed by the management tool.

It is furthermore concluded that most of the facets contained within the hierarchical taxonomy were adequately addressed in the initial conceptual framework, except for the *AM technology* development dimension that will be addressed in Chapter 6. Therefore, the initial conceptual framework provides an appropriate foundation for the development of the management framework.

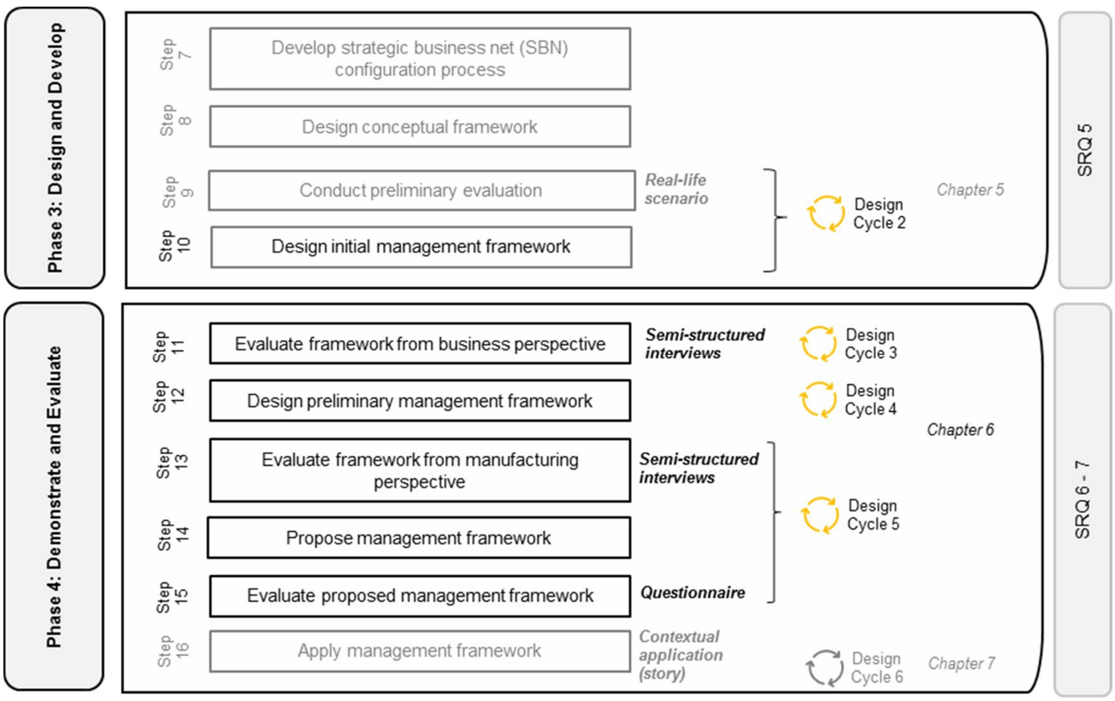
The next chapter discusses the development and evaluation of the management framework in detail to conclude the third phase and proceed with the fourth phase of this study.

Chapter 6: Management framework development

In Chapter 6 the development and evaluation of the management framework are discussed, answering SRQ6. The conceptual framework which was presented in Chapter 4 and evaluated in Chapter 5 forms the theoretical foundation of the management framework. The management framework is developed and evaluated using a systemic and stepwise approach. Building on the conceptual framework with a business perspective, a preliminary management framework is proposed, concluding the second design cycle iteration. During Design Cycle 3, the preliminary management framework is evaluated by business subject-matter experts and adjustments are made accordingly. After the evaluation, more of the study's context is added to the framework (AM, SMME) using the information identified in the structured literature review in Chapter 3, concluding Design Cycle 4. Following the next step in the evaluation process (Design Cycle 5), the management framework is evaluated by manufacturing subject-matter experts. As part of this cycle, the subject-matter experts from both categories evaluated the perceived effort and importance of the activities contained in the preliminary management framework. After all results, findings and modifications were applied, a management framework is proposed.

Chapter 6 key objectives:

- Present the development and evaluation approach of the management framework (Section 6.1).
- Present a high-level overview of the initial management framework (Section 6.3).
- Discuss the external evaluation process and findings conducted by business experts (Section 6.4).
- Present a high-level overview of the preliminary management framework (Section 6.5).
- Discuss the external evaluation process and findings conducted by the manufacturing experts (Section 6.6).
- Discuss the external evaluation process and findings on the framework's activities (Section 6.7).
- Present a high-level overview of the proposed management framework (Section 6.8).



6.1 Development and evaluation approach

Part E of the systemic approach concerns the development and evaluation of the management framework in a stepwise manner, depicted in Figure 6.1, answering SRQ6 namely: *What aspects must be included in a potential management framework, based on the conceptual framework and external evaluations?* During *Part E-1* of the development, the conceptual framework developed in Section 4.6 was used as the foundation, and more details were added to the steps. The details included the allocation of more specific activities within each step contained in the framework. Furthermore, selected tools (widely used in industry) were allocated to selected steps and specific concepts and definitions were included in the framework. The initial framework was only developed from a business perspective, and no specific details of AM were included yet at this stage.

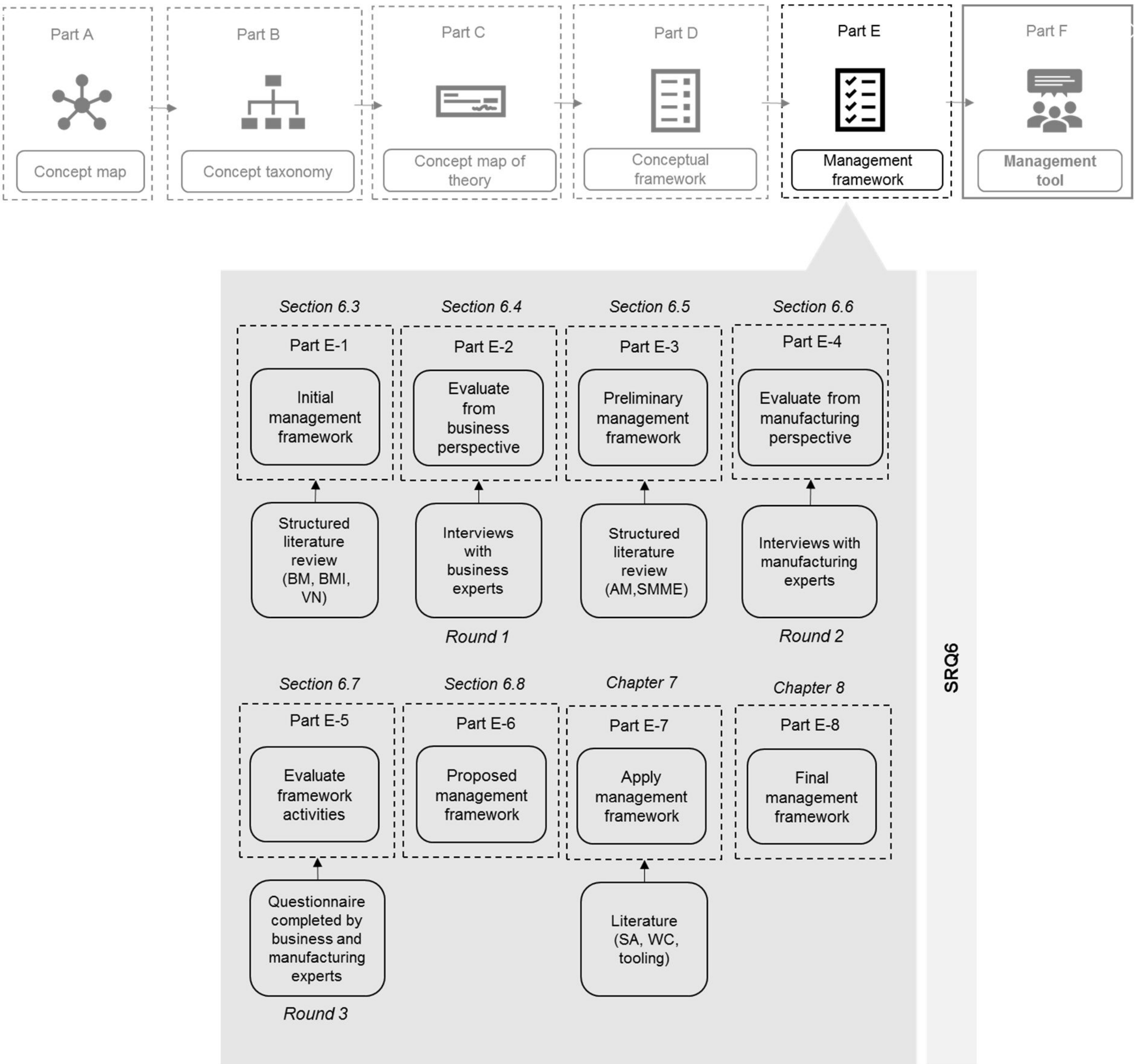


Figure 6.1: Systemic development and evaluation of the management framework (SRQ6)

After the initial framework was developed, four business management subject-matter experts were approached for semi-structured interviews, forming *Part E-2*. During the interviews, a few of the other research artefacts (including the hierarchical taxonomy, concept map of theory, and SBN configuration process) were also discussed and evaluated. The evaluation conducted through the semi-structured interviews ensured the framework was theoretically sound from a business perspective and practically relevant in a business environment, concluding *Round 1* of the external evaluation.

During *Part E-3*, the framework was further developed into a preliminary management framework through the addition of the literature findings regarding AM and operations of an SMME. Throughout each phase of the framework, steps were added to analyse, develop, and implement AM as an integral part of the business opportunity pursued by the strategic business net. In *Part E-4*, the proposed management framework's logic and soundness were evaluated by five manufacturing (including AM) subject-matter experts through semi-structured interviews, concluding *Round 2* of the external evaluation.

After the semi-structured interviews were completed, questionnaires were sent to the business and manufacturing experts with whom interviews were conducted, as well as a few additional experts from each category, completing *Part E-5*. The questionnaire contained the selected networked BM elements, the strategic business net features, as well as all the activities contained in the management framework, and perceived effort and importance ratings were allocated by the participating experts. After the experts completed the questionnaires, results were analysed and discussed, leading to a proposed management framework in *Part E-6,* concluding *Round 3* of the external evaluation as well as Chapter 6. Chapter 7 contains the details on the execution of *Part E-7* by applying the management framework to the prospective cemented tungsten carbide AM sector of South Africa. The final management framework, *Part E-8*, is presented in Chapter 8.

Table 6.1 below summarises all the subject-matter experts approached during this study, as well as the research artefacts evaluated by each expert. These experts are introduced in the following sections. Furthermore, Table 6.2 summarises the total participants approached from the two expert categories during each round of external evaluation, as well as the corresponding section that reports the findings.

Table 6.1: Subject-matter expert evaluation summary

Category	Background					Semi-structured interview					Structured questionnaire		
	Subject-matter expert	**Years of experience**	**Industry expertise**	**Academic expertise**	**AM expertise**	**Hierarchical taxonomy**	**Concept map of theory**	**SBN configuration process**	**Initial management framework**	**Preliminary management**	**Networked BM elements**	**Strategic business net features**	**Proposed management framework activities**
Business experts	**A**	>20	x			x	x	x	x		x	x	x
	B	>24	x			x	x	x	x		x	x	x
	C	>29	x			x	x	x	x		x	x	x
	D	>30	x	x		x	x	x	x		x	x	x
	J	>21	x	x							x	x	x
Manufacturing experts	**E**	<10		x	x			x		x	x	x	x
	F	>35	x							x	x	x	x
	G	>25	x							x	x	x	x
	H	>17	x	x	x					x			
	I	>10	x	x	x			x		x			
	K	>25	x								x	x	x
	L	>10	x		x						x	x	x

Table 6.2: Summary of external evaluation (Rounds 1-3)

	Total participants	Business experts	Manufacturing experts	Section reported
Round 1	4	A,B,C,D		Section 6.4
Round 2	5		E, F, G, H, I	Section 6.6
Round 3	10	A, B, C, D, J	E, F, G, K, L	Section 6.7

The management framework is ultimately an output from the other research artefacts designed and developed up until this point in the study. Figure 6.2 below illustrates the proposed relationships between all the artefacts. The concept map designed in Section 4.2 *informed* the concept taxonomy designed in Section 4.3. The concept taxonomy proposed a more structured and hierarchical approach to the networked BMI concept, based on the concepts contained in the concept map. The concept map was also used as a *checklist* during the design of the conceptual framework (Section 4.5), to ensure all fundamental concepts were addressed within the framework.

Furthermore, the concept map of theory designed in Section 4.4 provided a more holistic approach to the networked BMI concept and was thus regarded as a set of *requirements for* both the conceptual framework and the management framework. Due to the conceptual nature of the conceptual hierarchical taxonomy, a concept map of theory was designed to *depict* the information contained in the taxonomy in a more visual way. The concept map of theory, therefore, provided *theoretical guidance for* the design and development of the conceptual framework that aimed to provide more logical steps on how to practically approach the networked BMI concept. The management framework developed within this chapter is however an extension and more *detailed version of* the conceptual framework, through the inclusion of more activities, tools, and considerations. During the development process of the management framework, more AM aspects were added to ensure the framework is indeed applicable to the identified context.

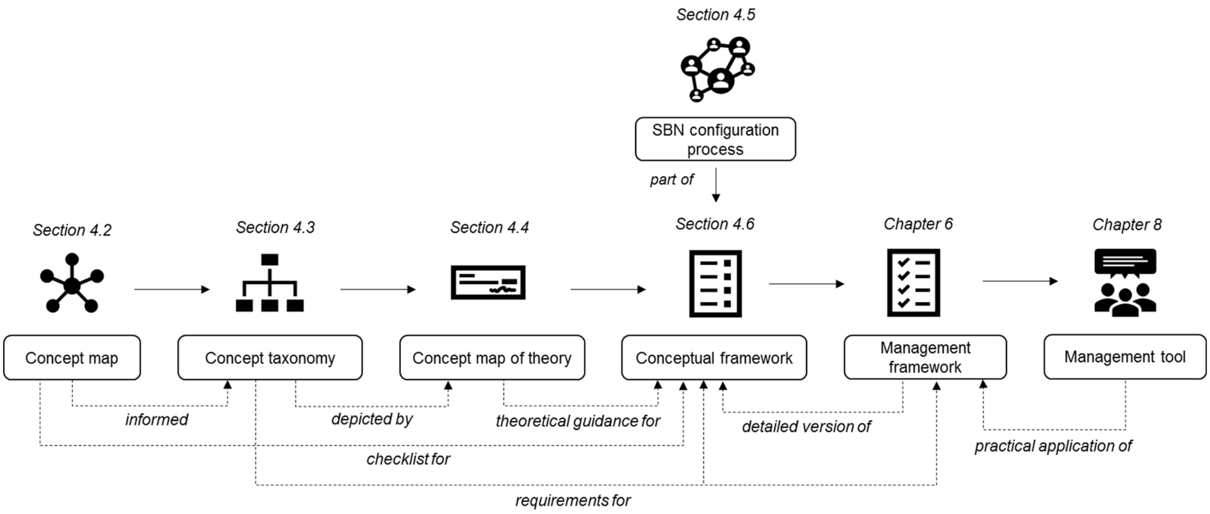


Figure 6.2: Relationships among research artefacts

Figure 6.3 aims to consolidate the six design cycles identified in Chapter 2, with the management framework development and evaluation described above. In summary, the aim of the first two design cycle iterations is to develop an initial management framework. During the third design cycle iteration, the initial management framework is evaluated from a business management perspective, concluding the business development phase. The following design cycle iteration aims to include the AM perspective, resulting in the preliminary framework that is evaluated from a manufacturing and AM manufacturing perspective. After all expert evaluations are completed, including the questionnaire, a management framework is proposed and applied in the context of this study during the last design cycle iteration. All findings are leveraged to ultimately present the final management framework and convert it to a management tool in Chapter 8.

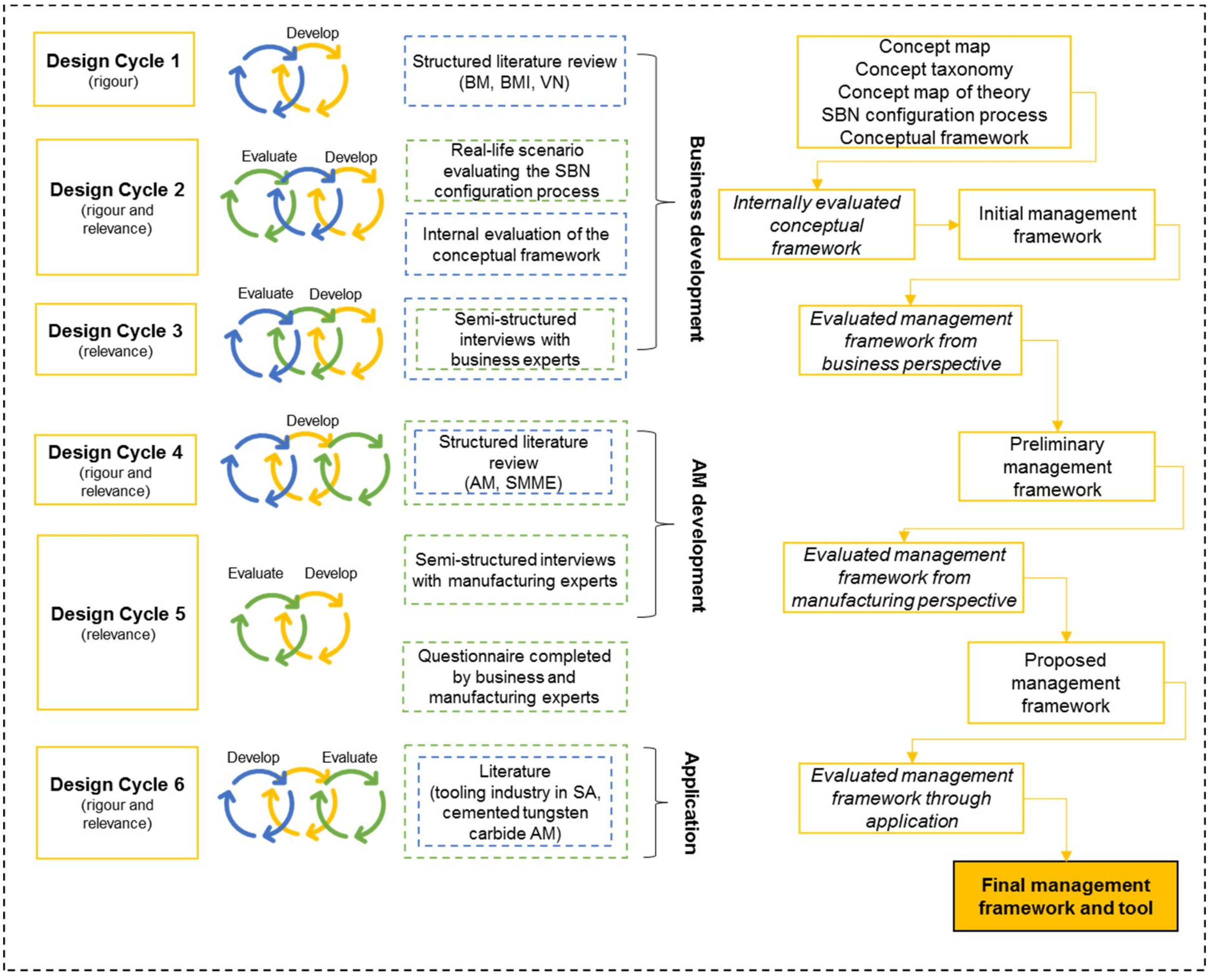


Figure 6.3: Design cycles execution throughout the study

6.2 Management framework and tool characteristics

In line with the Generic BMI Process suggested by Wirtz and Daiser [245] (discussed in Section 3.4.3) on a firm-level, this framework aims to provide a comprehensive and holistic perspective of the BMI process, on the network-level. Regarding opportunity networks which are emerging networks, Peppard and Rylander [181] stated *"no one knows what they will look like in the future".* Accordingly, the management framework and tool developed within this study aim to provide guidance towards the configuration of a possible opportunity network (and related aspects), that needs constant evaluation and adjustments as new insights and information become available. Furthermore, as in the case with the framework from Wirtz and Daiser [245], this management framework is not a ready-made, one-size-fits-all framework, but requires adjustments to the activities and sequence, according to the user's business requirements.

Another characteristic of the management framework, following Wirtz and Daiser [245], is the multi-directional character of the BMI process. It is presented as semi-structured flow of activities that must be matched with the specific requirements and needs of the respective BMI initiative (discussed in Section 3.4.3). Thus, it is not prescriptive in nature, but rather aim to provide guidance (check list) to users which are not necessarily business or business management experts. All the phases, sub-phases and development dimensions are not prerequisites for the networked BMI initiative, and some phases may be passed several times and some not at all [245]. However, the initial planning of the BMI initiative should start with an extensive process, taking into account each possible BMI process phase, and each decision concerning deviations from this plan or upcoming variances from the course of the BMI initiative should always be based on a holistic perspective on the BMI process [245].

Using the scheme of analysis proposed by Bankvall *et al.* [20] and presented by Jocevski *et al.* [111] (discussed in Section 3.2.1), the BM contained within the management framework (and tool) are 'network-centric', which are analysed from a 'network-level', meaning *"VN configuration to create and deliver a common value proposition"* [20]

Furthermore, using the classification criterion for BMI processes or frameworks suggested by Pieroni *et al.* [184] (discussed in Section 3.3.1), the proposed management framework (and tool) characteristics can be classified as follows, ensuring the research gaps identified in Chapter 1 are adequately addressed:

- **Data nature:** Qualitative
- **System boundaries:** Inter-organisational
- **Abstraction level of representation:** Moderately aggregated to detailed
- **Variation over time:** Dynamic
- **Representation style:**
    - **Method:** Guideline
    - **Tool:** Visualisation tool

The shift from firm-level BMs to network-level BMs require a change of management focus [243], therefore the proposed framework needs to be sound from a business or management perspective. The shift also requires the input of many actors [111], emphasising the inter-organisational nature of the framework. It is however recognised that although input from other actors is required, it is not necessarily needed to involve everybody from the beginning, nor needed to disclose all information to everyone. Therefore, the first two sub-phases of the framework are executed by the focal firm, whereafter partners are selected, approached, and included to participate in the execution of certain activities. The presented management tool provides a guideline of where in the process to potentially involve and include partners.

Furthermore, during the development of the management framework, the potential user or target audience of the management framework needed to be kept in mind. This includes general characteristics of typical manufacturing SMMEs, as well as potential AM SMMEs and start-ups or entrepreneurs that relate to the contextual application of this study. Therefore, the subject-matter experts were asked to state the user requirements from their perspective. The requirements suggested by the experts are presented in Section 6.4 and discussed in Section 8.9.

6.3 Part E-1: Initial management framework

During the transformation process from the conceptual framework to the initial management framework, more details (activities, tools, guiding questions, and considerations) regarding each step were added to specifically help SMMEs with the development of their networked BMs as well as their strategic business nets. The development of this framework concluded

Design Cycle 2. Figure 6.4 provides a description of the different development phases contained within the framework.

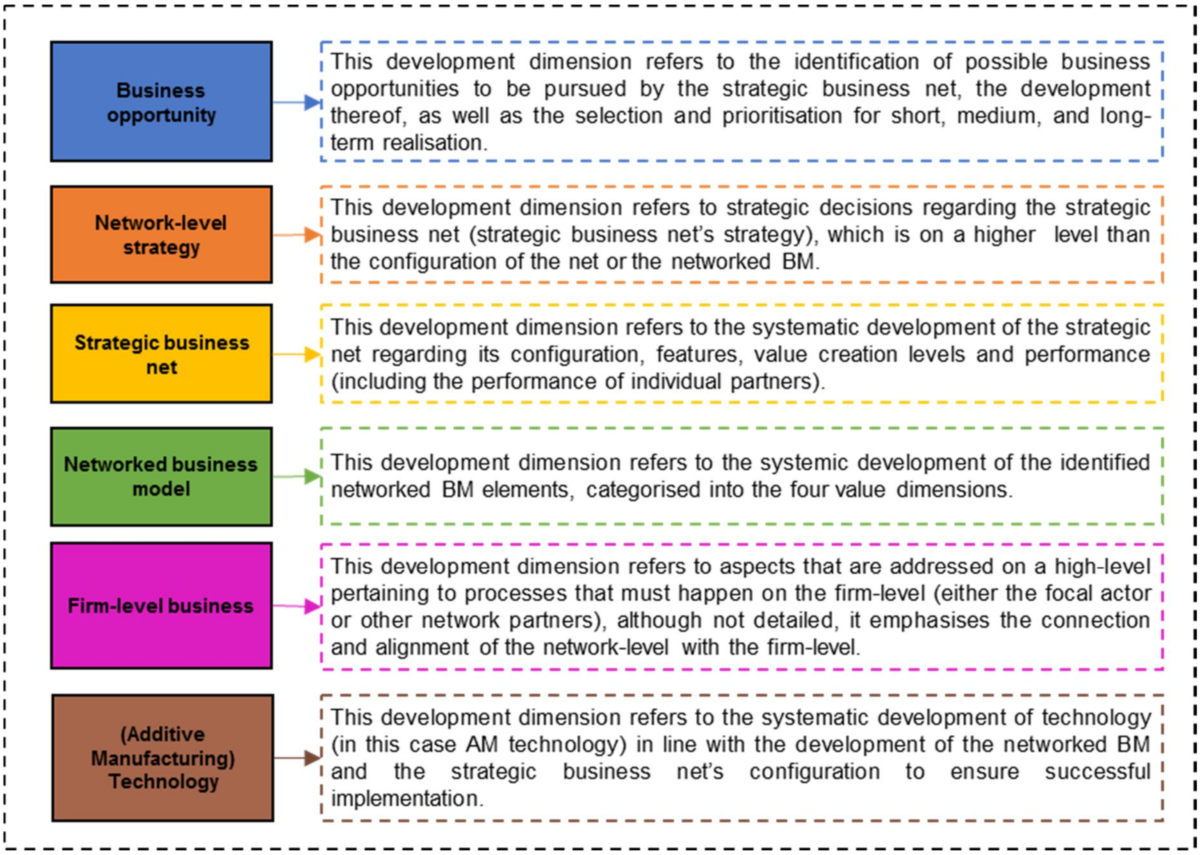


Figure 6.4: Development dimensions descriptions

Figure 6.5 provides the high-level structure of the initial management framework, indicating the main phases, sub-phases, and key steps within the framework (the colours are associated with the development dimensions). Although the steps may seem to be sequential, it need not be executed in this specific order as this is only one interpretation and one proposal as the sequence will almost definitely change, depending on the specific business and application. More details of the initial management framework are not displayed here, but the sub-steps are based on the conceptual framework, refer to Section 4.6. The final management framework is presented in Appendix F.

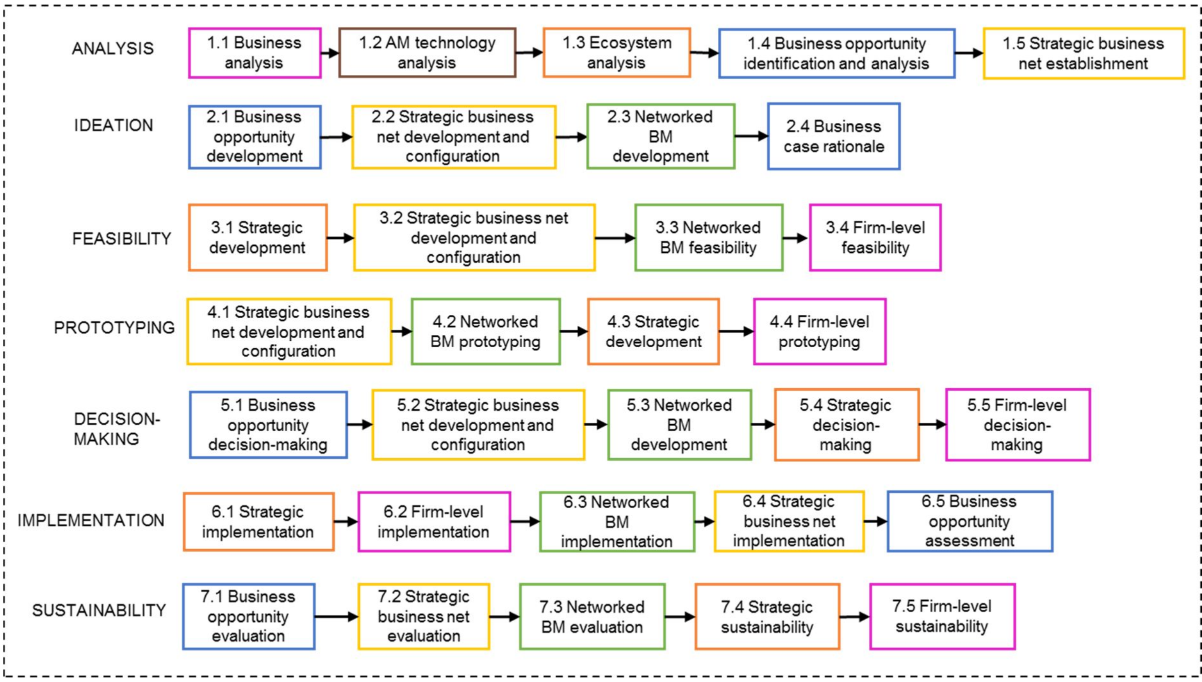


Figure 6.5: High-level overview of the initial management framework

6.4 Part E-2: External evaluation from a business perspective (Round 1)

This section discusses the first external evaluation of the designs of the research artefacts (including the initial management framework) from a business perspective, forming part of Design Cycle 3. After the evaluation was conducted through semi-structured interviews, the management framework was adapted to conclude this design cycle.

6.4.1 Interview purpose

The purpose of the first set of interviews conducted with business experts was to evaluate the theoretical argument presented in this study on which the framework is based, from a business perspective. Evaluating the framework from a business perspective is of utmost importance since the shift from firm-level BMs to network-level BMs require a change of management focus [243]. To evaluate the argument, the logic and process followed to develop the framework was explained to the experts. Throughout this process, the relevance of the hierarchical taxonomy, concept map of theory and the SBN configuration process was evaluated. The adapted hierarchical taxonomy and concept map of theory, presented in Chapter 8, were used which included all six development dimensions, instead of only the two dimensions presented in Chapter 4. In summary, the first set of interviews aimed to:

- Evaluate the applicability and relevance of the theoretical argument presented in this study from a business perspective.
- Confirm the logic followed to practically present the integration of the theoretical frameworks (hierarchical taxonomy, concept map of theory, SBN configuration process).
- Acquire the practical requirements of a management framework for SMMEs.
- Adapt the management framework according to suggestions made to ensure its relevance and rigour; and
- Obtain focused insights for further development of the framework.

6.4.2 Identification of the interviewees

The experts approached for these interviews formed part of the first category of subject-matter experts, namely business experts. Several potential interviewees were identified to form part of this group of experts and were contacted with a request for participation in this study. A total of four experts participated in these initial interviews and are introduced in the following section to provide a brief background to the participants and to establish their relevance, Table 6.3 provide a summary. An additional expert that also forms part of this first category of experts (business experts) were approached during the evaluation of the specific activities using the questionnaire, presented in Section 6.7.

The first interviewee (A) has a background in business management with more than 20 years of experience in management. The participant is the managing director of an SMME based in South Africa, with operations throughout Africa. The interviewee is well acquainted with BM development for SMMEs as well as the implementation of innovation endeavours in small businesses.

The second interviewee (B) has worked as a director and strategic development consultant for more than 24 years, focusing on innovation, sales and marketing, financial, strategic, and tactical management. Being the National Sales and Innovations manager, the participant obtained extensive knowledge on the implementation of innovation, including product, process, and BM innovation. The interviewee is currently managing an SMME that was established a few years ago as a start-up.

The third interviewee (C) has a background in engineering and general management for over 29 years. The participant's educational background includes a B.Eng Degree in Mechanical Engineering, a certificate in the senior management programme and strategic management, as well as a certificate in industrial engineering.

The fourth interviewee (D) for this category has a background in business, engineering, and manufacturing for over 30 years. The interviewee obtained a BEng, MBA, and PhD in Industrial Engineering throughout his career. The participant was also a professor at the University of Pretoria and specialises in supply chain management, manufacturing, project management and business efficiency.

Table 6.3: Subject-matter experts evaluation summary (Round 1)

Category	Background					Semi-structured interview			
	Subject-matter expert	Years of experience	Industry expertise	Academic expertise	AM expertise	Hierarchical taxonomy	Concept map of theory	SBN configuration process	Initial management framework
Business experts	A	>20	x			x	x	x	x
	B	>24	x			x	x	x	x
	C	>29	x			x	x	x	x
	D	>30	x	x		x	x	x	x

6.4.3 Interview protocol / guideline

The semi-structured interview was selected to collect relevant data from the subject-matter experts to achieve the purpose of the interview. Yin [249] suggested that a discussion guideline need to be developed when conducting interviews to ensure that the purpose of the interview is achieved. The discussion guideline followed in these interviews is provided in Appendix D.

Before the first interview, the interviewee was provided with the complete interview guideline, containing an overview of the research as well as the selected research artefacts (including the initial management framework) to enable the interviewee to familiarise themselves with the content that would be discussed. Due to the complex nature of the study and the relationships between the artefacts, this turned out to be ineffective as the expert was overwhelmed with the information. Therefore, it was decided to adapt the protocol from the second interview onwards to ensure the interviewee is comfortable and accommodated.

The approach was thus adapted, and the information contained within the interview guideline was shared with the participants in separate units. Before the interview, the interviewee received the briefing document to provide an overview of what the research study is about, and to obtain informed consent regarding participation in this study. A meeting was scheduled where the researcher discussed the research artefacts in more detail (see the slides in Appendix D), and to provide a thorough understanding of the reasoning behind each artefact. The interviewee was also allowed to ask clarification questions and provide some feedback or suggestions during this meeting. The interviewee was then given the chance to review the artefacts and management framework in their own time, whereafter another meeting was scheduled where the interviewee provided feedback and answers to the semi-structured questions.

The recordings of the feedback received, and discussions of the interview questions were analysed, and the findings from these interviews are discussed in the following sections, according to each research artefact.

6.4.4 Interview results and findings

The interview findings are firstly categorised according to the research artefacts evaluated within this evaluation phase. Therefore, the findings related to the hierarchical taxonomy is discussed first, whereafter the findings related to the concept map of theory is discussed. Following the discussion of the findings related to the SBN configuration process, and lastly, findings related to the initial management framework. The findings related to the initial management framework are discussed in terms of the different aspects and themes related to the framework.

6.4.4.1 Hierarchical taxonomy

All four of the interviewees agreed that the facets, classes, and relationships between the facets used in the hierarchical taxonomy make sense and are logical for this study. Regarding the completeness of covering elements from all three literature bodies, it was agreed that it was sufficient for this study, but not completely comprehensive, as it was noted that all three literature bodies have more relevant elements that could still be added. This was acknowledged during the development of the concept map in Section 4.2, but to ensure a logical and understandable structure, the most prominent concepts were selected to form part of the hierarchical taxonomy, which are based on the BM structure proposed by Al-Debei and Avison [6] and the addition of the main concepts from the selected theoretical frameworks.

Interviewee B confirmed that based on their experience, the taxonomy is indeed holistic, including the selected networked BM elements, as it touches on aspects from each business function and all managers or executives within an SMME would indeed be able to resonate with the argument presented and understand their role to be played during the transformation process. The participant stated *"If you present this model or taxonomy to an executive committee or something similar, typically the head of sales, marketing, finance and operations will sit around the table. It is therefore important to recognise everyone's role in the process so that they can resonate with the concept. Any executive that will look at this taxonomy, including the BM elements, will immediately steal ideas, and that is good, as they will use the knowledge you present and apply it to their focus area."* None of the experts suggested any structural changes or additions to the hierarchical taxonomy. Based on the positive feedback received, no modifications were made to the hierarchical taxonomy because of the interviewees (presented in Section 8.3).

6.4.4.2 Concept map of theory

The interviewees agreed with the proposed relationship between the technology innovation phases and the networked BMI process. However, the following was noted by interviewee C: *"this is the ideal situation, unless 'pressure' from outside forces the process to be faster, then there could be a slight overlap between phases."* It is therefore acknowledged that the entire argument and framework proposed within this study is an 'ideal' BMI situation but may not necessarily be practically implemented as suggested. Therefore, it is required that the management tool need to be easy to amend because of changing business requirements.

The second interviewee, participant B, noted that some of the terms or concepts used within the map (such as the four value dimensions) may be theoretical or academic terms that may be difficult to understand if one only has experience in the industry. The participant suggested that if the concept map of theory is to be explained to management, the use of the following terms and where they fit in will be valuable: *"finance, sales and marketing, operations, human resources".* However, interviewee C believed that the terms are commonly used within the industry and therefore well-known. Furthermore, all interviewees agreed that the concept map of theory presents a logical argument that can easily be interpreted and is therefore indeed a valuable contribution to the research body, being well defined and generally acceptable.

6.4.4.3 SBN configuration process

All interviewees agreed that the process makes practical sense with a good logical flow of steps. Regarding the usefulness of the process, the interviewees felt positive, with good applicability potential to SMMEs and manufacturing SMMEs. The interviewees furthermore agreed that it provides a good visualisation of the strategic business net on a strategic level, however one believed it is an excellent visualisation on the tactical level, two thought it was good, and one interviewee felt it was only fair. This dispersed view may be because of different perspectives and backgrounds, as well as due to different definitions or interpretations of what tactical visualisation is for a VN

Regarding suggestions for improvements of the process, participant A suggested the use of case studies to illustrate the framework more practically, as well as the possible inclusion of personas and user stories or use cases to make it more tangible, which may add some value to the process and framework. Although this suggestion may be valuable, within the context of planning a strategic business net, it may be too detailed, therefore it was not further investigated or implemented within this process.

6.4.4.4 Initial management framework

The interviewees agreed that due to the extensive nature of the management framework, it is indeed very practical as no *"foreign concepts"* are used, and thorough explanations of all concepts are provided, therefore the potential user knows what is going on and what must be done. During the discussion about the integration of the theoretical components into a unified framework, the interviewees agreed that it is a good representation, interviewee B stated: *"From practical experience, this is the most acceptable approach. There are clear gates to progress to the next phase or stop in a phase if a result is not acceptable, which is good. However, you can think on improving the details regarding the feedback process (who reports to who and when), as well as guidelines regarding conditions to proceed to the next phase".* Although it is a very valid point and could be a valuable contribution to the framework, those details are beyond the scope of what the management framework aims to achieve.

The discussions on the tools included in the framework led to the conclusion that all interviewees believed that the tools are well known, and can easily be applied, although various other tools might also be applicable and valuable, depending on the current operations of the SMME. Thus, although there are tools included in the framework to aid with the execution of some of the steps, it is merely just a suggestion, and can be changed to any other applicable tools, depending on what the user feels comfortable with or based on existing tools used within the organisation.

In addition, participant A proposed the use of 'de Bono models' to encourage employee participation during the BMI ideation phase, to aid in the challenge regarding the potential lack of participation from employees. As the interviewee stated that during change processes, employees might be resistant to change caused by the unknowns, and therefore it is important, especially in small businesses, to include everybody, acknowledge their opinion, and value their contributions to ensure a successful transformation. The interviewee furthermore also suggested the use of brainstorming as a tool to identify and explore business opportunities as it improves creative thinking and design. The second interviewee suggested the use of scrum sessions (an agile method) to implement the different steps and phases within the framework.

Regarding the implementation of the framework, three of the interviewees raised concerns regarding the *'ownership'* or *'facilitation'* of the framework i.e., who within the organisation will take responsibility for the framework and drive the implementation thereof. This also includes the feedback structures that need to be in place within the organisation or network, if decisions are made, who will approve it, and who will execute it. Furthermore, another discussion point that came up during one of the interviewees is the possibility that the potential facilitator of the management tool might need some form of training on the application of the management tool, as well as the other tools contained within the framework.

It is acknowledged that the implementation of the framework has many challenges related to it. During the interviews, time and resource constraints were noted as two of the main challenges of change processes within SMMEs. Furthermore, *'buy in'* from SMMEs, management and employees are a major factor to consider according to all four participants. Interviewee C noted that to ensure adoption, the framework will need to provide answers to the questions of *"what is in it for me?"* and *"how will it benefit me?" A*nother major challenge with such a framework is the integration of the process and activities with existing organisational processes, structures, and systems, proposed by interviewees number two and four. Participant A furthermore noted that the biggest constraint and challenge for any SMME operating in South Africa is *"political factors and influences"* as most of the problems and challenges often experienced by SMMEs is not internally but *"caused externally from politics*".

Participants B and D noted that the framework are very comprehensive and will provide sufficient guidance for an SMME or entrepreneur, given that they understand the potential of the framework and regard it as a guiding framework, and not a recipe that will guarantee success. Interviewee B also noted that the user-friendliness of the framework in its current table format is not very user friendly, but the presentation of the framework in a mind map format will indeed be user-friendly and easy to understand and practically execute the activities. None of the participants felt that any vital component or feature is missing in the framework.

Regarding overall comments regarding the framework and what it aims to achieve, the following comment was made by interviewee A: *"More qualified people within the business may be more optimistic about the process as they feel they need to change the world. Whereas less qualified people within the organisation may be more pessimistic and feel the framework is too theoretical, simply because they are more set in their own ways".*

From participant C: *"If any process or process introduced into an SMME is too complicated and/or too theoretical, adoption would be really slow."* Participants A and B also noted that the ability of the framework to embrace creativity and creative thinking is only fair but acknowledged that it is the downfall for any given or proposed process that aims to generalise a process. Therefore, based on the responses from the four participants, the following requirements for a management framework or tool have been identified: practical, easy to understand and use, show value (or add value), easily interpretable results, lead decision-making processes, easy to amend, comprehensive, address all the functions of the business.

Due to time limitations, it was not possible to have detailed discussions around each activity contained within the framework, nor the guidelines provided for each activity. Therefore, the participants agreed to also take part in the questionnaires regarding the specific activities, presented in Section 6.7.

6.4.5 Outcomes of the interviews with the business experts

The outcomes of the semi-structured interviews with the business experts have been divided into three sub-categories. The first category highlights where the expert's expertise is directly aligned with the content of the research artefacts. The second category contains all the additions to the research artefacts suggested by the experts. The third category summarises where an expert's response highlighted inadequate aspects which required modifications to the research artefacts. The consideration and implementation of the outcomes described in Table 6.4 concluded Design Cycle 3.

Table 6.4: Interview outcomes after Round 1

	Aspect	**Description**
Validations	Hierarchical taxonomy	The business experts confirmed that the proposed facets, classes, and relationships are applicable and appropriate for the context of this study.
	Concept map of theory	The business experts confirmed the argument presented to explain the concept map of theory is logical and valuable to explain what networked BMI entail.
	SBN configuration process	The business experts confirmed that the steps contained within the process make practical sense and follow a good logical flow.
		Most of the business experts felt positive regarding the process's applicability to SMMEs and manufacturing SMMEs.
	Management framework	The business experts confirmed that the framework is comprehensive as no vital component or feature is missing.

	Aspect	Description
		The business experts confirmed that the tools included in the management framework is applicable and well-known, although other tools might also be used to fulfil the same objective.
Additions	Tools	The inclusion of the brainstorming tool in the ideation sub-phase to improve the facilitation of creativity when identifying business opportunities.
	Activity	The inclusion of change management plans on the firm-level to address the challenge of possible resistance to change from employees.
	Facilitator instructions	The inclusion of facilitation instructions to facilitate the use of the management tool. The facilitation instructions is presented in Chapter 8 to provide a few practical guidelines on how to facilitate and complete the process and who to include where.
	Management framework	The business experts proposed the following framework requirements: practical, easy to understand and use, show value (or add value), easily interpretable results, lead decision-making processes, easy to amend, comprehensive, address all the functions of the business.
Modifications	Management framework	The re-evaluation of certain aspects of the framework to consider the questions *"what is in it for me?"* and *"how will it benefit me?"* as well as considering the practical implications of some of the steps.
	Management framework	The reduction of the use of templates for the tools to embrace more creativity throughout the process.

6.5 Part E-3: Preliminary management framework

With the initial management framework, the *Additive Manufacturing Technology d*evelopment dimension was not completely developed and incorporated throughout the framework, only one analysis step was included. Therefore, during this design cycle iteration, adequate steps were added based on the theoretical findings reported in Section 3.6. This section, therefore, presents the high-level overview of the preliminary management framework, see Figure 6.6, through the addition of the relevant aspects relating specifically to AM. After which an overview of the steps contained within each sub-phase is illustrated in Figure 6.7. These modifications and improvements presented in this section conclude Design Cycle 4.

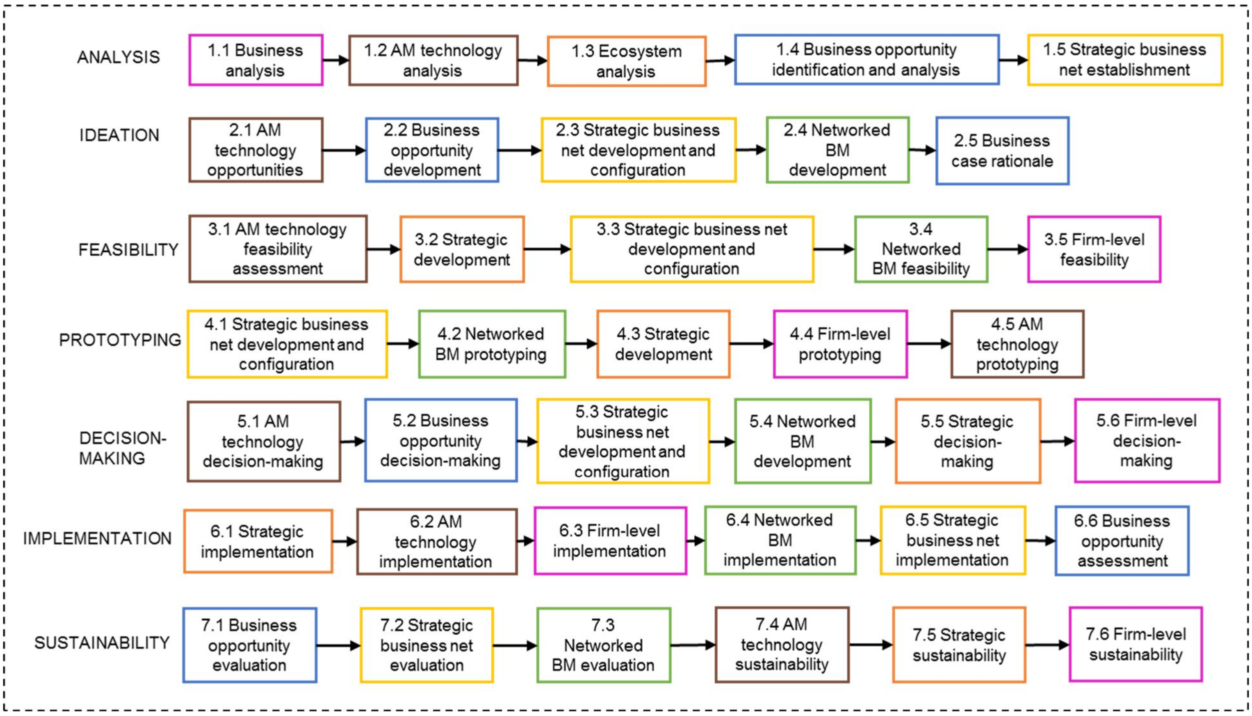
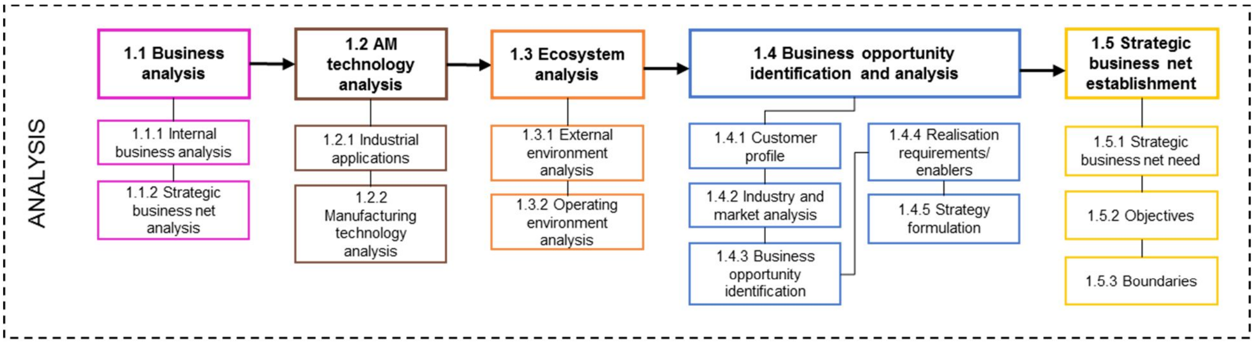
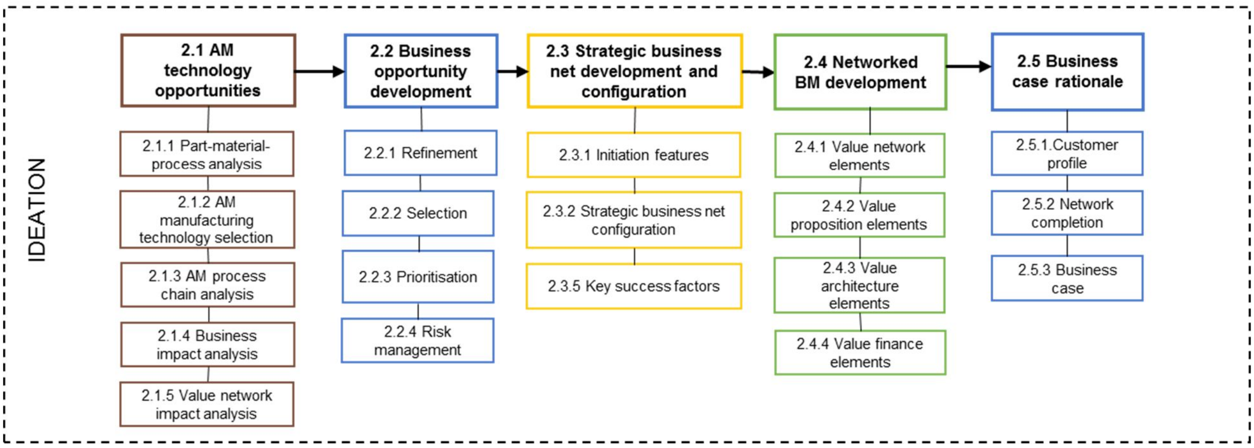
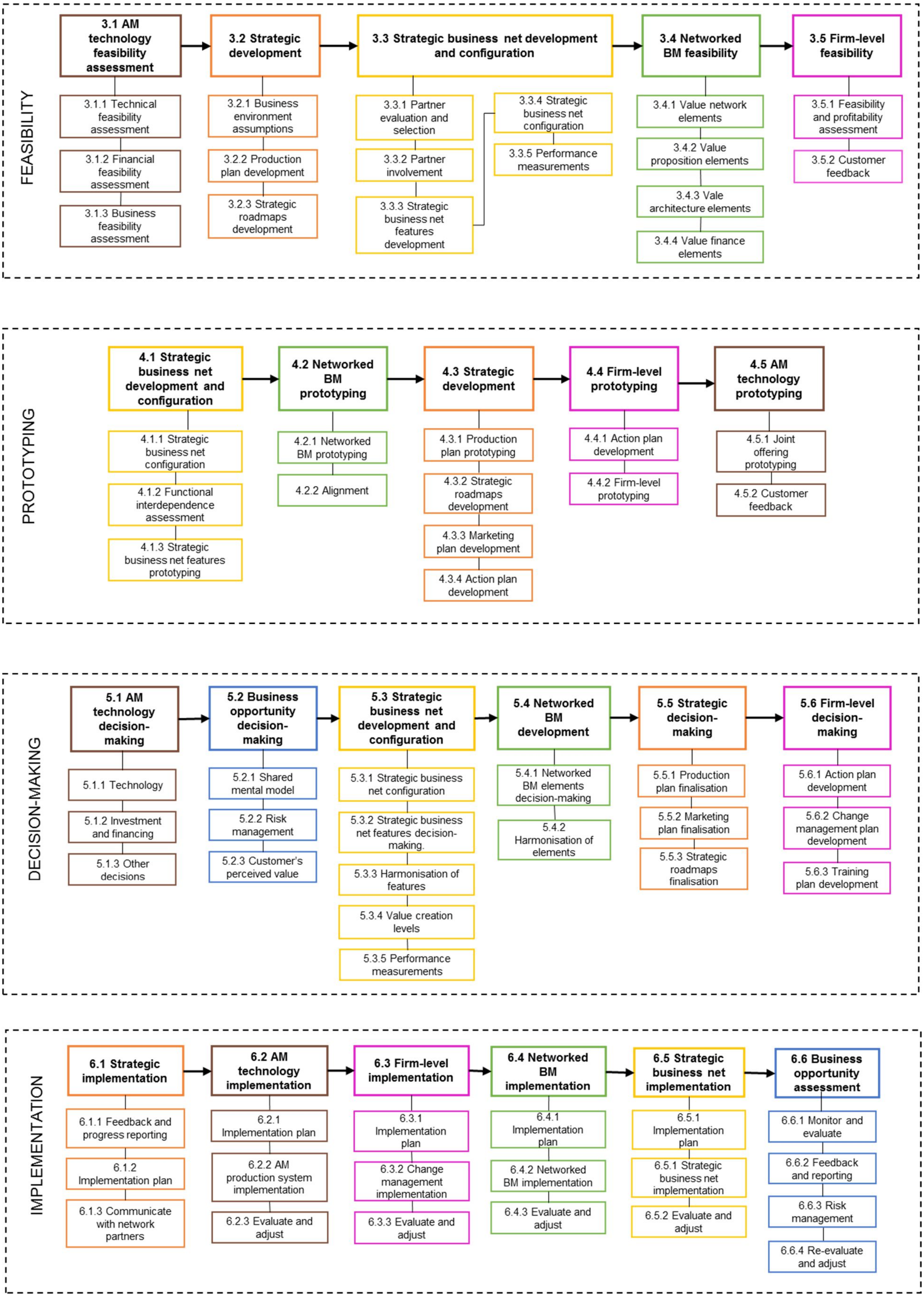


Figure 6.6:High-level overview of the preliminary management framework






FEASIBILITY
3.1 AM technology feasibility assessment
3.1.1 Technical feasibility assessment
3.1.2 Financial feasibility assessment
3.1.3 Business feasibility assessment
3.2 Strategic development
3.2.1 Business environment assumptions
3.2.2 Production plan development
3.2.3 Strategic roadmaps development
3.3 Strategic business net development and configuration
3.3.1 Partner evaluation and selection
3.3.2 Partner involvement
3.3.3 Strategic business net features development
3.3.4 Strategic business net configuration
3.3.5 Performance measurements
3.4 Networked BM feasibility
3.4.1 Value network elements
3.4.2 Value proposition elements
3.4.3 Vale architecture elements
3.4.4 Value finance elements
3.5 Firm-level feasibility
3.5.1 Feasibility and profitability assessment
3.5.2 Customer feedback
PROTOTYPING
4.1 Strategic business net development and configuration
4.1.1 Strategic business net configuration
4.1.2 Functional interdependence assessment
4.1.3 Strategic business net features prototyping
4.2 Networked BM prototyping
4.2.1 Networked BM prototyping
4.2.2 Alignment
4.3 Strategic development
4.3.1 Production plan prototyping
4.3.2 Strategic roadmaps development
4.3.3 Marketing plan development
4.3.4 Action plan development
4.4 Firm-level prototyping
4.4.1 Action plan development
4.4.2 Firm-level prototyping
4.5 AM technology prototyping
4.5.1 Joint offering prototyping
4.5.2 Customer feedback
DECISION-MAKING
5.1 AM technology decision-making
5.1.1 Technology
5.1.2 Investment and financing
5.1.3 Other decisions
5.2 Business opportunity decision-making
5.2.1 Shared mental model
5.2.2 Risk management
5.2.3 Customer's perceived value
5.3 Strategic business net development and configuration
5.3.1 Strategic business net configuration
5.3.2 Strategic business net features decision-making.
5.3.3 Harmonisation of features
5.3.4 Value creation levels
5.3.5 Performance measurements
5.4 Networked BM development
5.4.1 Networked BM elements decision-making
5.4.2 Harmonisation of elements
5.5 Strategic decision-making
5.5.1 Production plan finalisation
5.5.2 Marketing plan finalisation
5.5.3 Strategic roadmaps finalisation
5.6 Firm-level decision-making
5.6.1 Action plan development
5.6.2 Change management plan development
5.6.3 Training plan development
IMPLEMENTATION
6.1 Strategic implementation
6.1.1 Feedback and progress reporting
6.1.2 Implementation plan
6.1.3 Communicate with network partners
6.2 AM technology implementation
6.2.1 Implementation plan
6.2.2 AM production system implementation
6.2.3 Evaluate and adjust
6.3 Firm-level implementation
6.3.1 Implementation plan
6.3.2 Change management implementation
6.3.3 Evaluate and adjust
6.4 Networked BM implementation
6.4.1 Implementation plan
6.4.2 Networked BM implementation
6.4.3 Evaluate and adjust
6.5 Strategic business net implementation
6.5.1 Implementation plan
6.5.1 Strategic business net implementation
6.5.2 Evaluate and adjust
6.6 Business opportunity assessment
6.6.1 Monitor and evaluate
6.6.2 Feedback and reporting
6.6.3 Risk management
6.6.4 Re-evaluate and adjust

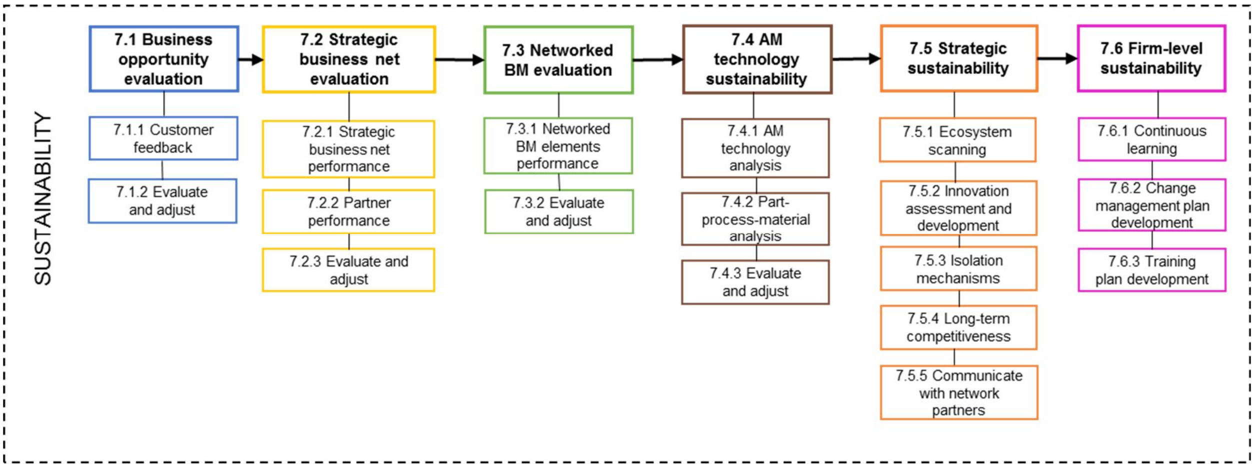


Figure 6.7: Overview of the preliminary management framework's sub-phases

In Section 4.4 the relationship between the technology development phases (*Innovation phases* facet of the hierarchical taxonomy) and the selected networked BMI process was illustrated and explained. The implementation of these technology development stages in the form of steps within each sub-phase of the preliminary management framework, categorised within the AM technology development dimension, is illustrated in Figure 6.8 below.

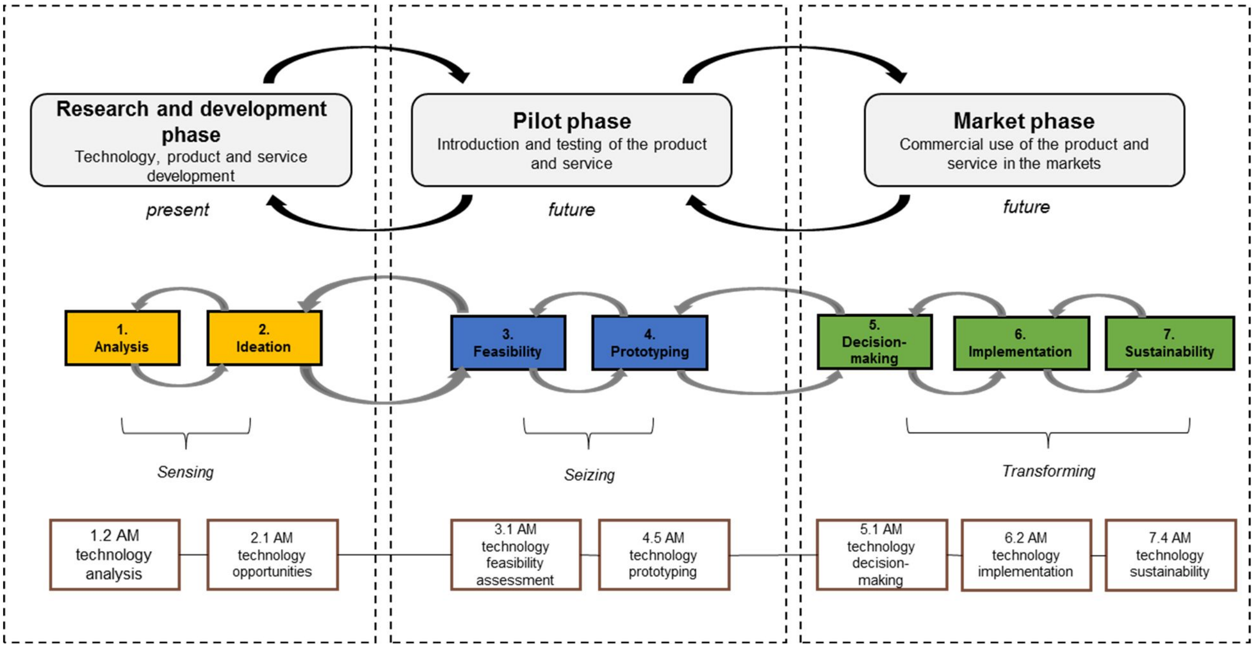


Figure 6.8: Implementation of the innovation phases and the networked BMI process

6.6 Part E-4: External evaluation from a manufacturing perspective (Round 2)

This section discusses the second external evaluation of the management framework from a manufacturing perspective, forming part of Design Cycle 5. After the evaluation was conducted through semi-structured interviews, the management framework was adapted accordingly. As part of this design cycle, questionnaires were sent to the business and manufacturing experts to rate the activities contained in the framework according to perceived effort and impact, these findings are discussed in Section 6.7.

6.6.1 Interview purpose

The purpose of the second set of interviews conducted with manufacturing and AM experts was to evaluate the theoretical argument presented in this study on which the framework is based, from a manufacturing perspective. To evaluate the argument, the logic and process followed to develop the framework was explained to the selected experts. In summary, the second set of interviews aimed to:

- Evaluate the applicability and relevance of the theoretical argument presented in this study from a manufacturing perspective.
- Confirm the logic followed to practically present the integration of the theoretical frameworks (SBN configuration process).
- Adapt the management framework according to suggestions made to ensure its relevance and rigour; and
- Obtain focused insights for further development of the framework.

6.6.2 Identification of the interviewees

The experts approached for these interviews formed part of the second category of subject-matter experts, namely manufacturing experts. Several potential interviewees were identified to form part of this group of experts and were contacted with a request for participation in this study. A total of five experts participated in these interviews and are introduced in the following section to provide a brief background to the participants and to establish their relevance, Table 6.4 provide a summary. All five of them comes from very diverse backgrounds with different experiences, to ensure a multi-disciplinary view. An additional two experts that also form part of this second category of experts (manufacturing experts) were approached during the evaluation of the specific activities using questionnaires, presented in Section 6.7.

The first interviewee (E) has experience and an educational background in industrial engineering and AM. The participant completed a PhD in industrial engineering, with a focus on Laser Powder Bed Fusion (LPBF) Metal AM. The interviewee worked closely with international organisations (including Fraunhofer-Gesellschaft) and international research groups on technical projects demonstrating AM development capabilities, as well as managing the different projects which are strongly related to industrial engineering.

The second interviewee (F) is a business and manufacturing expert with more than 35 years of experience in manufacturing and industrial engineering consulting, as well as corporate management. The interviewee obtained his BEng Industrial Engineering as well as an MBA, the interviewee is part-time lecturer, as well as the chairman of a large aluminium manufacturing company located in South Africa for more than 20 years.

The third interviewee (G) that formed part of this group is a mechanical engineer who has more than 25 years of experience in manufacturing (including innovation) in South Africa. Throughout the years, the interviewee's SMME developed their own technology solution that are used in industries such as aerospace, agricultural, automotive, military and mining. They patented their technology, and over the last few years formed strategic alliances (partnerships) with various other SMMEs to enable the introduction of this technology into more industries and to expand operations into Europe.

The fourth interviewee (H) has experience in AM as well as extensive knowledge regarding the business processes thereof. The interviewee has more than 17 years of experience with AM in the industry and was also a part time lecturer for six years at the University of KwaZulu-

Natal. Furthermore, the participant has an educational background in chemical engineering, obtaining an undergraduate and masters degree in the discipline.

The fifth interviewee (I) has experience and a strong educational background in AM. The participant has obtained a BEng Mechanical Engineering degree, followed by a masters and PhD in industrial engineering. The participant's research focused on Laser Powder Bed Fusion of Tungsten Carbide Cobalt Cutting Tools. The participant's experience and research breakthroughs make him an AM expert of hardmetals (specifically using LPBF). Up until this point in time, the participant is the only researcher that can successfully manufacture a tungsten carbide cobalt cutting tool using only the LPBF AM process (thereby excluding the need for hybrid manufacturing). The participant furthermore has their own business, an SMME, operating in the South African AM market with a focus on manufacturing as well as AM as a service and R&D using LPBF.

Table 6.5: Subject-matter experts evaluation summary (Round 2)

Category	Background					Semi-structured interview			
	Subject-matter expert	Years of experience	Industry expertise	Academic expertise	AM expertise	Hierarchical taxonomy	Concept map of theory	SBN configuration process	Preliminary management framework
Manufacturing experts	E	<10		x	x			x	x
	F	>35	x						x
	G	>25	x						x
	H	>17	x	x	x				x
	I	>10	x	x	x			x	x

6.6.3 Interview protocol / guideline

As with the first set of interviews, the semi-structured interview was selected to collect relevant data from the subject-matter experts to achieve the purpose of the interview. The discussion guideline followed in these interviews is provided in Appendix D.

Before the interview, the interviewee was provided with a briefing document to provide an overview of what the research is about and to obtain informed consent regarding participation in this study. A brief meeting was scheduled where the researcher discussed the process followed to develop the management framework, as well as some aspects of the framework (see Appendix D), the interviewee was also allowed to ask clarification questions and provide some feedback or suggestions. Furthermore, the researcher also explained the strategic business net configuration process to some of the interviewees to obtain multi-disciplinary feedback on the visualisation tool designed as part of this study. The interviewee was then given the chance to review the management framework in their own time, whereafter another meeting was scheduled, or an email was sent, to obtain some feedback and answers to the semi-structured questions.

The recordings of the feedback received, and discussions of the interview questions were analysed, and the findings from these interviews are discussed in the following sections, according to the main themes.

6.6.4 Interview results and findings

The main interview findings related to the SBN configuration process is discussed first, whereafter the key aspects and themes related to the management framework are discussed.

6.6.4.1 SBN configuration process

The SBN configuration process was evaluated by participants E and I that formed part of the manufacturing expert category. This was done because these two participants have strong academic backgrounds as well as expertise related to AM and the use of AM technologies in South Africa, which is the context of this study.

During the discussion regarding the SBN configuration process, both interviewees were very positive about the process and felt that it had excellent practical applicability to SMMEs. Participant E confirmed that the process is logical and enables a good visualisation of the strategic business net on both strategic and tactical levels. Participant I furthermore noted that the output generated using the SBN configuration process are valuable, especially for providing an initial understanding of the network on a strategic level. However, one needs to constantly re-visit the map as the configuration will frequently change.

Interviewee E did however note that the process might only have fair usefulness as part of the framework application. As a suggestion, the interviewee noted that the use of the identified capabilities related to AM can be used to identify and select possible partners to be included in the strategic business net. Another added value the process could provide, as suggested by the interviewee, is to calculate the percentage contribution of different partners to a function, as well as the overall percentage contribution of an actor to the strategic business net.

Another discussion point participant I raised was, that the dynamics of the VN in the AM context might become tricky as one actor may be your competitor regarding one set of capabilities, but regarding another set of capabilities, the same actor might be your partner. Also, if one runs out of capacity, it will be important to form partnerships with competitors with the same capabilities. Therefore, according to the interviewee, managing these relationships with partners and competitors becomes crucial and must be approached carefully.

6.6.4.2 Strategic business net formation

The third interviewee, participant F, confirmed the argument regarding the formation of strategic business nets presented within this study, as it is in line with their knowledge and own business structure. The participant furthermore noted that most of the time *"we as manufacturers work in our businesses, instead of working on our businesses",* and thus as a result hinder growth, but a management framework such as the one proposed may help owners working on their businesses.

Although the framework is perceived to be very comprehensive, participant H noted that presenting a spreadsheet or document to engineers that is long, with many steps, may not be a feasible approach, as they won't even read it because they do not have the time to understand it. But the participant also noted, that due to priority areas being different for every single business, this may be the appropriate approach, if businesses are allowed to select the activities, they deem most important. This suggestion is in line with the argument presented in this study, and therefore the framework will be converted to a tool that can be adapted by the user as needed.

Lastly, participant H stated that due to the focus of the framework being on emerging technologies and emerging industries, some of the activities contained in the framework might be difficult to complete now due to a lack of knowledge and various assumptions to be made. These activities might only be relevant later as the technology and industry grow in maturity, emphasising the relevance of a cyclic and iterative BMI process.

6.6.4.3 SMME applicability

Participant F believed that the basis and logic of the management framework are good, comprehensive, coherent, and theoretical sound. However, the interviewee did not feel the framework is completely applicable to SMMEs, the interviewee stated: *"The practical application to the SMME market is problematic for me – the framework is correct, but I believe it is too elaborated for the chosen market".* The interviewee furthermore noted that the framework's ability to embrace creativity and creative thinking may be rather poor as the use of structured steps, activities, and tools may hinder creative thinking.

Furthermore, interviewee F noted that it may be too technical and theoretical for manufacturing SMMEs as they tend not to give too much attention to *"business things".* The participant also confirmed that a lot of the elements contained within the framework are indeed actually done, without knowing the academic or business terminologies. According to participant F, manufacturing SMME owners are *"master jugglers"* as they try to do everything in the business, without much help from other people, as they cannot appoint a person for each portfolio as it is simply too expensive.

Nevertheless, both participants E and I agreed with the theoretical foundations presented as part of the development of the framework and was positive regarding the applicability of the management framework to SMMEs within AM context.

Regarding the BMI process and framework, participant I noted that a lot of their business knowledge, business planning and BM configuration is in their head, not necessarily placed on paper. The participant recognised the value of a mind mapping tool where one can just blot down some of the ideas to gain an overall, holistic picture of the business. The participant also acknowledged that not all manufacturers have adequate, or any business knowledge, and therefore some business guidance might be valuable for certain role-players.

Based on the results of the interviews conducted with the subject-matter experts, it seems like there may be primarily two views on the framework. The one view is that the management framework is extremely applicable to SMMEs, whereas the other view is that it is not applicable as it is too comprehensive or maybe too complex for SMMEs. What is however interesting from these two perspectives, is that it may have something to do with the age and years of experience of the experts. Some of the older experts, with more practical experience, thought it was too theoretical and too comprehensive because they may be set in their own ways. Whereas some of the younger experts (specifically those with AM expertise) that are a bit more open-minded, thought the framework is indeed applicable and practical and may aid as a guiding structure to prevent many pitfalls.

The feedback received from the experts, as well as the comments made, is a reflection on the expert's experience and background. Although some of the statements made might be relevant and applicable in their environment, it might not be applicable in the context of this study which is another environment. The interview findings however confirmed that there is not a one-size-fits-all approach or absolute agreement among all experts regarding all aspects of BMI.

6.6.4.4 AM applicability

Due to interviewee E's academic background and in-depth understanding of AM processes, the participant proposed a few modifications regarding the sequence of the different activities contained within the AM development dimension. These improvements were applied to the framework before the other manufacturing experts were approached. The interviewee furthermore noted that the collaboration effort using the proposed management tool among different partners (or people within the focal organisation) within the network, may lead to traceability issues, as it would be important to track changes and implement version control. Data security is also a challenge noted by the interviewee, both between network actors in general, as well as using AM software and when sharing files and data among different actors. The use of standards to communicate among network partners, regarding the use of different terminology, as well as interface and integration may be challenges for the networked framework.

In addition, interviewee E noted that the framework needs to include concerns related to regulatory requirements (including AM standards), or the lack thereof, as it influences failure liability which may also be a challenge for the network. Regarding the idea of distributed manufacturing, and bringing the manufacturer closer to the customer, the interviewee noted that when considering the location and transportation within the network, one need to consider that some powders used by AM may oxidise when transported, therefore may have an influence on lead time and proximity to suppliers. Throughout the interview, the interviewee continuously noted the importance of risks and liabilities assessments regarding the use of AM.

The fourth interviewee, participant H, agreed with the argument presented within this study, as the AM SMME the participant is working at, as well as their sister company, already collaborate with international organisations, their customers, and other companies that help them with the post-processing of 3D printed parts. The one business, consisting out of 9 employees, sell and support 3D printing equipment, help customers to sample parts and developing a business case for using AM to produce their parts. The sister company is the manufacturing entity that provides digital manufacturing solutions, more like a platform business, where they have the AM capability and use external people for post-processing work, where they are responsible for managing those relationships. According to participant H: *"The thing we find most challenging is getting customers to engage with our platform. So ideally what we want is the customers to log into the site, upload the file they want or select files from the library that is already set-up and then choose what he wants to generate and then the order goes directly into our production system. There may be several reasons for the lack of participation from our clients, one reason may be because the industry is nervous about AM, they want to send an email to somebody."* This statement from the participant, emphasise the need to equip potential AM users with a management tool that may help them overcome the 'nervousness' of using AM, if analysis and decisions are made in a structured manner.

Specifically related to the participant's recent experience, the interviewee stated "*What we found is that you cannot just take a part as is and produce it using AM as it is simply too expensive. The design of the part must be improved, called Design for AM, therefore we have engineers that do these designs, as well as helping to train our customers to do the design themselves and providing consulting services to our customers."*

Participant H furthermore stated, *"The use of AM tends to be very customer part specific, therefore every part, every project, and every customer will be different."* Consequently *"The identification of parts at the ideation stage will only be possible in a very broad general way. Prototyping, feasibility, and costing are only possible once actual parts have been identified."* Regarding the most important functions of AM the participant noted that *"Part screening is an* *essential part of AM, but this is done after the potential client is identified. There are AI's, software systems & consultants that focus on this element specifically."* The participant also added that detailed design, costing, and feasibility needs to be part of the workflow of the network, as those activities are *"not upfront business planning exercises."*

6.6.4.5 Hardmetals AM industry in South Africa applicability

The fifth interviewee, participant I, agreed with the relevance of the argument, regarding the need to form VNs, developing networked BMs and the interaction between emerging technologies and BMs, to the hardmetals and tooling industry in South Africa (which is the contextual application area). Accordingly, the participant stated "*It is very applicable, you have to have network partners*" since AM related capabilities are distributed among various actors with different know-how and required equipment and infrastructure. The small country, small economy, and small AM market force one to find a *"niche market"* where one quickly need to recognise the value one can offer. As an additive manufacturer, the participant noted that due to the high cost associated with auxiliary equipment used to perform post-processing, some functions will need to be outsourced to other actors. The interviewee noted that some of the processes might be able to be done in-house, but not necessarily in a safe manner, therefore it would be better to outsource those functions to be done in an environment that adheres to required health and safety protocols. Furthermore, one might be fulfilling one role, for example R&D, but also have other R&D partners.

Participant I stated that it is an *"IP-driven industry"* requiring high investments, and competition is therefore currently based on "*know-how"* and potentially your AM machine. This statement and view on the industry are in line with the 'closed business environment' argument presented by Savolainen and Collan [200], on which this study is built. There are different types of BMs, with different combinations one can adopt, depending on the capabilities one has and the role one wants to play. However, BMs will always change (including the configuration of the network) as one's capabilities change, the roles in the network will change, and consequently one's offerings and BM. In line with one of the other participants, the participant noted that it is important to use identified and required capabilities in approaching possible partners. The participant also confirmed the strong relationship between roles and actors and their associated capabilities.

6.6.5 Outcomes of the interviews with the manufacturing experts

The outcomes of the semi-structured interviews with the manufacturing experts have been divided into three sub-categories. The first category highlights where the expert's expertise is directly aligned with the content of the research artefacts. The second category contains all the additions to the research artefacts suggested by the experts. The third category summarises where an expert's response highlighted inadequate aspects which required modifications to the research artefacts. The consideration and implementation of the outcomes described in Table 6.6 form part of Design Cycle 5.

Table 6.6: Interview outcomes after Round 2

	Aspect	Description
Validations	SBN configuration process	The manufacturing experts confirmed the applicability of the process to SMMEs using AM in South Africa.
	Management framework	Although there were two different perspectives on the applicability of the framework to SMMEs, the experts with AM backgrounds agreed on the potential applicability of the framework and the ability to add value to SMMEs.

	Aspect	Description
		The manufacturing experts agreed with the relevance of the argument, regarding the need to form VNs, developing networked BMs and the interaction between emerging technologies and BMs, to the AM industry in South Africa.
		The manufacturing experts agreed with the need to collaborate with partners, competitors, and customers.
		The manufacturing experts confirmed that although the framework was perceived to be comprehensive, there cannot be a one-size-fits-all approach or framework to BMI.
		The manufacturing experts confirmed the logic on which the framework and study's argument is built regarding the formation of closed VNs, since the AM industry is IP-driven.
	AM	The manufacturing expert confirmed the logic and sequence of the activities related to the AM development dimension and confirmed that it provides an adequate overview of what is required.
Additions	Activity	The inclusion of the use of service bureaus etc. to create physical prototypes of the joint offerings within the prototyping phase, which do not require any capital investment from a network actor yet.
	Consideration	The inclusion of AM considerations regarding data security, communication standards, regulatory requirements, failure liability, and transportation.
	Consideration	The inclusion of some of the more specific activities (such as detailed design, costing, and feasibility) related to the AM process as pre-determined functions within the strategic business net (Chapter 7) as these need to be done per project and per client.
	Tool	The inclusion of AM capabilities as part of partner evaluation and selection criterion in the proposed actor selection template.
Modifications	Management framework	The framework was re-evaluated and modified to reduce the framework's technicality by making some definitions simpler and excluding some of the technical details of the framework.
		The inclusion of some of the proposed tools and templates to complete certain activities were simplified and reduced to encourage more creative thinking that is not bound to strict templates.

6.7 Part E-5: External evaluation of elements, features and activities (Round 3)

This section reports on the results and findings from the completed questionnaires by the selected business experts as well as the selected manufacturing experts. After the findings were implemented and proposed changes were made to the management framework, an overview of the proposed management framework is presented, concluding Design Cycle 5.

6.7.1 Questionnaire purpose

The primary purpose of the structured questionnaire was to evaluate the specific activities contained within the management framework. To enable this evaluation, perceived effort and importance ratings were obtained from the experts using the structured questionnaire. These quantitative data allowed the researcher to compare the results obtained from the two expert categories as well as to confirm that the activities included are indeed important from both perspectives.

In addition to the activities contained within each step of the framework, the selected networked BM elements, as well as the strategic business net features were also evaluated using the structured questionnaire. The reason for evaluating the networked BM elements as well as the strategic business net features, was to evaluate the application value of these elements (in terms of effort and importance) and to make the necessary adjustments. These elements and features were selected by the researcher and form a fundamental part of this study, as well as an integral part in the management framework and therefore required evaluation from the subject-matter experts.

In summary, the structured questionnaire aimed to:

- Evaluate the applicability and relevance of the selected networked BM elements.
- Evaluate the applicability and relevance of the selected strategic business net features.
- Evaluate the applicability and relevance of the activities contained within the management framework.
- Adapt the management framework according to suggestions made to ensure its relevance and rigour; and
- Obtain focused insights for further development of the framework.

The process (instructions) followed by the subject-matter experts to complete the questionnaire is provided in Figure 6.9 below. In addition to the questionnaire, the complete management framework was sent to the experts. The ratings used throughout the questionnaire for both effort and importance, was based on a qualitative scale of 1 to 5, with 1 indicating very low, 2 indicating low, 3 indicating medium, 4 indicating high and 5 indicating very high. An example of the layout of the structured questionnaire used (for one of the sub-phases) is provided in Appendix D.

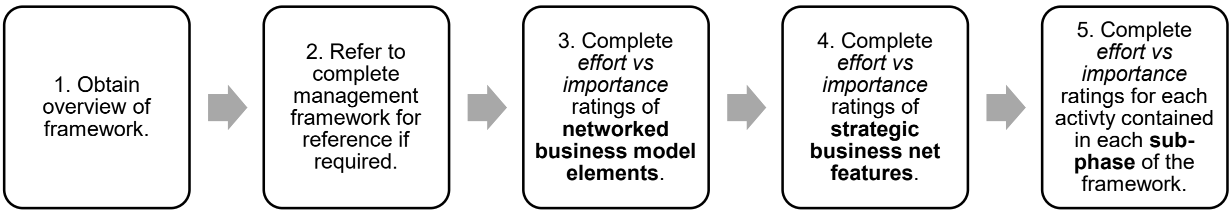


Figure 6.9: Process (instructions) followed by experts to complete the questionnaire

6.7.2 Identification of the participants

Besides the four business experts (A-D) identified in Section 6.3, one more expert was approached to form part of the business expert category to complete the questionnaire. Expert J from this category is introduced in the following section to provide a brief background to the participant and to establish their relevance.

The fifth business expert (participant J) is an industry expert with a strong academic background, having obtained an MSc Project and Programme Management as well as a PhD in Project, Portfolio, and Strategic Management and are still actively involved in research at the University of Pretoria, acting as a supervisor for PhD and masters students. The participant has also been a project management consultant for the past 21 years and has consulted with companies in information technology, airlines, banking and finance, mining, manufacturing, construction, pharmaceutical, and the telecommunications industry. The expert is furthermore the founder of a project management SMME operating in South Africa, practising as a full-time senior consultant.

For the manufacturing expert category; two additional experts were included. Expert six to seven from this category are introduced in the following section to provide a brief background to the participants and to establish their relevance. All experts were approached to complete the questionnaire, however participant H decided not to complete the questionnaire using the importance and effort ratings, but rather decided just to indicate the most important activities or steps within their AM business environment. These results are discussed in the next section. Furthermore, due to time limitations, participant I declined participation in the questionnaire.

The sixth manufacturing expert (participant K) is a manufacturing industry expert with more than 25 years of experience in manufacturing in South Africa. The participant obtained a diploma in mechanical engineering, where after a few years in the industry the participant decided to open a manufacturing SMME in 1995. The participant operates within the South African market and delivers manufactured products and services to the local market.

The seventh expert (participant L) forming part of this category, is a mechanical engineer who is currently busy pursuing an MBA at the University of Sydney Business School. The interviewee has experience and knowledge in the fields of sustainable energy, green buildings, AM, IoT and digital transformation. As an entrepreneur, the participant is also the co-founder and director of an SMME based in South Africa, with a focus on the engineering and design of bikes. Design, R&D, product testing, and ergonomic fitment forms part of their portfolio as the design engineer of the company. Table 6.7 below provides a summary of all the experts that participated in this round of external evaluation.

Table 6.7: Subject-matter experts evaluation summary (Round 3)

Category	Background					Structured questionnaire		
	Subject-matter expert	**Years of experience**	**Industry expertise**	**Academic expertise**	**AM expertise**	**Networked BM elements**	**Strategic business net features**	**Proposed management framework activities**
Business experts	**A**	>20	x			x	x	x
	B	>24	x			x	x	x
	C	>29	x			x	x	x
	D	>30	x	x		x	x	x
	J	>21	x	x		x	x	x
Manufacturing experts	**E**	<10		x	x	x	x	x
	F	>35	x			x	x	x
	G	>25	x			x	x	x
	H	>17	x	x	x			
	K	>25	x			x	x	x
	L	>10	x		x	x	x	x

The inclusion of five business experts and five manufacturing experts (excluding participant H) to complete the questionnaire from very diverse backgrounds allowed for a representative overall perspective on the framework's activities to ensure the proposed activities are indeed important.

6.7.3 Questionnaire results

The following two sections visually report on the results and findings obtained from the data gathered from the completed questionnaires. To plot the points of the networked BM elements, as well as strategic business net features, the average scores for each element or feature were calculated, distinguishing between the two expert categories. Furthermore, for each of the sub-phases, the average score for each step was calculated and plotted accordingly, for each expert category. Where steps consisted of two or more activities, the average was taken of the activities' scores to create the data points for each step. A distinction was made between the steps contained within the six development phases. The notation used to indicate what the points represent are presented in the tables below the scatter plots. The following four quadrants were used for the scatter plots:

- **Low hanging fruit:** concepts that are perceived to require low implementation effort but are perceived to have high importance.
- **High hanging fruit:** concepts that are perceived to require high implementation effort and are perceived to have high importance.
- **Leave:** concepts that are perceived to require low implementation effort and are perceived to have low importance.
- **Overkill:** concepts that are perceived to require high implementation effort but are perceived to have low importance.

Using the scatter plots, points of interest were identified, illustrated in the figures below the scatter plots and reflected upon. These points of interest were identified using the following criteria:

- Points that had a delta score (difference between the averages) of more than one between the two expert categories, regarding either the effort rankings or the importance rankings.
- Points that stood out for either expert category as outliers, either regarding the highest or lowest values for either effort or importance rankings.
- Points (steps) indicated by participant H, which is an AM business process expert, as the most important steps in the context of AM. These steps are indicated throughout this section using a '*' and indicating the steps in bold.

However, to draw the boxplots (in Section 6.7.3 as well as Section 6.7.4) all the individual scores for the elements, as well as the activities within each sub-phase, were used and not the averages. This was done to get a sense of how much the experts agreed with the various concepts (elements, features, or activities) and to observe the possible variances in the responses from the two expert categories. The interpretation of these boxplots was done based on the distribution of the points regarding effort and importance, in most cases distinguishing between the two expert categories.

6.7.3.1 Networked BM elements

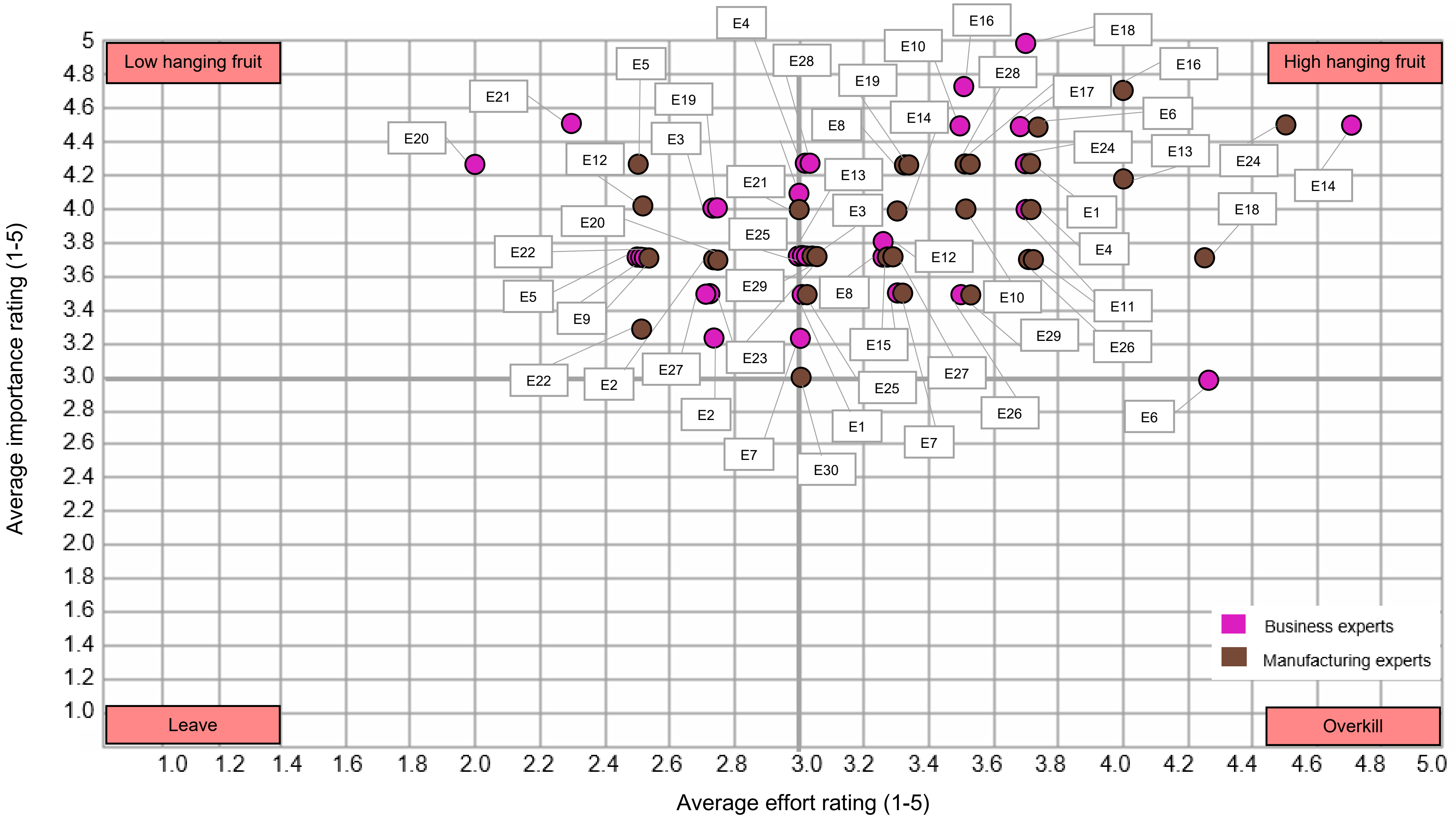


Figure 6.10: Scatter plot of effort and importance of networked BM elements

Table 6.8: Networked BM elements notation

Networked business model elements							
	Value network		**Value proposition**		**Value finance**		**Value architecture**
E1	Actors / Partners	E9	Target-segment	E16	Pricing method	E24	Resources
E2	Roles	E10	Product-service	E17	Revenue structure	E25	Functions
E3	Relationships	E11	Joint offering	E18	Total-cost of ownership	E26	Capabilities
E4	Governance	E12	Distribution channel	E19	Cost structure	E27	Information flow
E5	Communication channel	E13	Customer relationships	E20	Profit formula	E28	Data analytics
E6	Customisation	E14	Development and design	E21	Sales model	E29	Platform
E7	Push/pull	E15	Value-in-context	E22	Continuity	E30	Value exchange
E8	Communication			E23	Metrics		

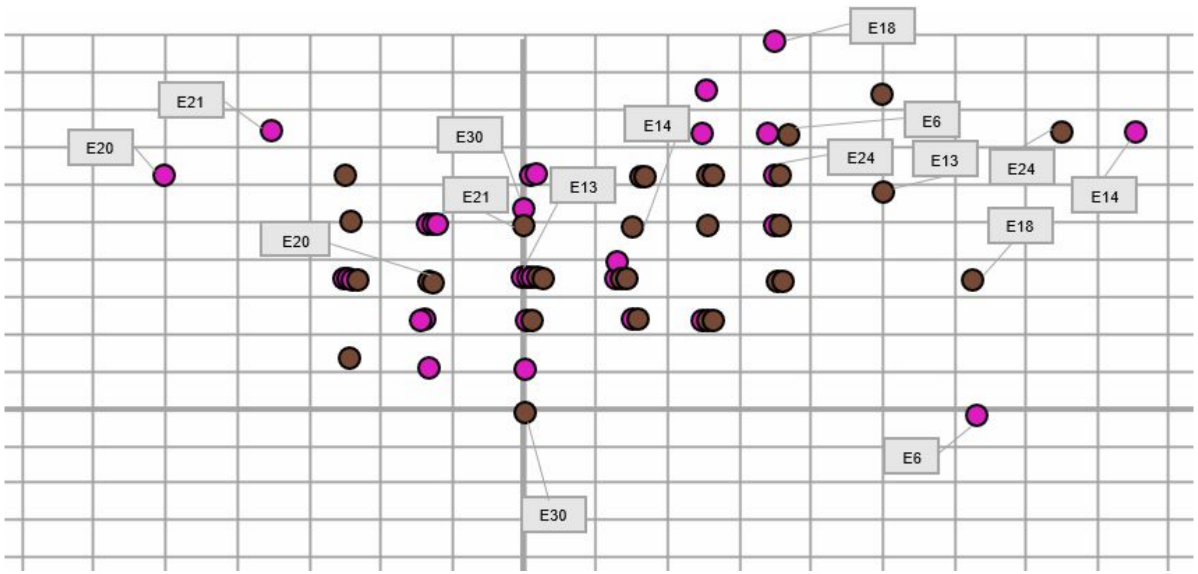


Figure 6.11: Scatter plot of points of interest of the networked BM elements

Figure 6.10 above summarises the business and manufacturing experts' rankings of the perceived effort and importance of the networked BM elements that form part of the networked BM development dimension within the management framework. Based on the scatter plot, it seems like most of the data points are gathered above the medium importance line, illustrating that most elements are perceived to be important by both expert categories. The scatter plot also illustrates that there is not really an agreement between the experts on the most important elements of a BM, as suggested by the BM literature body, and hence the numerous BM frameworks contained in the literature body.

The points of interest identified on the scatter plot are indicated in Figure 6.11 above. It was noted that almost all the elements were rated as either low hanging fruit or as high hanging fruit, with one element on the border according to the business experts (*E6 customisation*) and one element according to the manufacturing experts (*E30 value exchange*). It is furthermore interesting that these two elements obtained some of the highest delta scores regarding the importance rankings. The *customisation* element obtained a delta score of 1.5 and the *value exchange* element obtained a delta score of 1. The *customisation* element obtained the high importance ranking from the manufacturing expert category, indicating that they understand and acknowledge the importance of this element in the manufacturing environment. Whereas the *value exchange* element obtained the high importance ranking from the business expert category, indicating that they understand the importance of recognising value exchange within a network and that term might be unfamiliar or misunderstood by the manufacturing experts. Within the context of this study, the different perspectives on these two elements are furthermore interesting to note as AM enables customisation, and the formation and functioning of VNs or strategic business nets focus on the exchange of value between actors.

Another element that obtained a high delta score (1.25) for the importance ranking is the *total-cost of ownership (E18)* element. This element was also identified as an outlier with the highest importance ranking according to the business experts. This illustrates that total-cost of ownership is regarded as especially important for participants involved in SMMEs, but the perception of the implementation effort thereof differs depending on the background of the expert.

The following two elements of interest were identified based on their high delta scores for the effort ranking. The first element is *customer relationships (E13)* with a score of 1, and the second element is *development and design (E14)* with a delta score of 1.5. The manufacturing experts perceived the *customer relationships* element with high effort, whereas the business experts perceived the *development and design* element with high effort. This illustrates that there are potential differences between the perceived implementation effort of certain elements that may depend on expertise and backgrounds. Furthermore, the customer forms an integral part of the strategic business net and value co-creation effort proposed in this study and it is therefore interesting to note that it is perceived to be higher effort to develop and implement these relationships by the manufacturing experts. The big difference in perceived effort for the *development and design* element may be based on the backgrounds and may indicate that business experts might not be comfortable with implementing this element as it doesn't necessarily form part of their environments.

Considering the outlier points regarding the lowest effort, two elements within the value finance dimension stood out, namely, *profit formula (E20)* and *sales model (E21).* For both elements, the business experts perceived lower implementation effort, with higher importance, but the manufacturing experts perceived them with higher effort and lower importance. Considering the outlier points regarding the highest effort, the *resources (E24)* element stood out. It seems like the manufacturing experts perceived this element with higher implementation effort, compared to a slightly lower effort perceived by the business experts, both with similar importance rankings. This illustrates that business experts may perceive the implementation effort of some elements different than the manufacturing experts and the difference might be dependent on the industry and working environment. Furthermore, since numerous elements were ranked as low hanging fruit indicate that not all elements that have a major impact in terms of importance require a high degree of implementation effort.

The boxplots in Figures 6.12 to 6.14 below illustrate the results obtained for the elements contained in the four different value dimensions that form part of the networked BM. The big variance in the effort rankings for the value network and value architecture dimensions are interesting to note as they illustrate the lack of consensus regarding the perceived effort to implement the elements associated with these two dimensions, and therefore confirming the need for efforts to guide SMMEs to configure and implement elements associated with the strategic business net (this includes the SBN configuration process proposed by this study). The highly aggregated importance rankings for the elements contained within the value proposition dimension, illustrate that most experts from both categories are familiar with these elements and understand the importance of addressing and implementing these elements. And then lastly, it is visible that most experts understand and recognise the importance of the elements contained in the value finance dimension as the importance rankings are mostly aggregated between four and five, with only a few outliers.

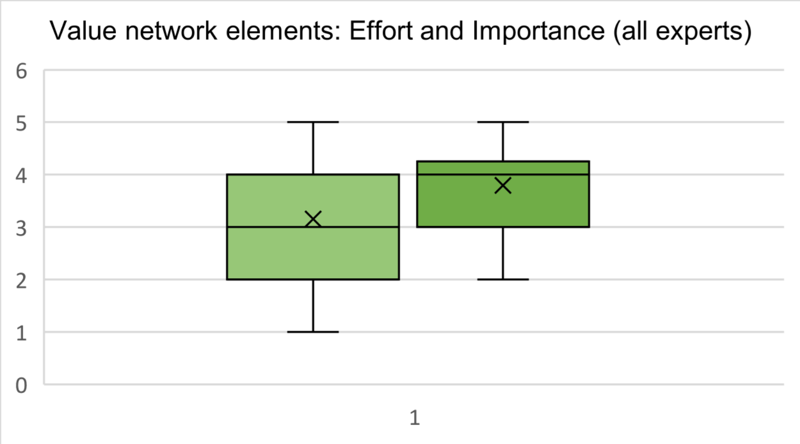


Figure 6.13: Value network dimension boxplot

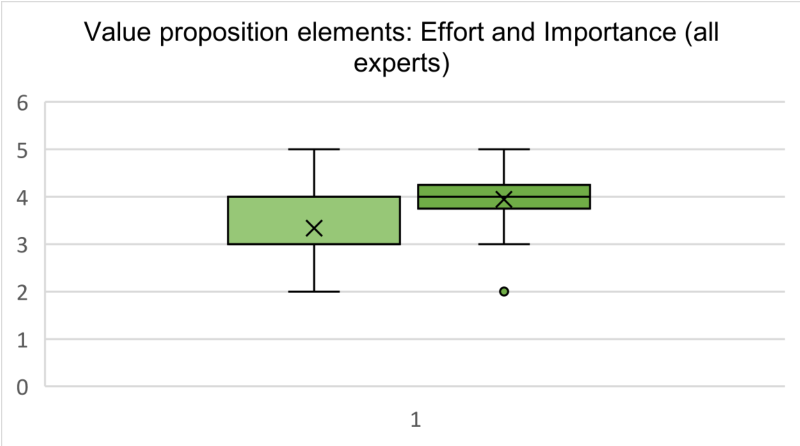


Figure 6.12: Value proposition dimension boxplot

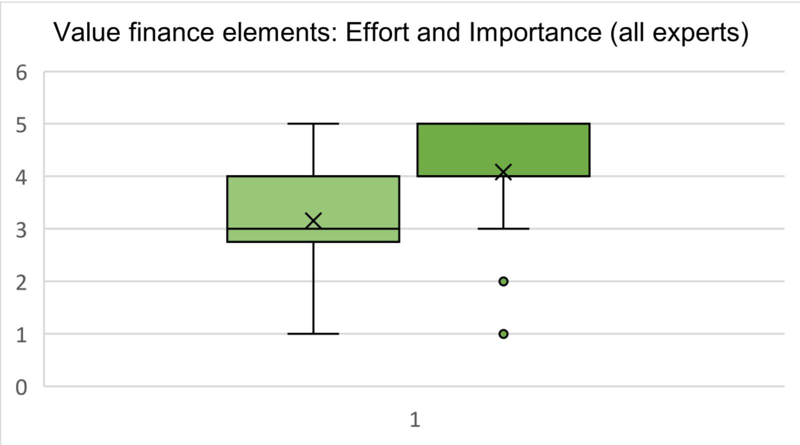


Figure 6.15: Value finance dimension boxplot

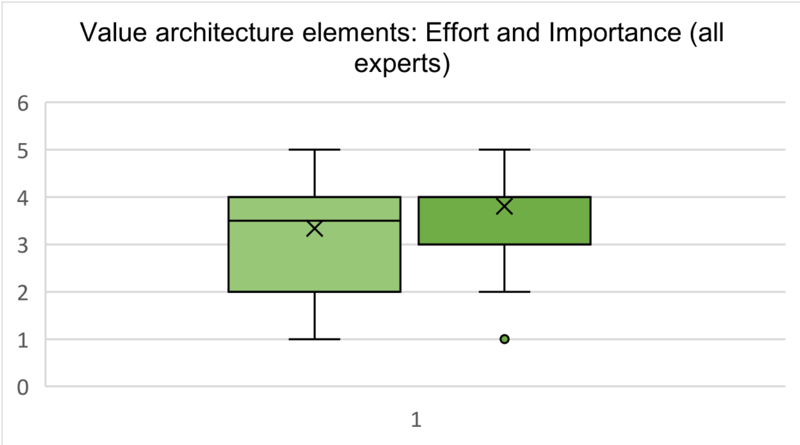


Figure 6.14: Value architecture dimension boxplot

6.7.3.2 Strategic business net features

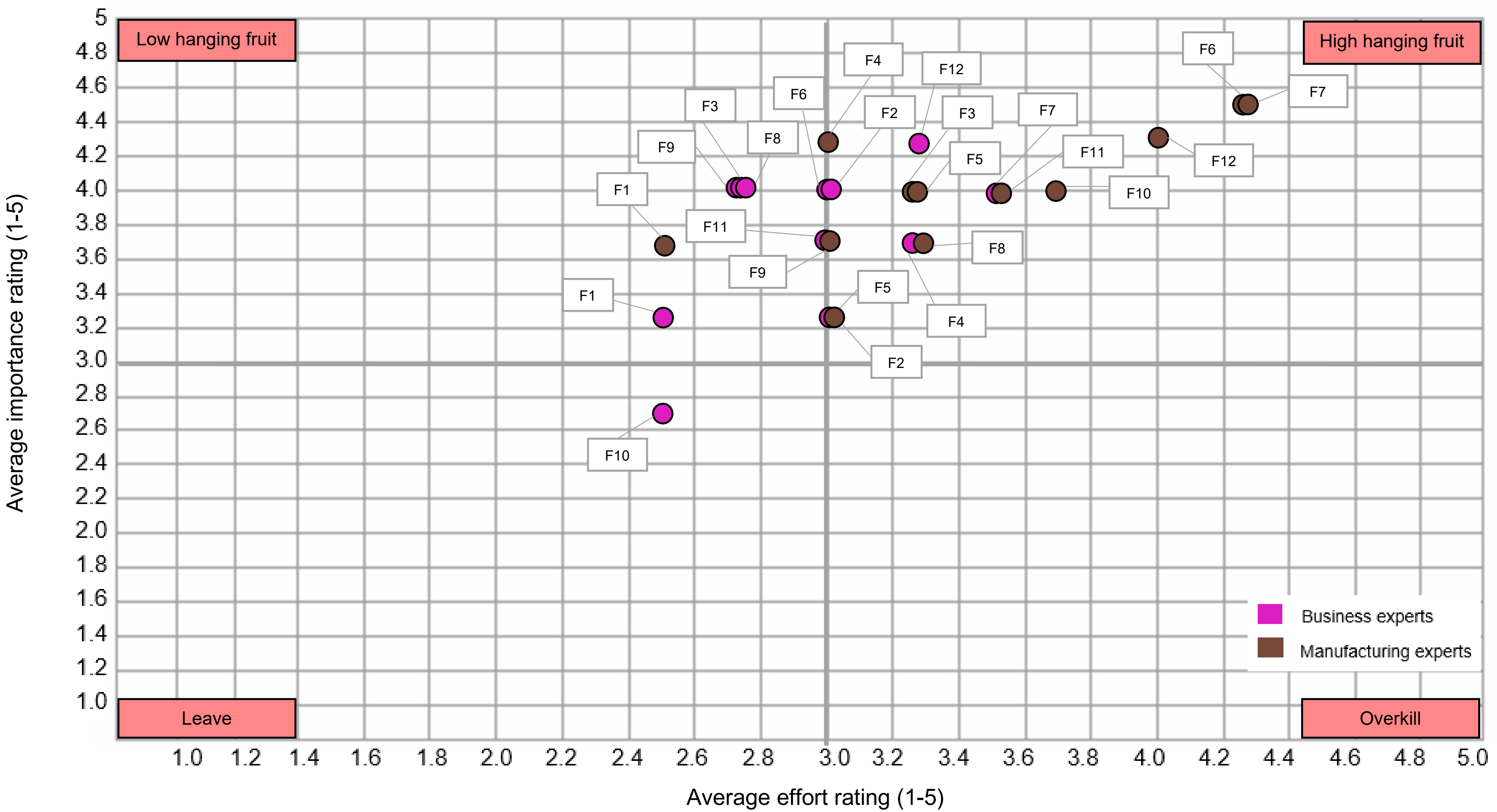


Figure 6.16: Scatter plot of effort and importance of strategic business net features

Table 6.9: Strategic business net features notation

Strategic business net features					
F1	Boundaries	F5	Co-operation	F9	Mode
F2	Control	F6	Culture	F10	Power
F3	Control points	F7	Integration	F11	Shared values
F4	Coordination	F8	Management	F12	Trust

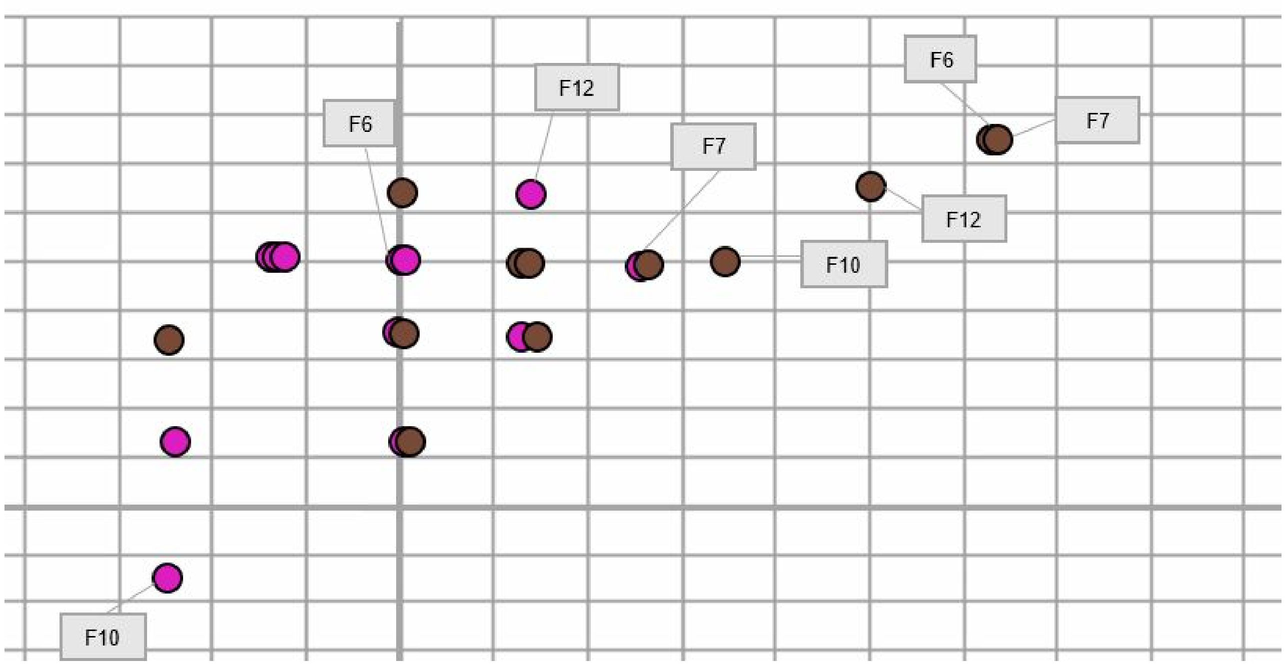


Figure 6.17: Scatter plot of points of interest of strategic business net features

Figure 6.16 above summarises the business and manufacturing experts' rankings of the perceived effort and importance of the strategic business net features that form part of the strategic business net development dimension within the management framework. Based on the scatter plot, it seems like the data points are slightly scattered regarding their effort, but gathered above the medium importance line, indicating that most features are perceived to be important. All features, except for one feature ranked by the business experts, form part of the low and high hanging fruit, indicating that the selected features are indeed perceived to be important by the experts regarding the formation and functioning of networks. The points of interest identified on the scatter plot are indicated in Figure 6.17 above.

The one feature that lies in the leave quadrant, according to the rankings form the business experts, is the *power (F10)* feature. This feature obtained the highest delta scores in terms of both perceived effort (1.25) and importance (1.25). This illustrates that the power dynamics within networks may be perceived differently depending on the working environment. Since the feature's rankings by the manufacturing efforts put the feature in the high hanging fruit quadrant, it will however not be discarded as a feature.

Concerning the delta scores, the other element that obtained a high score regarding perceived implementation effort, is the *culture (F6)* feature with a score of 1.25. This illustrates that culture and cultural fit between partners within a VN is something perceived with high effort and importance in the manufacturing environment but is perceived with less importance and effort within the business environment.

The *integration (F7)* feature stood out as an outlier with the highest effort and importance rankings (together with the *culture* feature) according to the manufacturing experts, although the business experts ranked these elements with relative average rankings. It seems like, within the manufacturing environment, the integration between partners within the network requires specific attention as it is perceived with high importance and high implementation effort. Furthermore, it is interesting to note that although the feature obtained lower average rankings by the business experts, it was noted as a challenge by one of the business experts during the semi-structured interviews.

The last feature that stood out as an outlier was the *trust (F12)* feature which the manufacturing experts perceived with higher implementation effort than the manufacturing experts. The average importance ranking from both categories is however similar. It is interesting to note that the establishment of trust between network partners in the manufacturing environment is perceived to be higher, requiring more effort to implement, than what is perceived in the business environment.

6.7.3.3 Sensing phase: Business experts

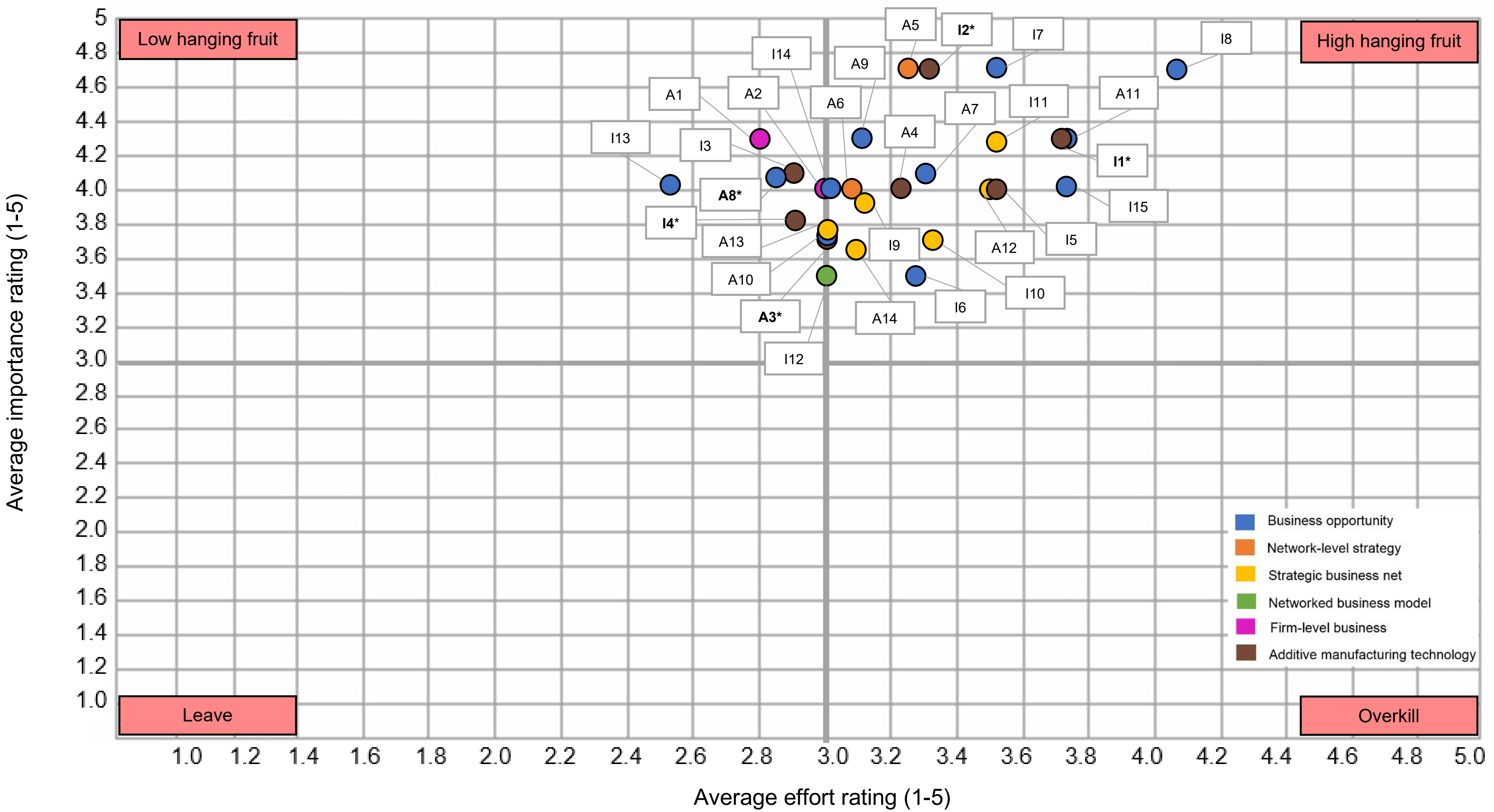


Figure 6.18: Scatter plot of effort and importance of sensing phase (business)

6.7.3.4 Sensing phase: Manufacturing experts

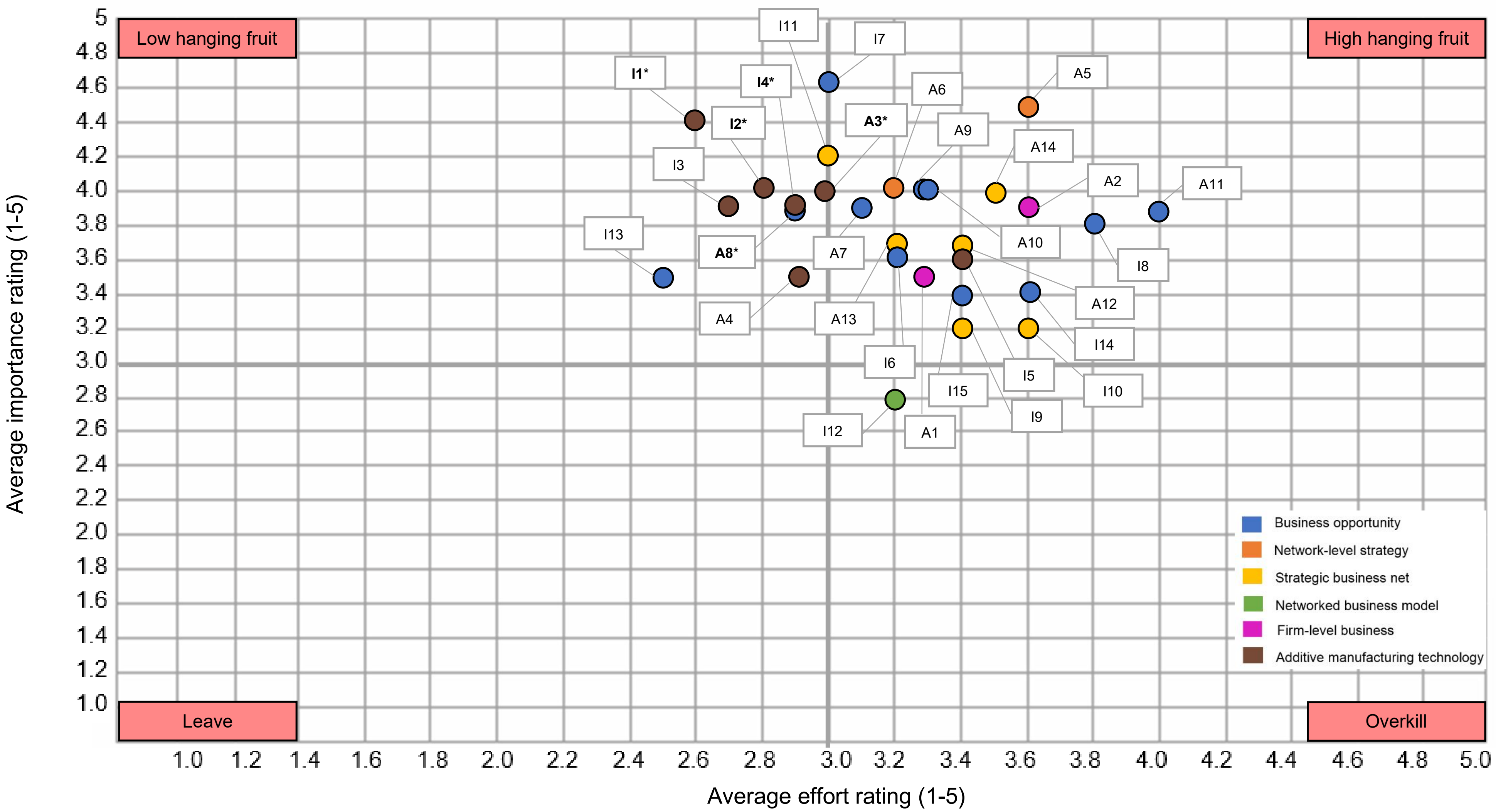


Figure 6.19: Scatter plot of effort and importance of sensing phase (manufacturing)

Table 6.10: Sensing phase notation

Analysis sub-phase				Ideation sub-phase			
A1	1.1.1 Internal business analysis	**A8***	1.4.2 Customer profile	**I1***	2.1.1 Part-material-process analysis	I10	2.3.2 Strategic business net configuration
A2	1.1.2 Value network analysis	A9	1.4.3 Industry and market analysis	**I2***	2.1.2 AM manufacturing technology selection	I11	2.3.3 Key success factors
A3*	1.2.1 Industrial applications	A10	1.4.4 Realisation requirements/ enablers	I3	2.1.3 AM process chain analysis	I12	2.4.1 Value network elements
A4	1.2.2 Manufacturing technology analysis	A11	1.4.5 Strategy formulation	**I4***	2.1.4 Business impact analysis		2.4.2 Value proposition elements
A5	1.3.1 External environment analysis	A12	1.5.1 Strategic business net need	I5	2.1.5 Value network impact analysis		2.4.3 Value architecture elements
A6	1.3.2 Operating environment analysis	A13	1.5.2 Objectives	I6	2.2.1 Refinement		2.4.4 Value finance elements
A7	1.4.1 Business opportunity identification	A14	1.5.3 Boundaries	I7	2.2.2 Selection and prioritisation	I13	2.5.1 Customer profile
				I8	2.2.3 Risk management	I14	2.5.2 Network completion
				I9	2.3.1 Initiation features	I15	2.5.3 Business case

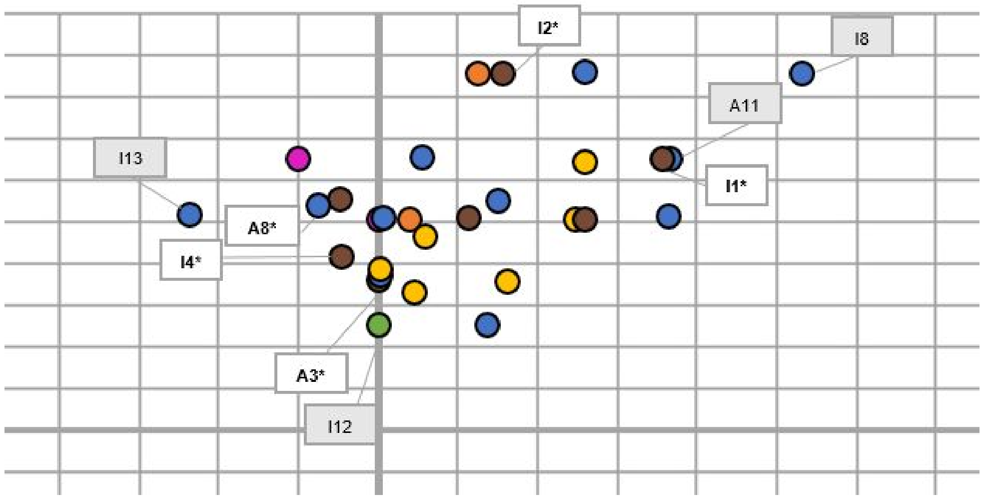


Figure 6.21: Scatter plot of points of interest within the sensing phase (business)

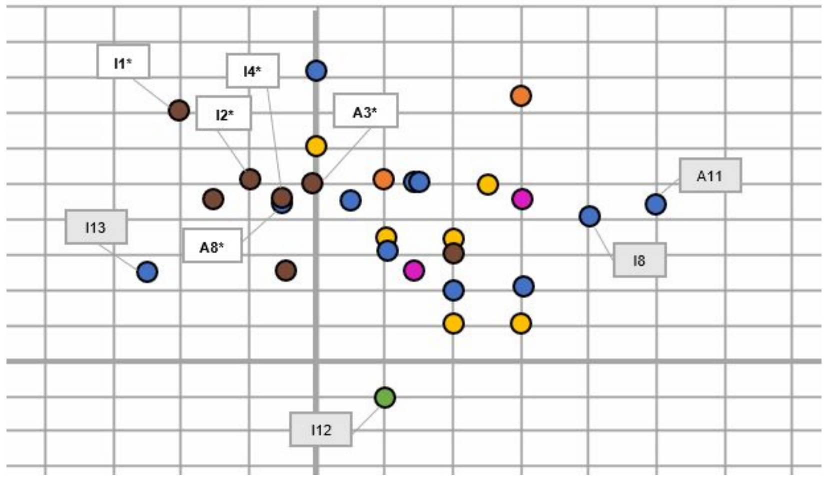


Figure 6.20: Scatter plot of points of interest within the sensing phase (manufacturing)

Figures 6.18 and 6.19 above summarise the rankings of the effort and importance of the steps contained within the sensing phase, consisting of the analysis and ideation sub-phases, from the business experts as well as the manufacturing experts' perspectives respectively. It seems like the data points from the manufacturing experts' scatter plot is slightly more scattered than those of the business expert's scatter plot, although in general, they seem mostly similar. However, for both scatter plots, it seems like most points are gathered above the medium importance line, indicating that both expert categories perceived most of the activities contained in the sensing phase as important.

Regarding the steps contained in the different development dimensions, the *AM technology dimension* (brown dots) stood out. It is interesting to note that it seems like these steps are perceived with lower implementation effort according to the manufacturing experts, but with higher perceived effort according to the business experts. A possible reason is that the business experts may not be as familiar with these steps due to their environments. Another development dimension that stood out, is the *firm-level business development dimension* (pink dots) because according to the business experts these steps are low hanging fruit, but according to the manufacturing experts, these steps are high hanging fruit that are perceived to require more effort to implement. These different perceptions illustrate that steps and activities may be perceived differently based on the environments and expertise of the experts.

The identified points of interest for the sensing phase are illustrated in Figures 6.20 and 6.21 for the two categories respectively. Within the analysis sub-phase, the step that specifically stood out is *strategy formulation (A11)*, which obtained the highest perceived effort ranking from the manufacturing experts, since these activities may not come naturally for these experts that are primarily engineers.

Within the ideation sub-phase, step *I12* regarding the ideation of the *networked BM elements* is perceived to be an overkill according to the manufacturing experts. However, this step was perceived with medium importance by the business experts. Since the networked BM elements are developed and evaluated throughout each sub-phase of the framework, it might seem like an overkill, however given the importance of the elements, it is important to be revised within each phase.

Concerning possible outliers, *risk management (I8)* stood out as it is perceived with the highest importance and effort ranking according to the business experts, with a high effort but only a relatively high importance ranking according to the manufacturing experts. Although the importance of this step differs a little bit, both categories recognise the effort of the step indicating that the implementation of this step is perceived to be difficult and require time, irrespective of the environment.

It is furthermore interesting to note that the activities regarding the ideation and defining of the *customer profile (I13)* obtained the lowest perceived effort ranking from both expert categories. This may indicate that in SMMEs are in touch with their customer's needs and have close relationships with their customers, even though the customer relationship BM element was perceived as high effort by the manufacturing experts. This is however a positive indication within the context of this study, as value co-creation efforts among network partners include contributions and close contact with customers.

Reflecting on the most important steps indicated by participant H, it is interesting that according to the business experts these steps are scattered on the effort axis, but according to the manufacturing experts, these steps are all ranked within the low hanging fruit quadrant.

6.7.3.5 Seizing phase: Business experts

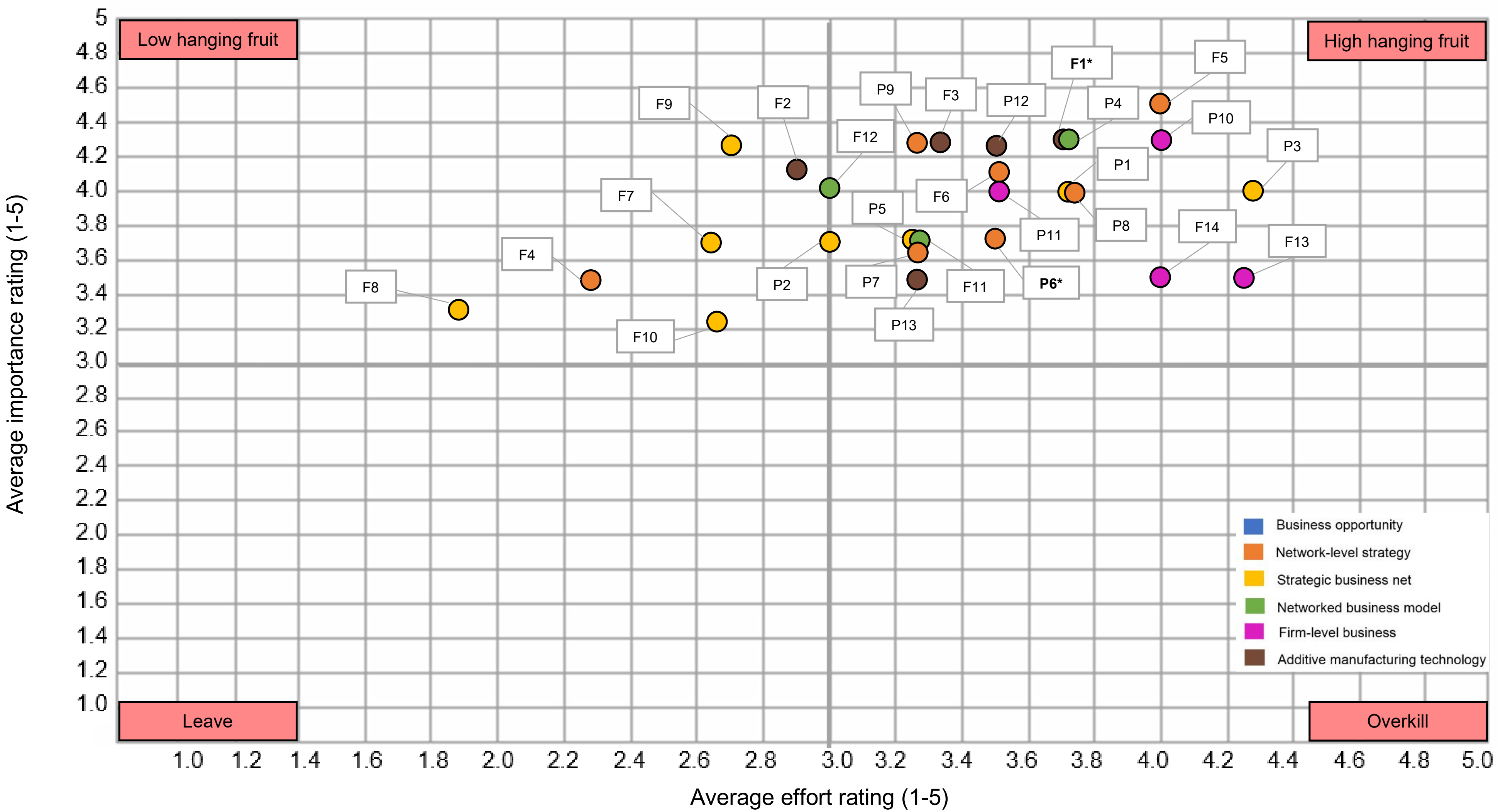


Figure 6.22: Scatter plot of effort and importance of seizing phase (business)

6.7.3.6 Seizing phase: Manufacturing experts

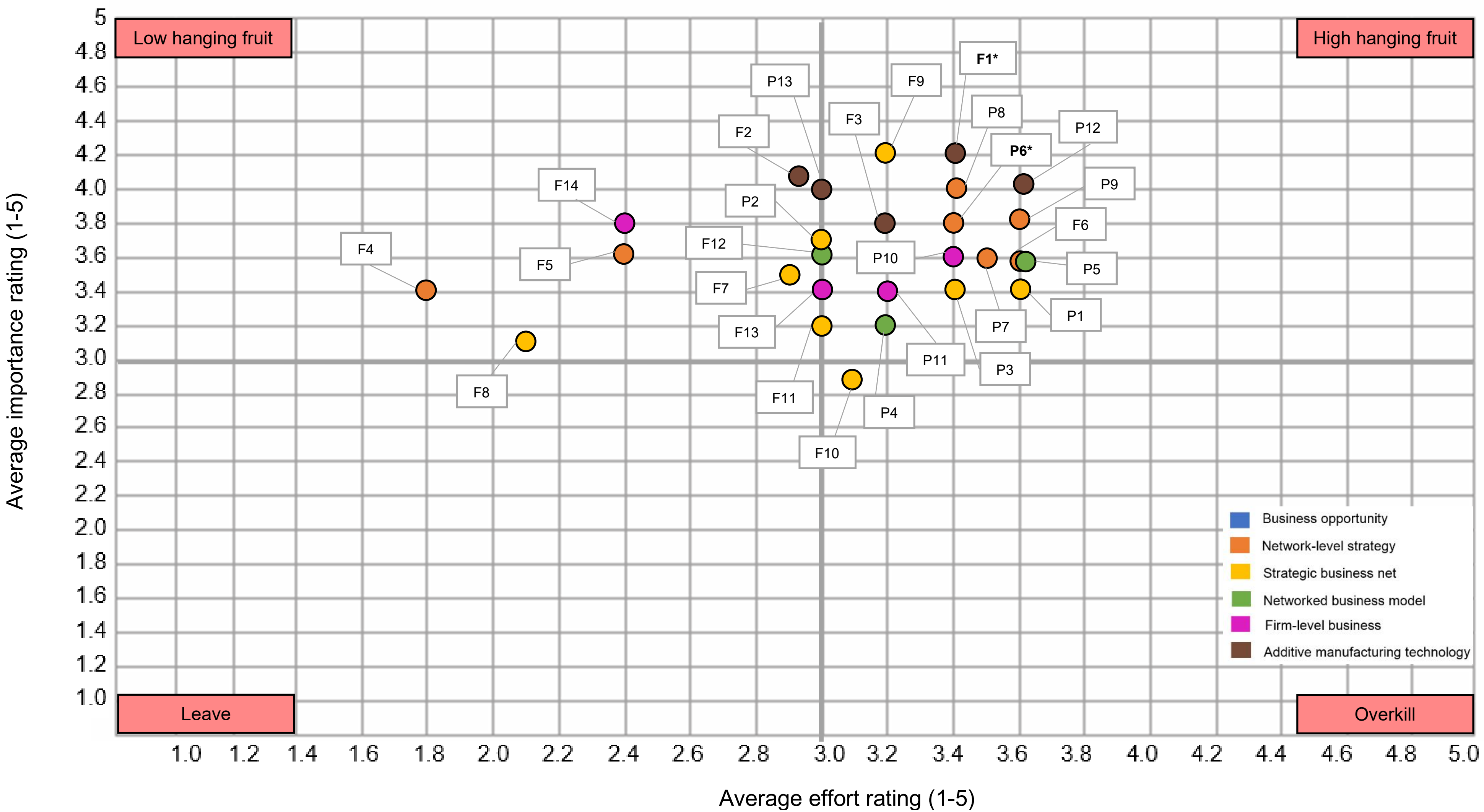


Figure 6.23: Scatter plot of effort and importance of seizing phase (manufacturing)

Table 6.11: Seizing phase notation

Feasibility sub-phase				Prototyping sub-phase			
F1*	3.1.1 Technical feasibility assessment	F10	3.3.4 Strategic business net configuration	P1	4.4.1 Strategic business net configuration	P8	4.3.3 Marketing plan development
F2	3.1.2 Financial feasibility assessment	F11	3.3.5 Performance measurements	P2	4.1.2 Functional interdependence assessment	P9	4.3.4 Action plan development
F3	3.1.3 Business feasibility assessment	F12	3.4.1 Value network elements	P3	4.1.3 Strategic business net features prototyping	P10	4.4.1 Action plan development
F4	3.2.1 Business environment assumptions		3.4.2 Value proposition elements	P4	4.2.1 Networked BM prototyping	P11	4.4.2 Firm-level prototyping
F5	3.2.2 Production plan development		3.4.3 Value architecture elements	P5	4.2.2 Alignment	P12	4.5.1 Joint offering prototyping
F6	3.2.3 Strategic roadmaps development		3.4.4 Value finance elements	**P6***	4.3.1 Production plan prototyping	P13	4.5.2 Customer feedback
F7	3.3.1 Partner evaluation and selection	F13	3.5.1 Feasibility and profitability assessment	P7	4.3.2 Strategic roadmaps development		
F8	3.3.2 Partner involvement	F14	3.5.2 Customer feedback				
F9	3.3.3 Strategic business net features development						

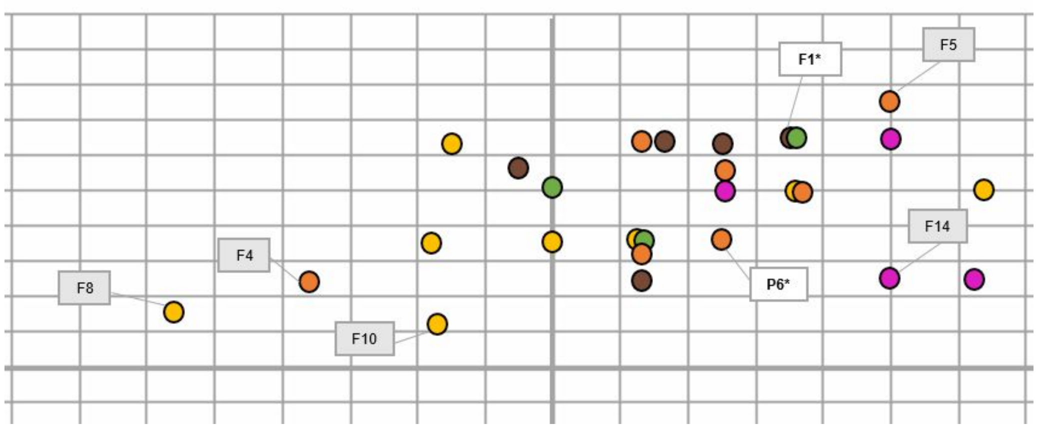


Figure 6.25: Scatter plot of points of interest within the seizing phase (business)

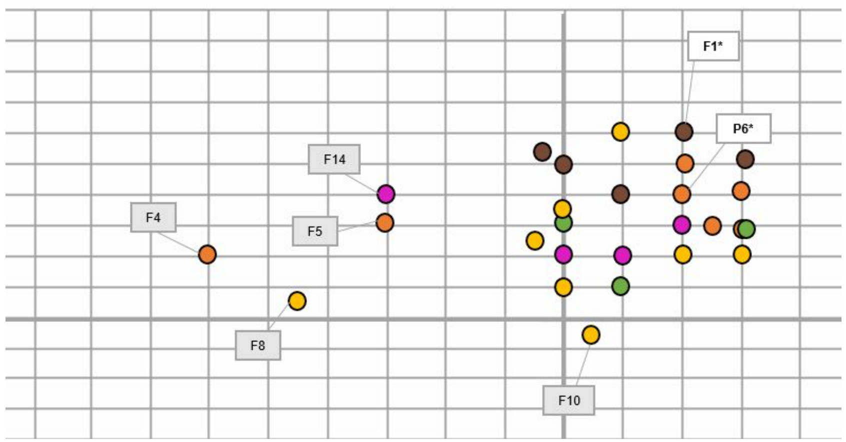


Figure 6.24: Scatter plot of points of interest within the seizing phase (manufacturing)

Figures 6.22 and 6.23 above summarise the rankings of the perceived effort and importance of the steps contained within the seizing phase, consisting of the feasibility and prototyping sub-phases, from the business experts as well as the manufacturing experts' perspectives respectively. It seems like the data points from the business experts' scatter plot is more scattered regarding implementation effort than those of the manufacturing expert's scatter plot. However, for both scatter plots, it seems like most points are gathered above the medium importance line, indicating that both expert categories perceived most of the activities contained in the seizing phase as important.

Regarding the steps contained in the different development dimensions, the *strategic business net development dimension* stood out. It is interesting to note that most of this development dimension's steps are contained within the low hanging fruit quadrant (perceived with less implementation effort) according to the business experts, but according to the manufacturing experts, these steps are perceived with a bit more effort. This illustrates that the manufacturing experts may perhaps need more guidance to execute these steps regarding the development and configuration of the strategic business net.

The identified points of interest for the seizing phase are illustrated in Figures 6.24 and 6.25 for the two categories respectively. It is however noteworthy that none of the steps contained within this phase obtained a very high average importance ranking that stood out from among the other points. However, the one step that was perceived with a low importance ranking according to the manufacturing experts, is *strategic business net configuration (F10)* that is located within the overkill quadrant. However, this step was perceived with slightly higher importance from the business experts, requiring a much lower effort to implement. This low importance score may indicate that the manufacturing experts might not have fully understood what was meant by the step or might not have understood the implications of this step, as it concerns the SBN configuration process that forms an integral part of the management framework.

Within the feasibility sub-phase, a few steps stood out among both the scatter plots. The first step is *partner involvement* (*F8)* that obtained a low average perceived effort and importance rankings from both expert categories. This step concerns the information disclosed and obtained from partners and seems to be perceived as one of the easier tasks to implement for SMMEs. The next step is *business environment assumptions (F4)* that also obtained low average perceived effort and importance rankings from both expert categories. This may be because within the SMME environment, business assumptions are not always clearly stated, but rather assumed and unknowingly adjusted as the environment changes. This can also reflect the flexibility of SMMEs as they frequently need to adjust to survive.

Production plan development (F5) obtained a lower average perceived effort score from the manufacturing experts, and a much higher perceived effort and importance ranking from the business experts. This may indicate that engineers, that primarily made up the manufacturing expert category, are much more comfortable with the development of production plans and production-related steps than the business experts, which do make sense as they do it as part of their daily activities. *Customer feedback (F14)* is another step that also stood out because it obtained a relatively low effort ranking from the manufacturing expert category, with a high effort ranking from the business expert category. This result may indicate that manufacturing SMME might have closer relationships with their customers, and therefore it might be easier for them to obtain customer feedback.

Reflecting on the most important steps indicated by participant H, both steps within this phase are contained within the high hanging fruit quadrant, according to both expert categories.

6.7.3.7 Transforming phase: Business experts

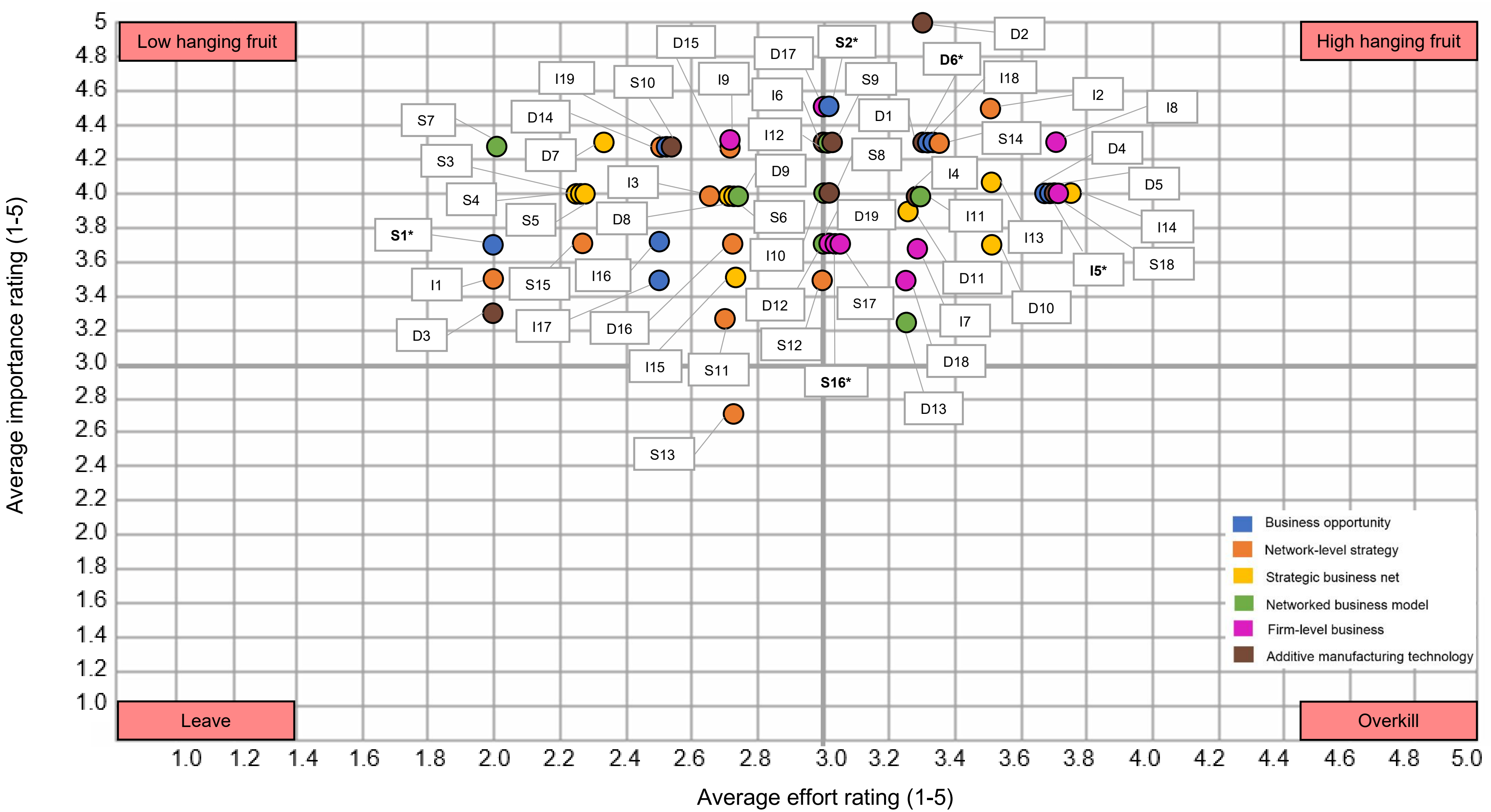


Figure 6.26: Scatter plot of perceived effort and importance of transforming phase (business)

6.7.3.8 Transforming phase: Manufacturing experts

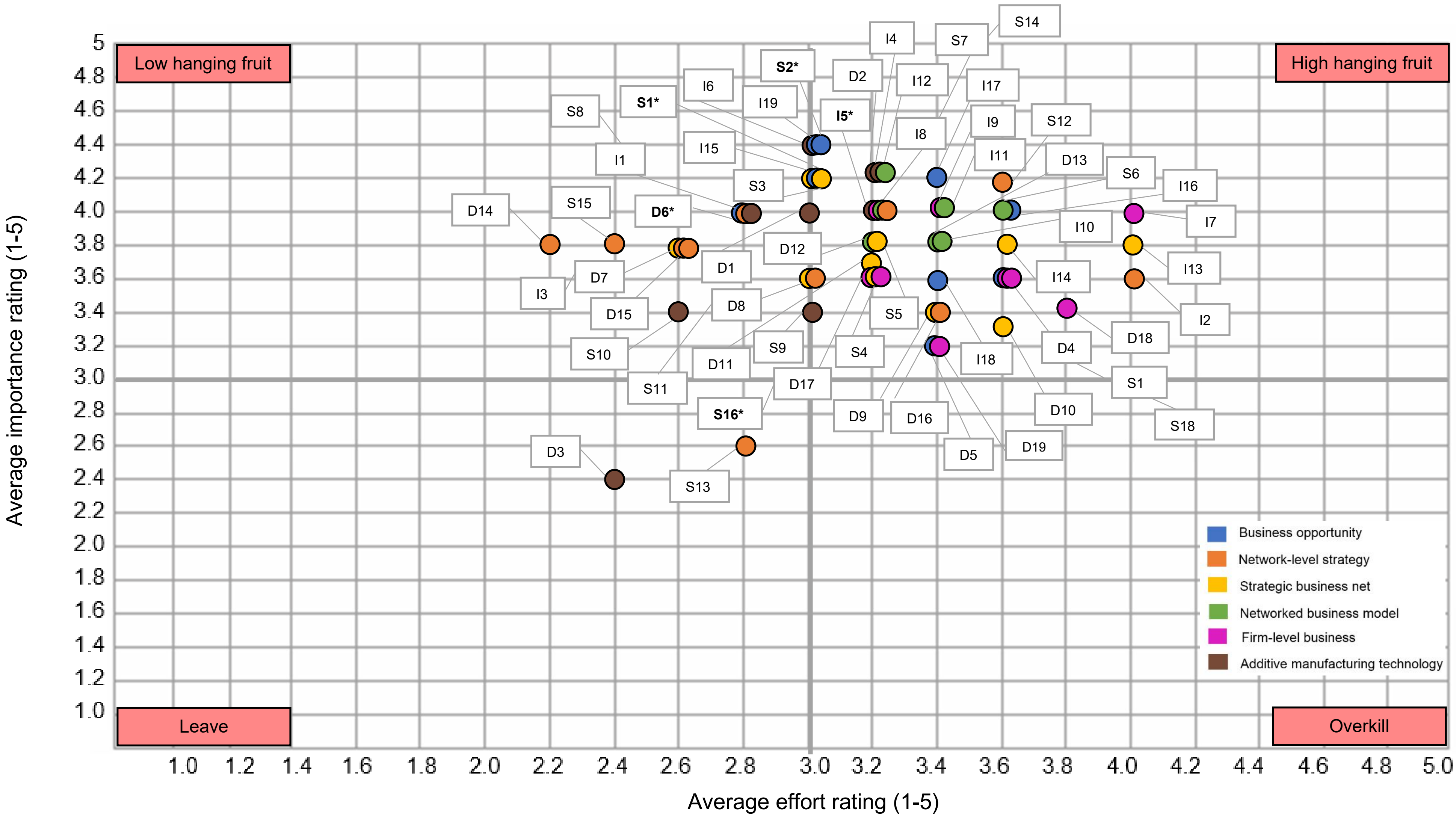


Figure 6.27: Scatter plot of perceived effort and importance of transforming phase (manufacturing)

Table 6.12: Transforming phase notation

Decision-making sub-phase		Implementation sub-phase		Sustainability sub-phase	
D1	5.1.1 Strategic integration and alignment (firm-level)	I1	6.1.1 Feedback and progress reporting	**S1***	7.1.1 Customer feedback
D2	5.1.2 Investment and financing (firm-level)	I2	6.1.2 Implementation plan	**S2***	7.1.2 Re-evaluate and adjust
D3	5.1.3 Other decisions	I3	6.1.3 Communicate with network partners	S3	7.2.1 Strategic business net performance
D4	5.2.1 Shared mental model	I4	6.2.1 Implementation plan	S4	7.2.2 Partner performance
D5	5.2.2 Risk management	**I5***	6.2.2 AM production system implementation	S5	7.2.3 Evaluate and adjust
D6*	5.2.3 Customer's perceived value	I6	6.2.3 Evaluate and adjust	S6	7.3.1 Networked BM elements performance
D7	5.3.1 Strategic business net configuration	I7	6.3.1 Implementation plan	S7	7.3.2 Evaluate and adjust
D8	5.3.2 Strategic business net features decision-making	I8	6.3.2 Firm-level implementation	S8	7.4.1 AM technology analysis
D9	5.3.3 Harmonisation of features.	I9	6.3.3Evaluate and adjust	S9	7.4.2 Part-process-material analysis
D10	5.3.4 Value creation levels	I10	6.4.1 Implementation plan	S10	7.4.3 Evaluate and adjust
D11	5.3.5 Performance measurements	I11	6.4.2 Networked BM implementation	S11	7.5.1 Ecosystem scanning
D12	5.4.1 Networked BM elements decision-making	I12	6.4.3 Evaluate and adjust	S12	7.5.2 Innovation assessment and development
D13	5.4.2 Harmonisation of elements	I13	6.5.1 Implementation plan	S13	7.5.3 Create isolation mechanisms
D14	5.5.1 Production plan finalisation	I14	6.5.2 Strategic business net implementation	S14	7.5.4 Long-term competitiveness
D15	5.5.2 Marketing plan finalisation	I15	6.2.3 Evaluate and adjust	S15	7.5.5 Communicate with network partners
D16	5.5.3 Strategic roadmaps finalisation	I16	6.6.1 Monitor and evaluate	**S16***	7.6.1 Continuous learning
D17	5.6.1 Action-plan development	I17	6.6.2 Partner feedback and reporting	S17	7.6.2 Change management plan development
D18	5.6.2 Change management plan development	I18	6.6.3 Risk management	S18	7.6.3 Training plan development
D19	5.6.3 Training plan development	I19	6.6.4 Re-evaluate and adjust		

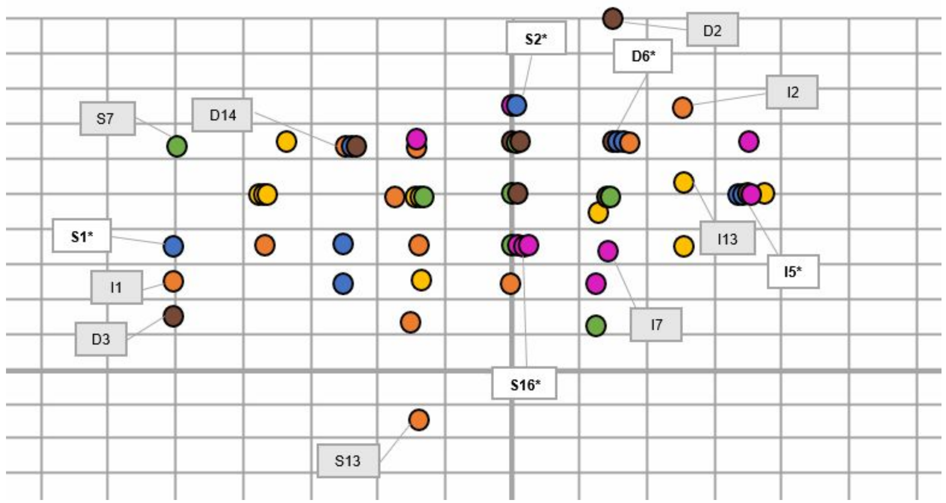


Figure 6.29: Scatter plot of points of interest within the transforming phase (business)

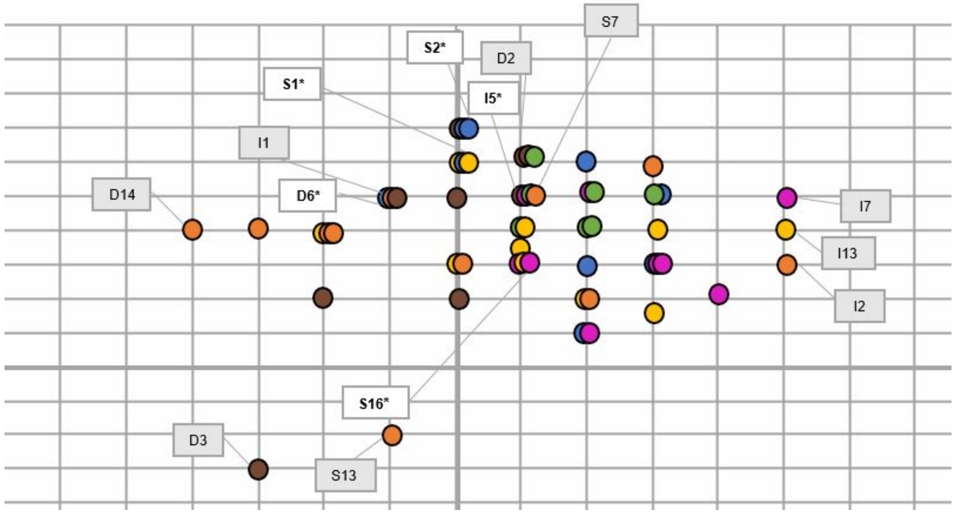


Figure 6.28: Scatter plot of points of interest within the transforming phase (manufacturing)

Figures 6.26 and 6.27 above summarise the rankings of the perceived effort and importance of the steps contained within the transforming phase, consisting of the decision-making, implementation, and sustainability sub-phases, from the business experts as well as the manufacturing experts' perspectives respectively. It seems like the data points from the business experts' scatter plot is more scattered regarding implementation effort than those of the manufacturing expert's scatter plot. However, for both scatter plots, it seems like most points (except for two) are gathered above the medium importance line, indicating that both expert categories perceived most of the activities contained in the transforming phase as important.

The identified points of interest for the transforming phase are illustrated in Figures 6.28 and 6.29 for the two categories respectively. The *create isolation mechanisms (S13)* step obtained similar low perceived effort and importance rankings from both expert categories, placing the step within the leave quadrant. Since the two expert categories agreed, it illustrates that within the SMME environment this may be an unnecessary step and will therefore be discarded. The leave quadrant contains another step according to the manufacturing experts, *other decisions (D3)* concerning AM technology, which is perceived with low effort and importance. This step also contained a relatively low perceived effort and importance ranking from the business experts. It may be because the concepts, decisions or considerations addressed within this step may be logical or more on a practical level for the manufacturing experts and therefore may not be deemed necessary to be included in a management framework.

It is furthermore interesting to note that three steps regarding implementation plans, including the *network-level strategy (I2)*, the *firm-level (I7)* and *strategic business net (I13)* obtained the highest perceived effort rankings from a manufacturing perspective. This may indicate that implementation efforts of plans and strategies might not always be so easy within manufacturing SMMEs, specifically regarding the strategic business net.

The step that obtained the highest average perceived importance ranking from the business experts is *investment and financing (firm-level) (D2)*, which obtained only an average perceived importance score from the manufacturing experts' perspective. This is interesting because the *total-cost of ownership (E18)* element that forms part of networked BM also obtained an average importance ranking of 5 from the business experts and only an average importance ranking from the manufacturing experts. Therefore, illustrating that costs, investments, and ownership are perceived to be very important aspects to consider from a business perspective. The last step that stood out is the *evaluate and adjust the networked BM (S7)* step that the business experts perceived with relatively low effort, with high importance, compared to the higher perceived effort of this step according to the manufacturing experts. This may be because business experts are more comfortable with developing and adjusting BM elements than manufacturing experts or engineers.

Reflecting on the most important steps indicated by participant H, most steps within this phase are contained within the high hanging fruit quadrant, according to both expert categories.

6.7.4 Questionnaire results comparison

The following section aims to compare the results from the business and manufacturing expert categories. Figures 6.30 and 6.31 below illustrate the difference between the two categories of experts' average perceived importance and effort rankings for each networked BM element respectively.

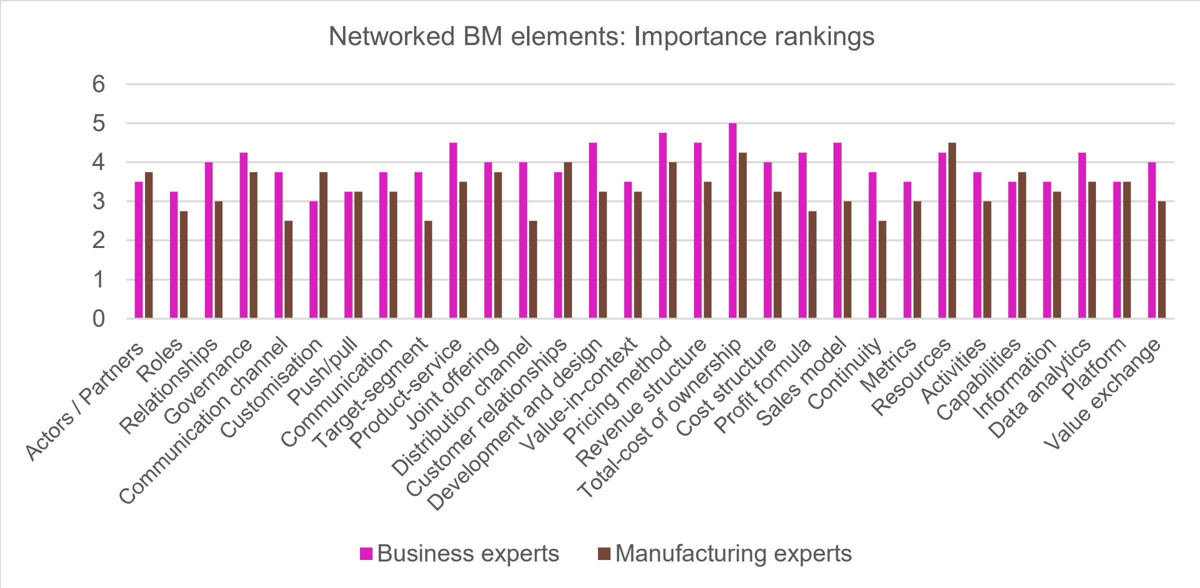


Figure 6.31: Comparison of networked BM elements importance rankings

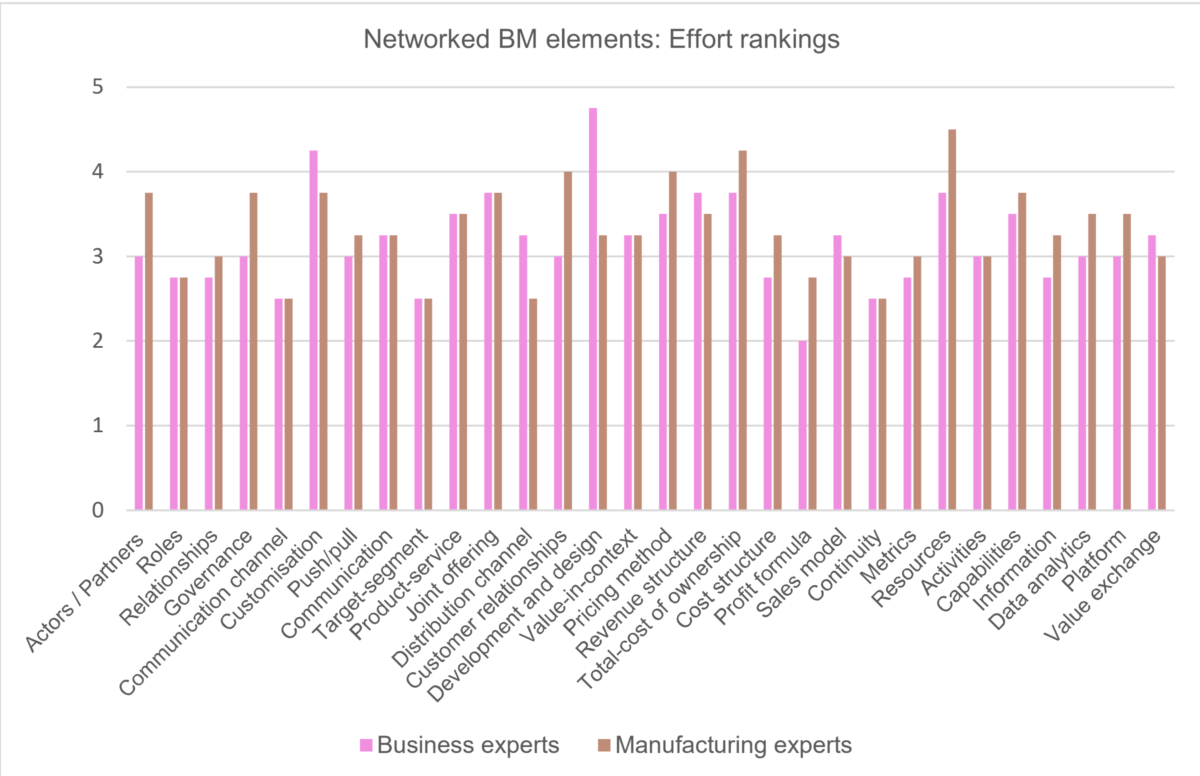


Figure 6.30: Comparison of networked BM elements effort rankings

Figures 6.32 and 6.33 below illustrate the difference between the two categories of experts' average perceived importance and effort rankings for each strategic business net feature respectively.

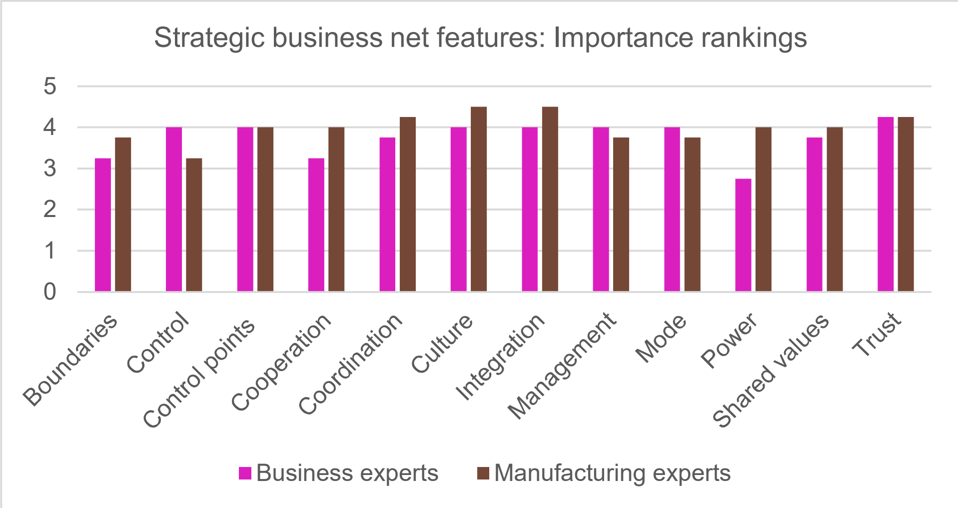


Figure 6.32: Comparison of strategic business net features importance rankings

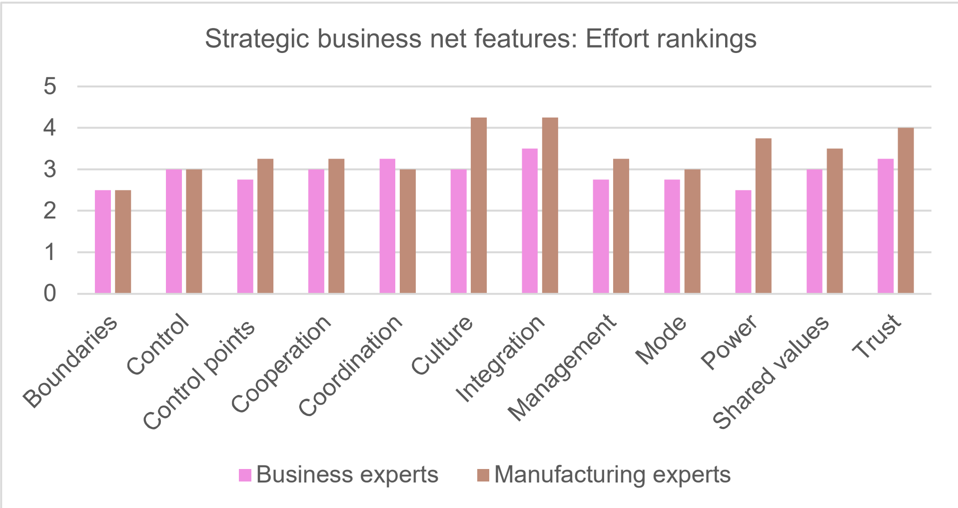
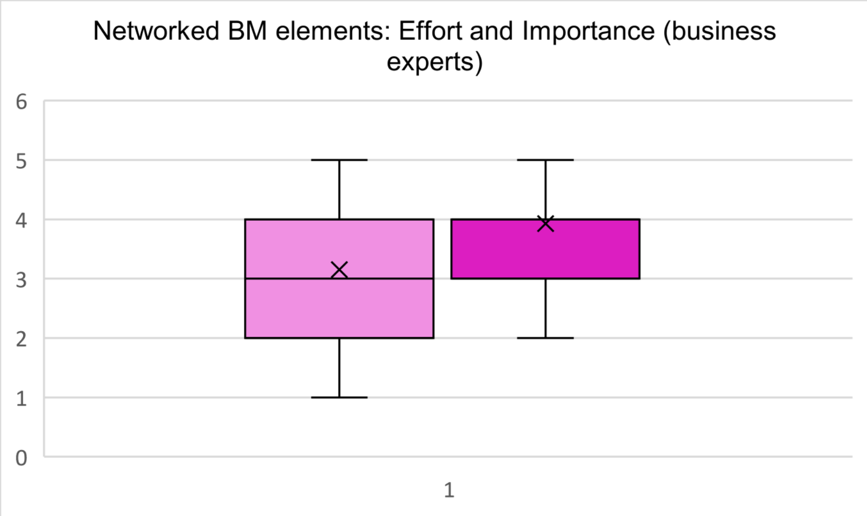


Figure 6.33: Comparison of strategic business net features effort rankings

Based on Figure 6.30, it seems like the manufacturing experts perceived the networked BM elements with slightly higher effort whereas it seems like the business experts perceived the elements with slightly higher importance, based on Figure 6.31. From Figures 6.32 and 6.33, it seems like the manufacturing experts perceived the strategic business net features with slightly higher effort and importance. Furthermore, these four figures can be used to analyse and compare each individual element or feature if needed.

The following section aims to compare the results obtained from the business experts and manufacturing experts in terms of variability and distribution, using all the data points obtained from the completed questionnaires. The results of the networked BM elements and strategic business net features are first presented and discussed, followed by the discussion and results of the activities contained in the seven sub-phases.



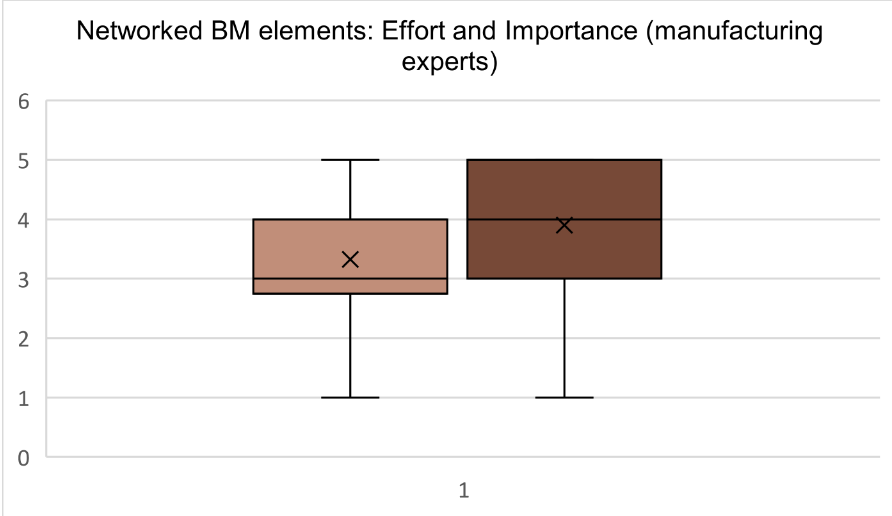
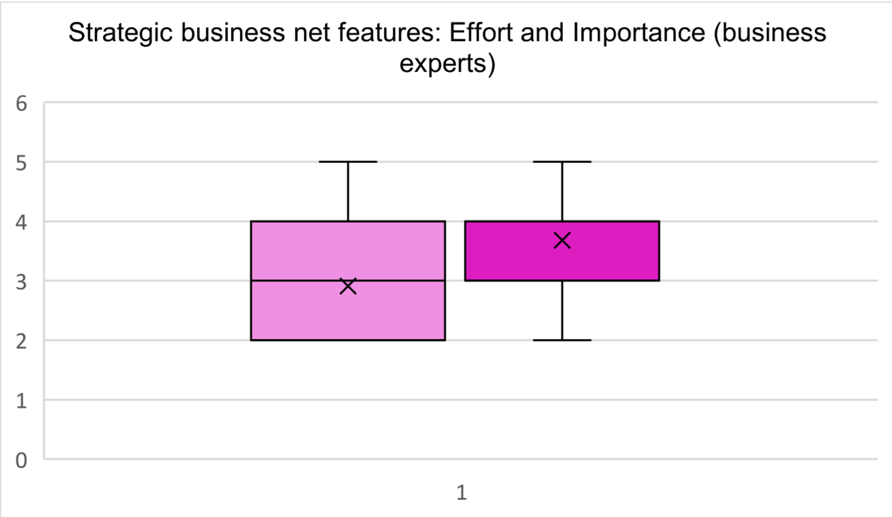


Figure 6.34: Networked BM elements: business vs manufacturing experts



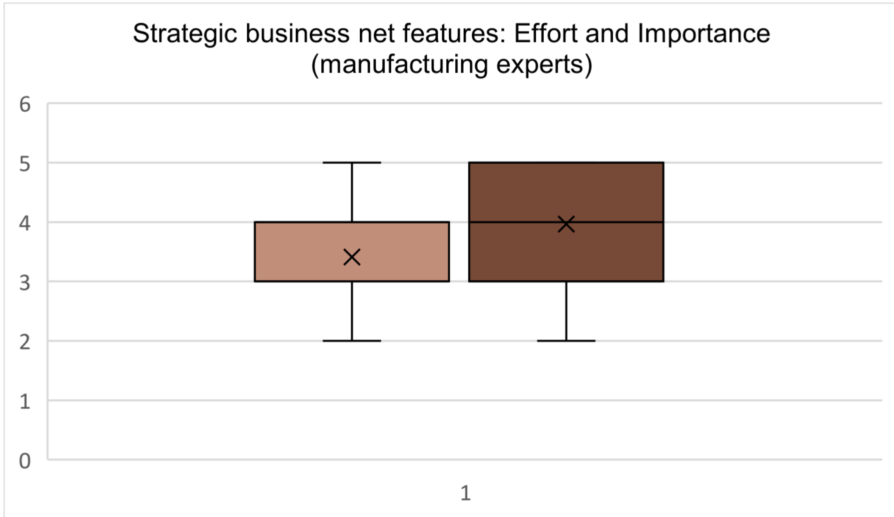


Figure 6.35: Strategic business net features: business vs manufacturing experts

Figure 6.34 above presents the results obtained regarding the perceived effort and importance rankings from the business experts (pink) and the manufacturing experts (brown) for the networked BM elements. From these boxplots, it is evident that the business experts had a higher variability regarding their perceived effort scores, and the manufacturing experts had a lower variability, implying they agreed more on the rankings. An interesting observation is that it is the other way around for the perceived importance rankings, as the variability is higher for the manufacturing experts than for the business experts. What is however important, is that 75% of the data points are above the threshold of 3 (medium importance) for both the expert categories. This result illustrates that the business experts are more in agreement regarding the perceived importance of the networked BM elements, which is an expected result given the backgrounds of the experts. On the other hand, this result illustrates that there seems to be more disagreement between the manufacturing experts regarding the importance of the networked BM elements, which may also be because of their backgrounds or due to being unfamiliar with some of the concepts.

Figure 6.35 above presents the results obtained regarding the perceived effort and importance rankings from the business experts (pink) and the manufacturing experts (brown) for the strategic business net features. It is noteworthy that there are similar distributions between the two expert categories for the strategic business net features, compared to the networked BM elements. That is, the business experts have higher variability regarding the effort of implementing these features, and the manufacturing experts have a higher variability regarding the importance of these features. Again, however, 75% of the data points are above the threshold of 3 (medium importance) for both expert categories. This result illustrates that the business experts are also more in agreement regarding the perceived importance of the strategic business net features, which is an expected result given the backgrounds of the experts. On the other hand, this result illustrates that there seems to be more disagreement between the manufacturing experts regarding the importance of the strategic business net features, which may also be because of their backgrounds.

The figures below present the results obtained regarding the perceived effort and importance rankings from the business experts (pink) and the manufacturing experts (brown) for each of the seven sub-phases. As mentioned above, all the raw data points for all the activities contained in each sub-phase were used in the construction of the boxplots.

For the analysis sub-phase, Figure 6.36, the effort has similar variability distributions for the two categories. However, the variability regarding importance is much more for the manufacturing category and much smaller for the business expert's category. The same is seen regarding the variability distributions for the ideation sub-phase, also Figure 6.34. From a business perspective, 75% of the points are above the threshold of 4 (high importance) for both sub-phases, indicating agreement among the experts regarding the activities' importance. From the manufacturing perspective, although a wider variability, 75% of the data points are at least above the threshold of 3 (medium importance) for both sub-phases. It also seems like all experts are in agreement regarding the effort of the sensing phase's activities. Most of the activities contained in this phase might be more business related and may be part of some of the business expert's daily activities, hence the agreement. These activities might not be very familiar to most of the manufacturing experts, and therefore the difference in the perceived importance.

For the feasibility and prototyping sub-phases, Figure 6.37, the effort has similar variability distributions for the two expert categories. Also, regarding the importance of the activities contained in the feasibility sub-phase, the two expert categories agree (75% of the points are above the threshold of 3), with little variability in the distribution of the data points. However, regarding the importance of the activities contained in the prototyping phase, all the business experts seem to agree, but the manufacturing experts don't necessarily agree due to the visible high variability.

For the transformation phase, Figure 6.38, it is interesting to note that the business experts are all in agreement regarding the importance of these activities, with almost no variability and only a few outliers visible within these three sub-phases. From a manufacturing perspective, the variability distribution for the importance is relatively small for the decision-making sub-phase as well as the sustainability sub-phase, and larger for the implementation sub-phase. Regarding effort, the boxplots for the decision-making and implementation sub-phases have higher variability, whereas the manufacturing experts have lower variability, similar for both sub-phases. Also, interesting to note is that all three sub-phases have similar (low) variability regarding effort from a manufacturing perspective. Despite the variance for importance, 75% of the points are above the threshold of 3 for all three sub-phases, from both expert categories

.

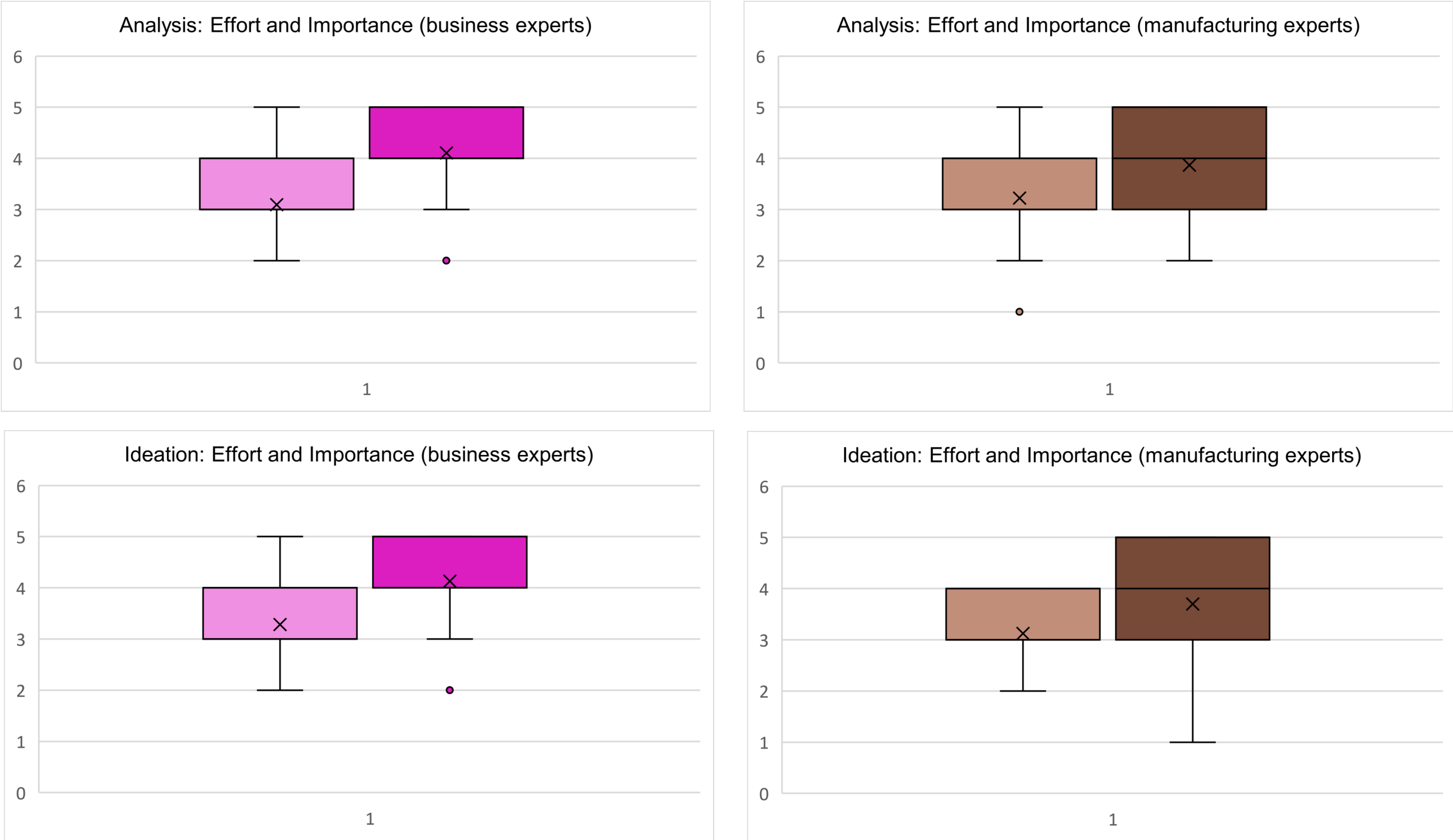


Figure 6.36: Sensing phase: business vs manufacturing experts

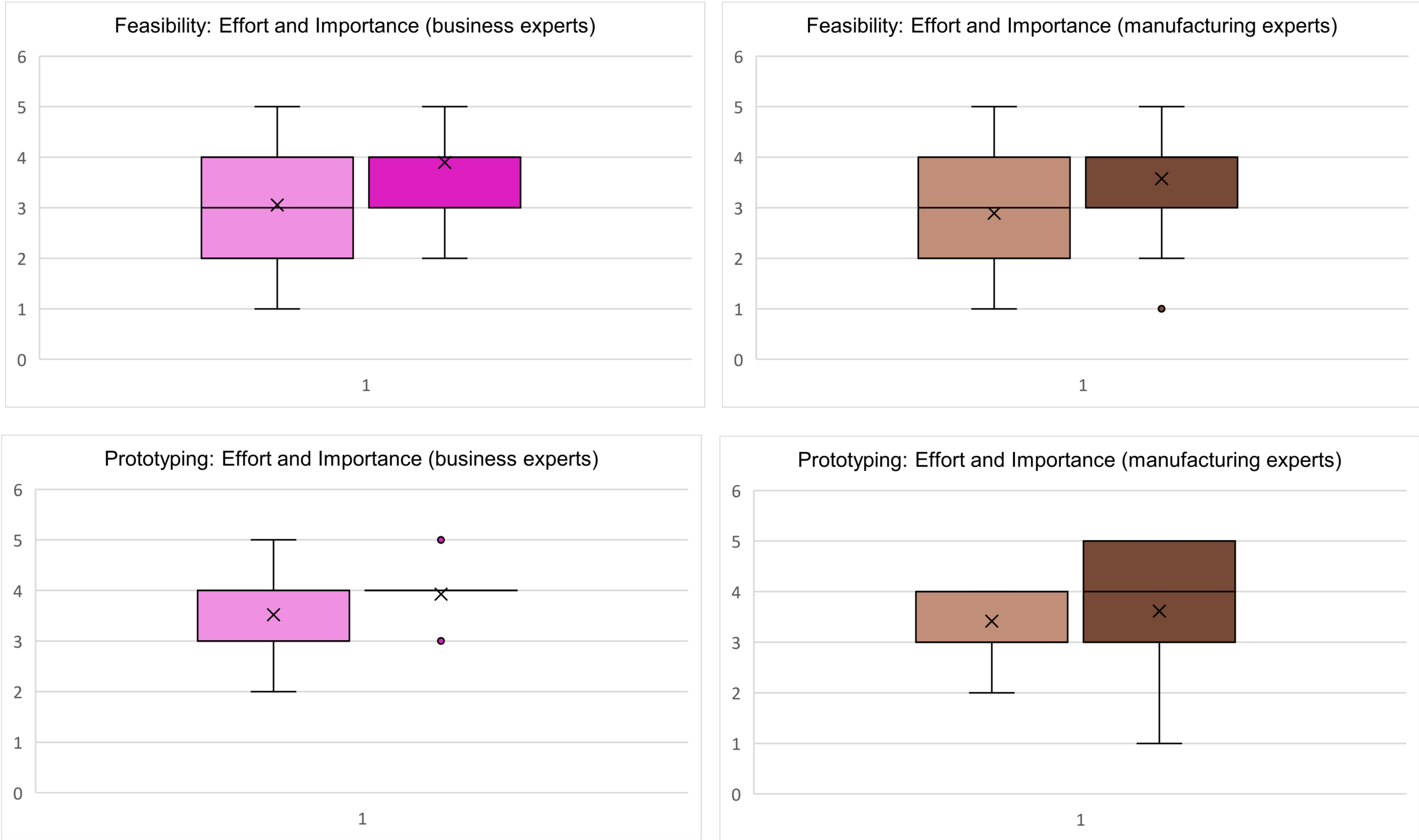
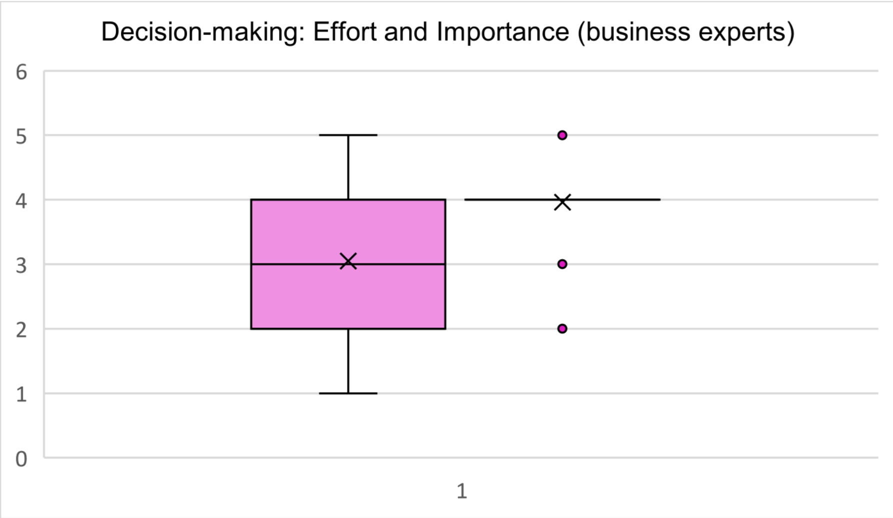
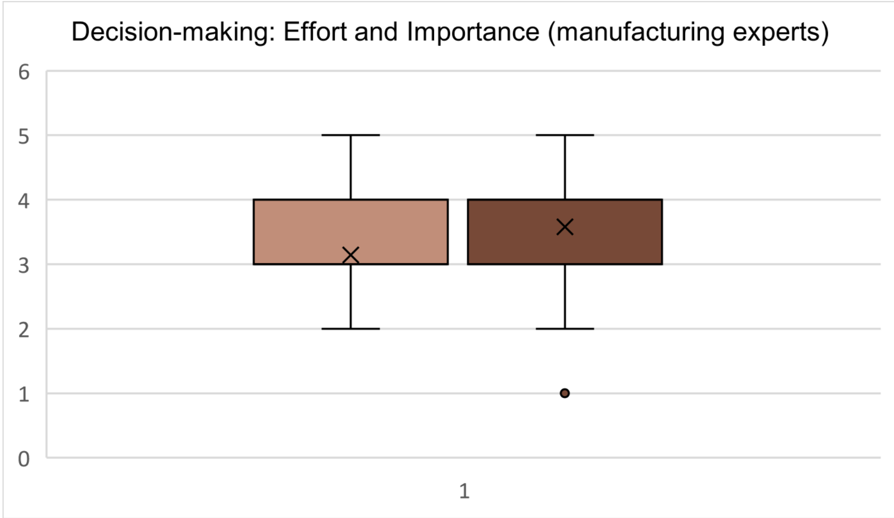
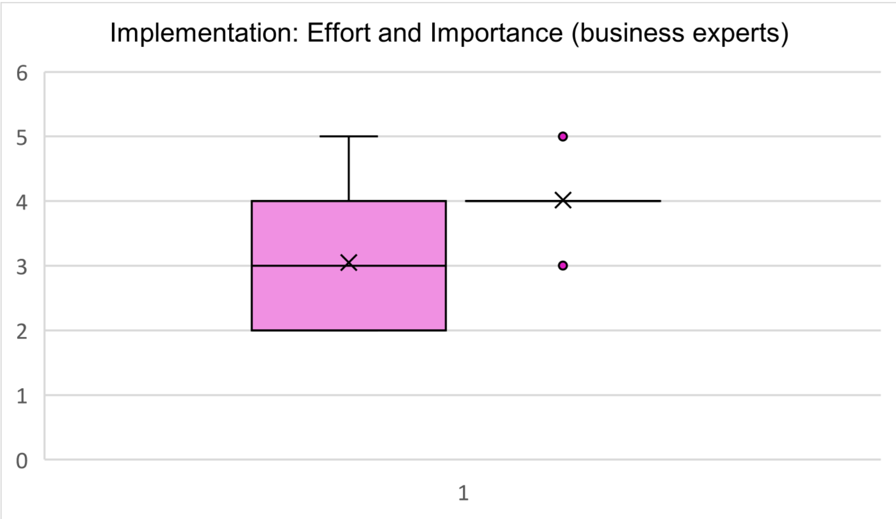


Figure 6.37: Seizing phase: business vs manufacturing experts


Decision-making: Effort and Importance (business experts)
6
5
4
3
2
1
0
1


Decision-making: Effort and Importance (manufacturing experts)
6
5
4
3
2
1
0
1


Implementation: Effort and Importance (business experts)
6
5
4
3
2
1
0
1

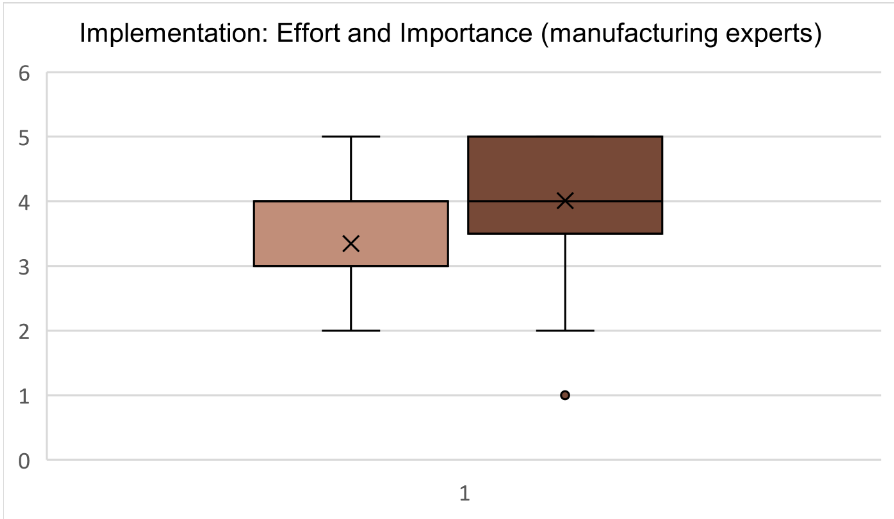

Implementation: Effort and Importance (manufacturing experts)
6
5
4
3
2
1
0
1

Figure 6.38: Transforming phase: business vs manufacturing experts

6.7.5 Outcomes of the questionnaire

Based on the discussions and reflections of the results of the structured questionnaire, it is concluded that the evaluation of the concerned aspects is positive and satisfactory within the context of this study. Most of the networked BM elements, strategic business net features, as well as the steps contained within the framework turned out to be ranked within either the low hanging or high hanging fruit quadrant. Furthermore, the gathering of the data points in terms of perceived effort and importance are also deemed adequate. These findings verify that the selected elements, features, and activities have satisfactory importance, as perceived by experts from diverse backgrounds.

Regarding the variability among the rankings provided by both the expert categories, none of the gatherings or variability in distributions turned out to indicate any irregularities or areas of concern. As indicated by the figures in the section above, some differences between the two expert categories were visible regarding the perceived effort and importance for the aspects evaluated. The differences were interesting to note, however, none of the results was particularly unexpected or unacceptable. The observed differences also confirmed the approach evaluating the framework by two distinct categories of experts from various backgrounds, to ensure the framework is applicable from both perspectives.

Furthermore, the other outcomes and findings of the structured questionnaire have been divided into two sub-categories. The first category highlights where the findings are directly aligned with the content of the research artefacts. The second category summarises where the findings highlighted inadequate aspects which required modifications to the research artefacts. The consideration and implementation of the outcomes described in Table 6.13 concluded Design Cycle 5.

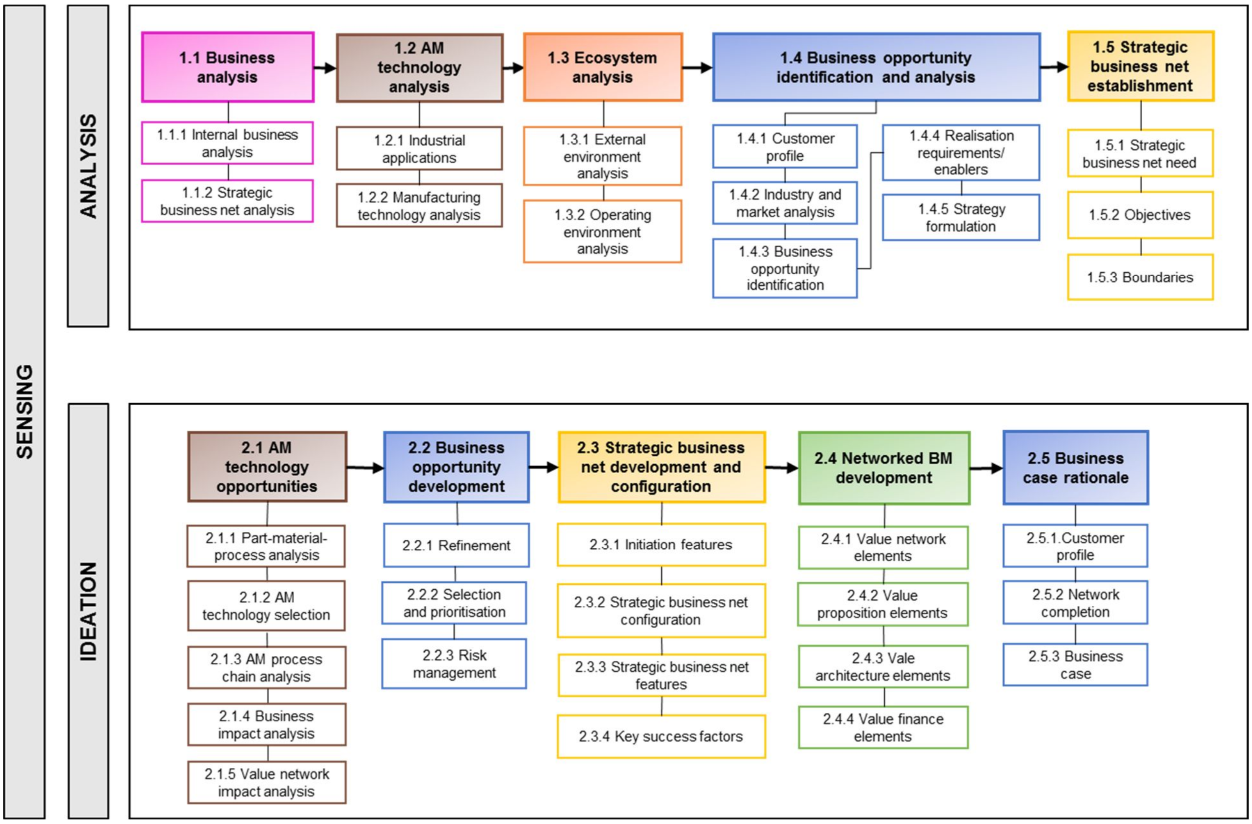
Table 6.13: Questionnaire outcomes after Round 3

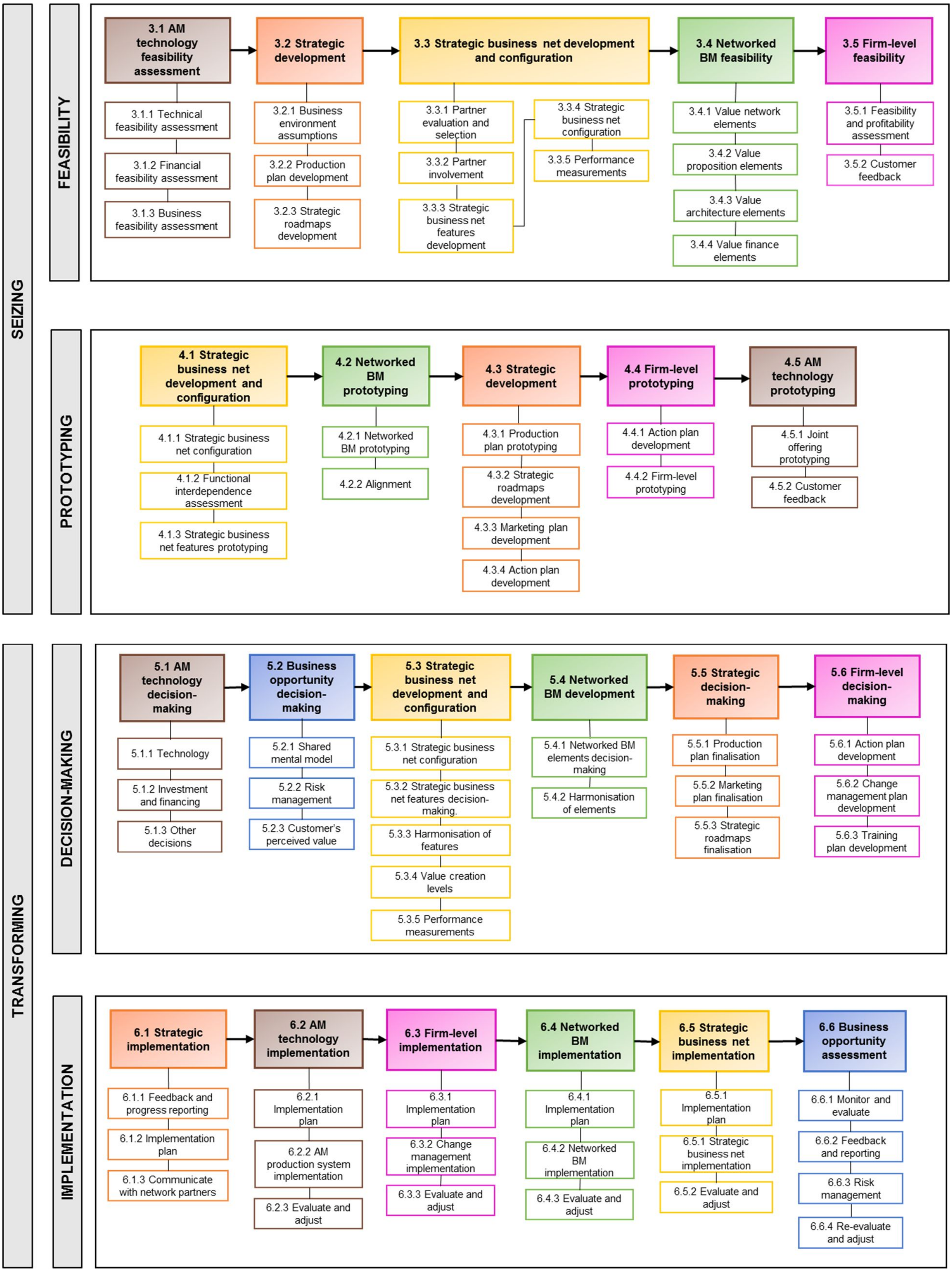
	Aspect	**Modification**
Validations	Networked BM elements	The results of the questionnaire confirmed that relevant and applicable networked BM elements were selected (overall average importance rating of 3.24 for all the elements).
		The results of the questionnaire confirmed that there are differences regarding the most important elements of a BM (as suggested by the literature) and that it may be dependent on each person's background and working environment.
		The results of the questionnaire confirmed there are a lack of consensus regarding the perceived effort to implement value network and value architecture elements, and therefore the need for efforts to guide SMMEs to configure and implement these elements that are associated with the strategic business net.
	Strategic business net features	The results of the questionnaire confirmed that relevant and applicable strategic business net features were selected (overall average importance rating of 3.16 for all the features.
	Management framework	Th results of the questionnaire confirmed that relevant and applicable activities were included in the management framework.
		The results of the questionnaire confirmed that aspects might be perceived differently based on the evaluator's background and expertise.
		The results of the questionnaire indicated that manufacturing experts perceive some of the business activities with higher implementation effort, whereas the business experts perceive some of the manufacturing activities with higher implementation effort.
		The results of the questionnaire confirmed that manufacturing experts working in SMMEs perceive some activities associated with the strategic

	Aspect	Modification
		business net with higher effort and may perhaps need more guidance to execute these steps (the aim of the management tool).
	Activity	During the analysis of the questionnaire's results, activities related to the customer specifically stood out, validating the importance of the customer within the operations of SMMEs. Furthermore, it seemed like manufacturing SMMEs have close relationships with their customers.
		The most important activities within the AM context, indicated by participant H, obtained satisfactory perceived importance rankings from the other experts. Most activities were located within the high hanging fruit quadrant, and only a few in the low hanging fruit within the sensing phase.
Modifications	Activity	The removal of the *create isolation mechanisms* step within the sustainability sub-phase as both expert categories agreed on the low perceived effort (average of 2.75 and 2.80 respectively) and importance (average of 2.75 and 2.60 respectively) of this activity.

6.8 Part E-6: Proposed management framework

After all the changes, modifications and improvements to the initial management framework were made, based on the expert feedback and questionnaire's results, a management framework was proposed. An overview of this framework is provided below in Figure 6.39. The first two phases of this framework are tested in the contextual application domain in the next chapter.




SEIZING
FEASIBILITY
3.1 AM technology feasibility assessment
3.1.1 Technical feasibility assessment
3.1.2 Financial feasibility assessment
3.1.3 Business feasibility assessment
3.2 Strategic development
3.2.1 Business environment assumptions
3.2.2 Production plan development
3.2.3 Strategic roadmaps development
3.3 Strategic business net development and configuration
3.3.1 Partner evaluation and selection
3.3.2 Partner involvement
3.3.3 Strategic business net features development
3.3.4 Strategic business net configuration
3.3.5 Performance measurements
3.4 Networked BM feasibility
3.4.1 Value network elements
3.4.2 Value proposition elements
3.4.3 Value architecture elements
3.4.4 Value finance elements
3.5 Firm-level feasibility
3.5.1 Feasibility and profitability assessment
3.5.2 Customer feedback
PROTOTYPING
4.1 Strategic business net development and configuration
4.1.1 Strategic business net configuration
4.1.2 Functional interdependence assessment
4.1.3 Strategic business net features prototyping
4.2 Networked BM prototyping
4.2.1 Networked BM prototyping
4.2.2 Alignment
4.3 Strategic development
4.3.1 Production plan prototyping
4.3.2 Strategic roadmaps development
4.3.3 Marketing plan development
4.3.4 Action plan development
4.4 Firm-level prototyping
4.4.1 Action plan development
4.4.2 Firm-level prototyping
4.5 AM technology prototyping
4.5.1 Joint offering prototyping
4.5.2 Customer feedback
TRANSFORMING
DECISION-MAKING
5.1 AM technology decision-making
5.1.1 Technology
5.1.2 Investment and financing
5.1.3 Other decisions
5.2 Business opportunity decision-making
5.2.1 Shared mental model
5.2.2 Risk management
5.2.3 Customer's perceived value
5.3 Strategic business net development and configuration
5.3.1 Strategic business net configuration
5.3.2 Strategic business net features decision-making
5.3.3 Harmonisation of features
5.3.4 Value creation levels
5.3.5 Performance measurements
5.4 Networked BM development
5.4.1 Networked BM elements decision-making
5.4.2 Harmonisation of elements
5.5 Strategic decision-making
5.5.1 Production plan finalisation
5.5.2 Marketing plan finalisation
5.5.3 Strategic roadmaps finalisation
5.6 Firm-level decision-making
5.6.1 Action plan development
5.6.2 Change management plan development
5.6.3 Training plan development
IMPLEMENTATION
6.1 Strategic implementation
6.1.1 Feedback and progress reporting
6.1.2 Implementation plan
6.1.3 Communicate with network partners
6.2 AM technology implementation
6.2.1 Implementation plan
6.2.2 AM production system implementation
6.2.3 Evaluate and adjust
6.3 Firm-level implementation
6.3.1 Implementation plan
6.3.2 Change management implementation
6.3.3 Evaluate and adjust
6.4 Networked BM implementation
6.4.1 Implementation plan
6.4.2 Networked BM implementation
6.4.3 Evaluate and adjust
6.5 Strategic business net implementation
6.5.1 Implementation plan
6.5.1 Strategic business net implementation
6.5.2 Evaluate and adjust
6.6 Business opportunity assessment
6.6.1 Monitor and evaluate
6.6.2 Feedback and reporting
6.6.3 Risk management
6.6.4 Re-evaluate and adjust

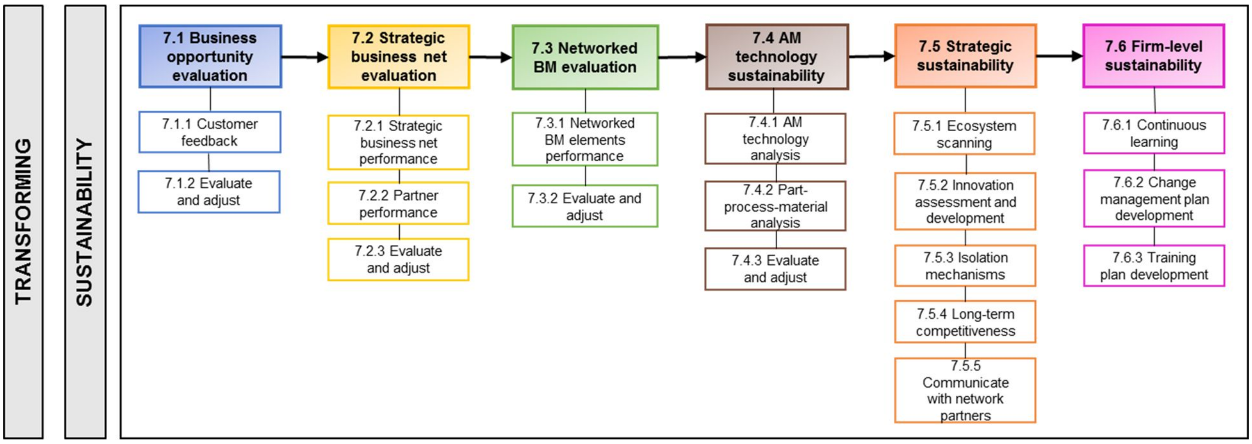


Figure 6.39: Overview of proposed management framework

6.9 Conclusion: Chapter 6

This chapter presented the results from the external evaluation of the management framework, from a business as well as manufacturing perspective as part of the sixth design cycle iteration. It was found that the framework is adequate regarding the perceived effort and importance of the steps and activities contained within the framework. Furthermore, some of the other research artefacts were also evaluated by the experts and feedback received was positive and confirmed the applicability and relevance of the artefacts in a real-life environment.

Although the manufacturing and AM experts confirmed the applicability of the framework and recognised the framework's potential to the industry, some limitations were however present. Firstly, only a limited number of experts were consulted with knowledge and experience pertaining to the manufacturer role, and no other potential role players (suppliers, customers etc.) were included. Secondly, only two of the experts have knowledge (mostly academic knowledge) about the hardmetals industry, and findings could therefore be limited regarding the industry, although the inclusion of various other experts tried to mitigate this limitation. Thirdly, due to time limitations and restrictions, not all details contained within the framework could be evaluated. As the last limitation, none of the experts had knowledge and experience regarding the manufacturing of tools, dies or moulds in the traditional (current) manufacturing industry.

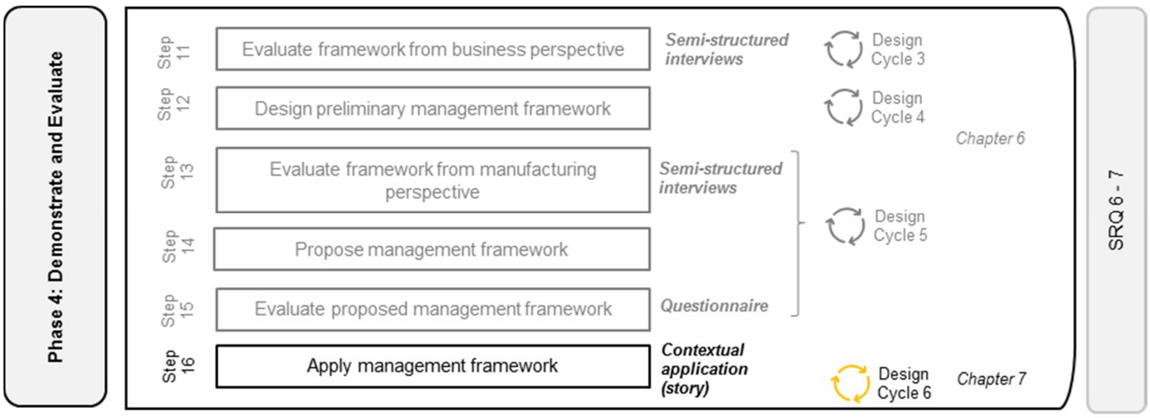
The next chapter discusses the results of the application of the proposed management framework in the contextual application domain of this study.

Chapter 7: Contextual application

Chapter 7 reports on the contextual application of the management framework, i.e., the cemented tungsten AM sector in South Africa (specifically the tooling industry), answering SRQ7. The chapter forms part of the final design cycle, Design Cycle 6. Due to the comprehensive nature of the framework, all steps could however not be performed and evaluated, therefore it was decided to only partially complete the steps contained in the sensing phase, with information obtained from the selected literature body. In addition, a potential configuration of a future strategic business net for the tooling industry adopting AM is created, as well as possible configurations for the networked BM elements. The chapter first presents the objectives, followed by the identification of relevant resources. The analysis of the resources is presented in a structured approach, whereafter the information is used in the application of the selected steps contained in the management framework. The chapter ends with a reflection on the tooling industry and a discussion of the outcomes of the application.

Chapter 7 key objectives:

- Define the objectives of the contextual application (Section 7.2).
- Discuss the identification of relevant resources (Section 7.3).
- Present the analysis of the resources (Section 7.4).
- Present the results on the application of two sub-phases of the management framework (including the use of the SBN configuration process) (Section 7.5).
- Reflect on the application with regards to the tooling industry (Section 7.6).
- Discuss the outcomes based on the contextual application (Section 7.7).



7.1 Introduction

As described in Chapter 2, a case study and a story are closely related, with two major differences. The one being that a story need not be entirely based on facts, figures and data, and the second difference is that a story may contain fictionalised elements [109]. Since the focus is on an emerging technology that are not yet introduced into the selected industry, some assumptions were required (fictionalised elements), and therefore this contextual application is rather referred to as a story, than a formal case study (although a similar approach will be followed). These assumptions must however be reviewed as time progress and the required changes need to be assessed, prioritised, and then implemented (as discussed in Section 4.5.2). The aim of the story is to start with the 'construction' [177] of the aspects contained within the networked BMI framework, although information is limited, a mental picture can be created [177].

The best way to complete the contextual application (story) would have been to conduct a workshop, in line with Henriques and Peças [103], with input and ideas from industrial clients, entities from the finance system, other entities with relevant knowledge on the sector, suppliers, and tool-makers. However, due to the Covid pandemic, and additional time constraints applicable to this study, this was unfortunately not a feasible option. Therefore, it was rather decided to conduct the contextual application theoretically using a variety of available literature resources. Furthermore, since a few assumptions need to be made regarding the configuration of a potential strategic business net (strategic level) for the industry, those elements were evaluated by an AM expert. This expert also formed part of the framework evaluation and was introduced as participant E in Section 6.6.

This chapter, therefore, reports on the theoretical application of the proposed management framework to the cemented tungsten carbide based (for example cobalt) TDM industry in South Africa as the selected contextual application area, see Figure 7.1 below. This application forms part of answering the following sub-research question: *What insights can be obtained through the demonstration of the management framework within the context of this study? (SRQ7).*

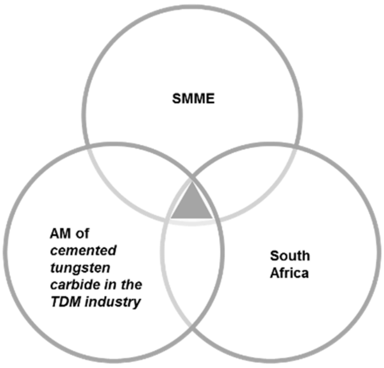


Figure 7.1: Contextual application area (scope)

To ensure successful completion of the contextual application story, the following process, adapted from Yin [249] and depicted in Figure 7.2, is followed throughout this chapter:

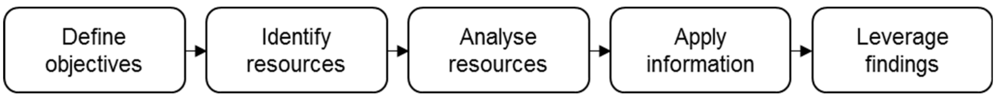


Figure 7.2: Contextual application process followed (adapted from [249])

7.2 Objectives

The overall aim of the contextual application is to provide an initial overview (not being comprehensive, nor being 100% accurate) of what the adoption of AM technologies by manufacturing SMMEs within the TDM industry could potentially entail within the South African environment (in terms of the networked BMI endeavour). This includes the configuration of a potential 'blueprint' networked BM and future strategic business net. This aim is to be achieved through the application of the first phase of the proposed framework, as well as the SBN configuration process. In addition to the overall aim, this would also provide the opportunity to evaluate and adjust the framework based on findings obtained through the application. Since the contextual application is based on an emerging technology, within an emerging industry, some assumptions (fictionalised elements) will be made, and therefore the proposed configuration of the networked BM and strategic business net are merely a possible prototype or story and not a recipe for success, nor ready to be implemented. In summary, the following objectives were formulated:

1. Conduct the activities possible within the analysis and ideation sub-phases (sensing phase) to create an overview of the current business environment of the identified context.
2. Apply the SBN configuration process to propose a prototype of one possible configuration of a strategic business net on the strategic level for the tooling industry.
3. Propose one possible configuration for the networked BM elements.
4. Based on the application of the framework, re-evaluate the applicability and relevance of the steps contained within the management framework and make the necessary adjustments.
5. Propose adjustments to the proposed management framework.

7.3 Identification of appropriate resources

As described in this chapter's introduction, the case selected for analysis is the TDM industry in South Africa. The possible introduction of cemented tungsten carbide AM technologies will potentially benefit the industry once the technology is commercially feasible. It is with this assumption, that the contextual application is pursued. The resources gathered to inform this application, consisted of theoretical studies, or existing literature, which is described below.

In addition to the relevant articles already identified in Chapter 3, a few additional open access resources were identified to inform this application. Knowing the type of information and data needed to achieve the objectives, different literature search strings were used on both Google and Google Scholar to identify relevant studies (peer-reviewed articles as well as grey literature studies). The search strings used throughout this process consisted of a variety of combinations using the following relevant search terms: 'additive manufacturing', 'metal', 'cemented tungsten carbide', 'South Africa', 'tooling', 'tools', 'tooling industry', 'business model', 'business model innovation', and 'value network'.

Several relevant articles were scanned, and consequently, the most appropriate and informative studies or reports were selected to be included, see Table E.1 in Appendix E for the complete list. In total 17 publications were selected of which 11 were articles, 4 reports and 2 theses. It was found that these 17 publications contain the most relevant information which could be used for further analysis and the application of the selected management framework steps. Since the selected contextual application is not based on a single company, nor an established sector or technology, the articles were selected to cover all the necessary contextual concepts, see Table E.1 in Appendix E for the relevance of each publication with regards to the contextual application domain. Where gaps were identified regarding specific activities, additional websites and grey literature were searched to inform these gaps (not indicated in Table E.1).

The timeline of the years in which the publications were published is presented in Figure 7.3 below. Although the studies and reports related to the South African industry are not particularly very recent, they were the only studies that could be found. Since it is not a fast-paced and fast-growing industry in South Africa, it is assumed that most of the findings are still relevant and therefore used within this application.

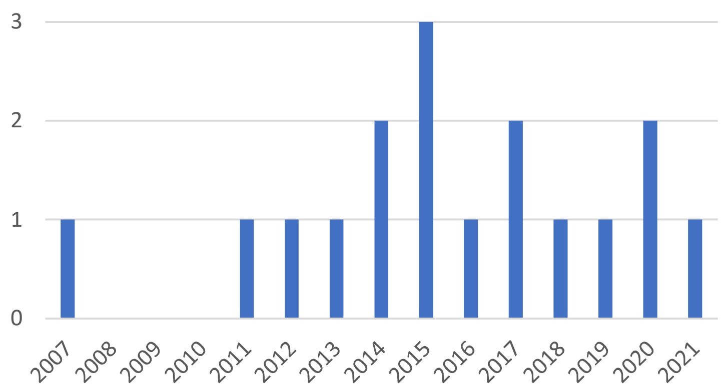


Figure 7.3: Timeline of publications used to inform the contextual application

To evaluate the functions contained in the proposed future strategic business net, the AM expert (interviewee E) that formed part of the manufacturing expert category, was approached. The expert confirmed the general logic and applicability of the function's configuration on the strategic level.

7.4 Literature data analysis

7.4.1 The South African TDM industry

This industry was selected as it is a key contributor to the industrial value-adding chain, being the link between product development and production and thus determining whether innovative products can successfully be introduced into the market [238]. 90% of these tooling manufacturers in South Africa are SMMEs [64] that are usually family-owned businesses [64]. World-Class TDM firms from other continents implemented technologies, altered business strategies, and adopted new management philosophies to stay competitive [64]. These rapid changes give them a competitive advantage in terms of price and lead time as their products are designed, manufactured, and delivered quickly and reliably to customers [64]. Due to the lack of adoption and rapid response, most South African companies in the TDM sector cannot compete globally and therefore their profitability and growth are under immense pressure [64]. Furthermore, the South African tooling industry is currently working significantly below domestic demand, while battling with ageing and low-tech capital layout equipment [138].

Although collaboration among tool rooms is not common within South Africa [29], von Leipzig and Dimitrov [238] as well as Malherbe [138] argued that collaboration among tool rooms is necessary to uplift the competitiveness of the industry, and accordingly, von Leipzig and Dimitrov [238] proposed the formation of clusters, which simply refer to tool rooms being located in similar geographical locations. According to Henriques and Peças [103], a way to develop and sustain the tool making business is indeed to promote collaboration among tool rooms (competitors) to increase capacity to cope with the requirements and risk of large tool programmes, but also collaboration and co-operation with clients to develop focused competencies, as well as collaboration with partners that provide access to complementary competencies. It is however no easy task as the South African's tooling industry deals with a lack of trust in their suppliers and therefore supplier development is not pursued, whereby strategic partnerships cannot be developed [29]. This problem must be addressed, as Boos *et al.* [29] stated: *"To increase the average process maturity of South African tool shops a rethinking of process design and value creation in terms of value creation networks needs to be done."* Accordingly, von Leipzig and Dimitrov [238] quoted the International Special Tooling

& Machining Association's (ISTMA) European president, Menezes, about the future of the tooling industry: "*The classical business model of the tooling industry is dead.*" Subsequently, after the completion of his dissertation on a benchmarking model for the TDM industry, Malherbe [138] stated the following: "*Funding for research into the development of a business model for tool room clusters in South Africa will be the first step towards realising a revival of the industry.*"

7.4.2 Cemented tungsten carbide and AM

The tungsten carbide market can be segmented into end-user, application and region [218]. Among the application sub-segments, cemented carbide application led the tungsten carbide market in 2018 holding a market share of 61% owing to the growing demand for metal cutting tools in machinery [218]. China dominates the tungsten carbide market being the largest tungsten provider [130]. This places a huge burden on emerging manufacturing countries, including South Africa, because of the high importing costs due to tightening export restrictions in China [130]. Furthermore, the supply of tungsten is at risk as it is expected that worldwide tungsten reserves are going to be depleted in 40 years, making it one of the critical raw materials for the European Union [196].

Tungsten carbide hardmetal parts are manufactured by the powder metallurgy technique and due to this technique, parts can only be manufactured with limited geometrical complexity [175]. This process includes different complex stages such as powder processing, mixing and milling of powders, pressing in die tool to get the required shape, dewaxing, liquid phase sintering, and post-sintering operations like grinding and blasting [175]. During each stage, process parameters need to be controlled as any change in the variable directly influences the following process and final product quality [175]. Therefore, until recently, it was believed that it is either impossible to manufacture tungsten carbide parts using an AM process or it is impossible for the manufactured parts to meet the prerequisites and fulfil the functional requirements [175]. However, according to the review conducted by Padmakumar [175], researchers have recently overcome the main challenges and succeeded in finding techniques to manufacture tungsten carbide parts with properties close to their conventional counterparts, but these parts are not able to replace their conventional counterparts yet [175], therefore it is still emerging and an ongoing research field.

7.4.3 Tooling manufacturing and AM

Cutting, forming, and joining technologies are often used in traditional manufacturing to shape and form materials [55]. In most cases, these technologies are dependent on tooling to process materials and to produce the final part [55]. Additive manufacturing is becoming increasingly attractive to be used as a tooling fabrication method since tooling products are often produced in low volumes with complex shapes, for a specific use [55]. Additive manufacturing enables the production of complex tooling inserts (including complex internal structures) that are not possible with traditional manufacturing technologies [78]. In addition, AM enables damages to these complex tooling parts to be repaired without having to refurbish or remanufacture the complete tool [55]. Therefore, AM is not just valuable for the direct production of parts in new or emerging industries, but the technology can also be used to support and improve existing manufacturing sectors [55]. However, the overall impact of AM used in the tooling industry will not revolutionise the supply chain or the end product as much as other applications of AM [55]. This is because, for most applications of AM for tooling, the end product will not differ greatly from the products related to using conventional tooling [55]. Further, in most cases, the adoption of AM for tooling fabrication will not dramatically affect the overall production supply chain [55]. In their study, Rayna and Striukova [192] investigated the impact of AM on rapid prototyping, rapid tooling, direct manufacturing and home fabrication. The authors concluded that rapid prototyping and rapid tooling has a limited impact on BMs, although cost structures may be impacted [192].

Tools manufactured using AM will be able to have similar mechanical properties as traditionally manufactured tools. During the AM manufacturing process, conventional machining and polishing techniques can also be used to finish the tool to specification (referred to as hybrid manufacturing). Tooling performance improvement in small tools with conformal cooling channels manufactured using AM has been demonstrated to have a significantly higher throughput than tooling using conventional cooling technology. Therefore, AM technology offers significant opportunities for accelerated tooling development as well as tooling performance enhancement. [60]

Additive manufacturing provides numerous opportunities regarding innovation in tooling design, reduced lead times resulting in shorter time-to-market, cost savings due to better performing tools and improved quality and shorter lead time for tool repair [29]. These opportunities have the ability to contribute to the transformation of South Africa's manufacturing industry (and therefore also the tooling industry), and increase the country's ability to compete globally [29]. Furthermore, within the tooling industry the use of AM technologies enables the introduction of additional services (also referred to as servitization). The tooling industry is able to utilise cyber-physical systems to track the tool condition in the series production with sensors and offer tailored services [29]. The gained expertise through collaboration with services can be utilised to address potentials in the series production and offer innovative and more productive tooling solutions for the customer [29].

7.5 Part E-7: Framework application

As described above, the identified literature resources, together with information from a few additional websites, were used to inform the activities of the analysis and ideation sub-phases. To demonstrate the potential value of the management framework within the contextual application area, this section is structured as follows. The application and potential 'answers' of the activities contained in the analysis sub-phase is presented in Table 7.1 in Section 7.5.1. Below the table, a potential configuration of the current VN of the tooling industry, manufacturing hardmetal parts, are illustrated, see Figure 7.4 (associated with *step 1.1.2*). The configuration of this VN was done using the steps contained in the SBN configuration process, and the associated tables are presented in Appendix E.

To elaborate a bit, during *step 1.1.2* the main functions within the tooling VN were identified, as well as some of the key actors or roles. This information is depicted in Figure 7.4, together with assumed capabilities (fictionalised elements) and the roles or actors' involvement in the functions. These possible relationships were based on the researcher's assumptions and were not based on literature findings, nor were they evaluated by an AM expert. Within this (fictionalised) configuration, the reader or potential user can get an overview of the type of actors or roles within the tooling VN, the variety of functions needed to deliver a tooling product (from pre-sales to post-sales) and the variety of capabilities that are required to compete within the industry. The proposed configuration can also be used by a network actor that wants to enter the VN, or that wants to integrate their functions upstream or downstream as an overview can be acquired of what is potentially required. Furthermore, if one function within the network needs to change for whatever reason, it is easy to see who is involved and who needs to be notified of any possible changes or improvements.

To ensure the map read easy, some capabilities were repeated along with the network. The configuration illustrates that the *tool shop (manufacturer)* is the focal actor within the network, as it is involved in most functions and only a few other actors are involved upstream and downstream. Within the current network, customers play a small 'informative' role and are not involved with the value creation activities, but rather only 'approve' certain functions, illustrating the need to involve customers more.

The application of the activities contained in the ideation sub-phase is presented in Table 7.2 in Section 7.5.2. However, not all activities within these two sub-phases could be completed, due to a lack of information and insight into the tooling industry or the potential use of AM in the industry. These incomplete activities are indicated to be completed by the future potential user.

One potential visualisation of a future strategic business net of the tooling industry, aiming to adopt AM, is presented in Section 7.5.3 (Figure 7.5) (associated with *step 2.3.2*). The configuration was also done using the steps contained in the SBN configuration process (the tables are presented in Appendix E), illustrating the process's applicability and value to the industry as a visualisation tool. Two functions were also presented on the tactical level of the network, as an illustration of the potential value and applicability, see Figure 7.6. Section 7.5.3 elaborate on the proposed configuration and discuss some insights obtained.

Furthermore, as part of the ideation sub-phase, possible ideas or configurations for the networked BM elements needed to be proposed, these possible configurations or ideas are presented in Section 7.5.4 (associated with *step 2.4*). However, for a few of the elements a satisfactory configuration could not be proposed, these were indicated and need to be completed by the future potential user.

7.5.1 Analysis sub-phase

Table 7.1: Contextual application: Analysis sub-phase

Phase	**Sub-phase**	**Steps**			**Application**
Sensing	*1. Analysis*	*1.1 Business analysis (if existing manufacturer)*	1.1.1 Internal business analysis	*Analyse the current BM.*	**Actors:** • Tool designers/engineers (knowledge of design requirements and production techniques, transform die concept into a detailed design and work breakdown structure) [138]. • Tool makers (making and repairing tools and parts) [138]. • External engineering services companies (for example numerical simulations) [103]. • Suppliers (materials, machines, etc.). **Relationships:** • The South African's tooling industry deals with a lack of trust in their suppliers and therefore supplier development is not pursued, whereby strategic partnerships cannot be developed [29]. **Product-service:** • Tools are complex and unique systems which require intensive knowledge regarding engineering and production [103]. • The majority of tools do not exceed the size of 250mm x 250mm, and typically weigh less than 100kg [29]. • The tools are almost exclusively manufactured for the local market with a high percentage of single cavity injection mould [29]. • The tools mostly do not feature high requirements in terms of precision and accuracy [29]. • Some (31%) orders include additional services [29]. • The tool making industry follows a strict on demand principle [103]. **Target-segment:** • Product type: dies & molds, forging, jigs & fixtures, machine tools, and gauges [49]. • End-user industry: automotive, electronics & electrical, aerospace, marine & defense, plastics industry, construction & mining, and others [49]. • Majority focus on injection moulding or simple stamping tools for the local market [29]. **Customer relationships:** • Tool makers typically have long term relationships with different anchor clients [103]. **Distribution channel:** • Website. **Resources:** • The tooling industry have a lack of qualified human resources, particularly in management areas [103]. **Revenue structure:**

					• Until recently, tool makers made used of payment parcels (30% -30% -30% -10%) allocated to fixed milestones along the tool production process. However, this payment process has been progressively eliminated and replaced by more aggressive pay-out schemes and by stretch out reimbursements [103]. **Cost structure:** • Cost distribution as a percentage of internal costs associated with each phase in the process chain [138]. • Internal cost as a percentage of the total costs allocated to different aspects within the tool room [138]. • Internal/ external cost distribution refers to the estimated cost for each phase in the process chain concerning internal and external work done [138]. **Pricing method:** • Cost estimation (quoting): labour costs, material cost, service costs [64].
				Analyse the current strategies.	• Take on any manufacturing work, instead of focusing on a specialised product range [29] or industry [138]. (Some of the leading tool shops in SA limit their product portfolio by serving only certain industries [29].) • Produce lower quality products at lower prices in order to retrieve some profit from lower production runs [138]. • Low levels of investment in necessary technology as tool rooms work with aging technology and inefficient work methods compared to competitors [138]. • The majority of tool shops manufacture only locally for the domestic and Sub-Saharan markets with a limited and simple tool range, little process know- how as well as a lack in resources that restricts the manufacturing of complex tools [29]. • However, there are few tool shops in South Africa that can compete internationally. The wide spread of available tooling competences and tooling know-how shows potential for a positive development of the industry in upcoming years. Furthermore, the few outstanding tool shops confirm that tooling on an international best practice level is possible in South Africa, regardless of the still noticeable restraints of the industrial environment [29]. • The majority of tool shops focus on injection moulding for the consumables and appliances industry [29]. • Very few tool shops have ties with the international automotive industry [29]. • Profitability is maximised, usually at the expense of continuous improvement [238]. • Low turnover [238]. • Focusing on cost cutting or differentiation through high quality tools is no longer sufficient to meet the challenge of a fast-changing globalised market [203].
				Analyse the as-is business situation of the focal actor.	***SWOT analysis of TDM industry in SA in general** **Strengths:** • Majority tool shops offer a wide range of different products [29]. • Experience and technological background of toolmaking [103]. • High level of technical background facilitates a good understanding of the client's needs and requirements [103]. • Technical background help to facilitate the incorporation of new technologies [103]. • Well-developed tool design and tool engineering competences [103]. • SMMEs have higher flexibility [103]. • SMMEs have lower business risk [103]. • SMMEs have easy management [103]. **Weaknesses:** • Take on any manufacturing work regardless of its specification, no specialisation [29]. • Severe skills shortage in South Africa [138]. • Lack of funds for investment in proper operational systems, equipment, and training of personnel [138]. • Production costs are significantly higher than its competitors [138].

					• The overall tool complexity and innovative capacity of South African tool shops is low [29]. • Most tool shops with repetitive and low complex tools are still not able to address the potential of standardisation [29]. • Collaboration among specialised tool shops and its suppliers is not common in SA, only the leading and excellent tool shops begin to form competence-based supplier networks [29]. • Long time to prepare an offer, may be caused by a missing systemic support of the quotation process in SA [29]. • Non-conformance on delivering products on time [29]. • Simulation and 3D programming are still exceptions to the most sophisticated tool shops working for the automotive industry [29] • Weak negotiation power with clients and suppliers [103]. • Long production cycles and severe payment conditions (negative cash flows) [103]. • Few clients (high dependency on anchor clients) [103]. • Lack of qualified human resources particularly in management areas [103]. • Difficulties in accommodating a highly changing demand on a stable capacity [103]. • Lack of networking competences (self-sufficiency tradition) [103]. • Capital intensive business [103]. • Weak strategic management and financial expertise (strategic focus not clear) [103]. • Difficulties to deal with crises and drastic market changes (globalisation) [103]. • Tool-making industry is not taking advantage of available domestic opportunities, due to lack of capacity with economies of scale being the central motive. South African tool rooms are generally small with little capacity compared to international counterparts [138]. (Capacity is defined here as the ability of TDMs to perform tool making effectively, efficiently and sustainably [138].) • Struggle in global market due to intense external competition [64]. • Poor organisational practices [64]. **Opportunities:** • Growth in domestic demand of TDM products increased with expanding domestic economy, especially in demand for automotive tooling [138]. • Vertical integration, within tool industry means the integration of some complementary areas of business traditionally at the clients' sphere, from part design and prototypes, part production, tool maintenance and repairing services to large tools programme management [103]. • Integration of complementary services [103]. • Global networking (clients, partners, and even competitors) [103]. • Efficiency and lean manufacturing applied to tool making [103]. • Exploitation of new geographical markets [103]. • New business areas – technical prototypes and tool maintenance [103]. • Clustering of activities has been proven to be very effective, and can enable rapid growth and economic success for the firms involved in such a cluster [238]. • The growth of the renewable energy systems such as wind power energy generation plants, solar energy generation plants, hydro-electricity plants, and others require sophisticated and properly designed die molds, measuring devices, and machine tools to produce the parts and machines. Thus, growth in renewable sources industry is expected to drive the growth of the global tooling market [49]. **Threats:** • Globalisation and the rapid growth in ICT have changed views about the way production is being done in the TDM sector [64] • The free forming nature of AM lead to the lack for the need for tooling [26].

					• In-house 3D printed metal part production (having 3D printing capabilities in house help manufacturers bring products to the market quicker, simplify supply chains and the associated IP risks.) [189] • International market pressure introduced by increasingly competitive tooling markets in emerging countries in Asia and Eastern Europe [29]. • Reductions in demand [103]. • Changing of technology [103]. • New owners of tools [103]. • New and difficult client demands [103]. • Tool ownership is changing from the OEM (official equipment manufacturer) to the tool user which is responsible for the systems assembly [103]. • Fluctuation in raw materials prices is likely to hamper the demand for dies and molds to manufacture the detailed parts in the high-end manufacturing industries such as aerospace and automotive [49].
			1.1.2 Value network analysis	*Analyse the current value network by mapping the current configuration.*	Current tool-making process (value chain) functions [103]: **Quotation** Part specifications Part model Production requirements **Design** Part design for manufacturing Tool initial design Process and structural analysis Materials order Tool detail design **Manufacturing** (adapted from [103] according to **powder metallurgy process** used for tungsten carbide products from [175]) Process planning Powder processing Powder mixing Powder milling Powder pressing Dewaxing (Liquid phase) Sintering Post-sintering Inspection **Try-out** Tool try-out (tool shop) Parts inspection (tool shop) Tool try out (client shop) Parts inspection (client shop) Tool approval Upstream: **Product development** Part design Prototypes Downstream: **Parts production** Part production Tool maintenance Tool recycling Tool end-of-life **Actors:** • Tool designers/engineers (knowledge of design requirements and production techniques, transform die concept into a detailed design and work breakdown structure) [138]. • Tool makers (making and repairing tools and parts) [138]. • External engineering services companies (for example numerical simulations) [103]. • Suppliers (materials, machines, etc.). See visual mapping below table. Note: Roles (or actors) and their involvement in functions, as well as the identified capabilities are formulated by the researcher and not based on facts, nor were they evaluated.
		1.2 AM technology analysis	1.2.1 Industrial applications	*Understand and select the targeted application area(s).*	**Applications** within tooling industry (different stages of the process) [214]: • **Rapid prototyping:** Create physical models to review and validate a design.

					• **Rapid tooling:** Producing a tool using AM. Especially helpful when the tool is used to produce small series, where traditional manufactured tool is too cost intensive. An advantage is that design changes can be applied more quickly. (Include tooling used in casting and machining processes, assembly jigs and fixtures, and customer medical guides [55]) • **Rapid manufacturing:** Quick and flexible methods to produce parts without using tools, often involves AM, makes sense when part not only needs to be produced quickly but also has a geometry that is hard to realise with traditional methods. • **Other:** AM can also be used to directly produce components or parts, not just the tool. This may include producing mould inserts or even equipment needed to optimise the manufacturing process. It can also be used to optimise the mould itself with the added possibilities that AM offers. E.g., cooling channels can be added to injection moulds that cannot be manufactured with traditional methods like milling and drilling – thereby reducing cycle times of injection moulding by up to 40% if the temperature profile is homogenised simultaneously. **Industries using AM:** Many industries have already embraced the use of AM for tooling, including automotive, aerospace and defence, industrial products, consumer products, and even health care [55]. Note: Some industries are demanding (such as aerospace, automotive, medical, tool) and require certification, repeatability, and uniform part quality comparable to conventional processes [189]. **Industries using cemented tungsten carbide:** Cemented tungsten carbide used in the following industries: tool manufacturing, oil and gas, steel and metal processing, aerospace, construction, food processing, automotive, medical [45]. **Selected industry:** automotive industry, rapid tooling application area and other.
			1.2.2 Manufacturing technology analysis	*Understand how traditional manufacturing and AM compare.*	√√√ *Checked.*

				Understand applicable AM process categories, associated technologies and possible materials.	**Material:**
					• Cemented tungsten carbide based (for example cobalt) materials (given).
					
					Applicable AM process categories for cemented tungsten carbide:
					• Binder Jetting
					• Powder bed fusion
					
					Associated and applicable technologies for the manufacturing of tungsten carbide hardmetal parts:
					• **Binder Jetting**
					  • Binder Jet 3D Printing (BJ3DP) [175]
					• **Powder bed fusion**
					  • Selective Laser Melting (SLM) [175], more generally referred to as Laser Powder Bed Fusion (LPBF).
					  • Selective Laser Sintering (SLS) [175].
					• Other techniques also investigated to produce tungsten carbide products [175]:
					  • *"Selective Electron Beam Melting (SEBM)*
					  • *3D Gel-Printing (3DGP)*
					  • *Fused Filament Fabrication (FFF)*
					  • *Laser Engineering Net Shaping (LENS)*
					  • *Thermoplastic 3D Printing (T3DP)"*

					• Essentially, SLM and SLS are two instantiations of the same concept (Powder Bed Fusion technique) with very little differences. The SLM process to print metallic parts uses a laser with higher intensity to achieve a full melt of the powder, whereas SLS uses a comparatively lower laser intensity to fuse or bind the particles together on a molecular level. However, in the case of AM of tungsten carbide- based parts, SLM and SLS are fundamentally the same . [175] • BJ3DP is a non-laser, non-heat-based process that uses a binder liquid to join the powder particles followed by a post-process sintering [175]. Selected process: LBPF (SLM)
				Understand the potential of a possible hybrid production model.	AM as a supporting technology, can improve the mould-making process drastically, upgrading manufacturing efficiency [214]. **Implications of hybrid manufacturing:** • Production using AM process. • Post-production using traditional methods. • AM can act in parallel with core manufacturing techniques, and therefore not compete with main production [198].
		1.3 Ecosystem analysis	1.3.1 External environment analysis	*Analyse the external environment and marketplace the focal actor/ potential strategic business net will operate in.*	**Political factors:** • Political instability. • Political influences have an impact on finance and access to finance. • BEE have a huge impact on funding and allocation of contracts. • State capture had an impact on all businesses and the entire economy. • Lack of adequate and sufficient policies. • Apart from mining industry, there is no industrial sector with strong international ties to Europe [29]. • Multiple work shifts per day are not common in the South African industrial sector and difficult to implement due to the characteristics of the South African labour law [29]. • The influence of unions is strong, which led to frequent strikes and significantly increasing labour costs over the last few years [29]. **Economic factors:** • Declining economy over the last few years. • High cost of capital. • Highly volatile and weak currency compared to Euro and US-Dollar. • High unemployment rate [29]. • Manufacturing, mining, agriculture are the main industries in SA [29]. • Majority of international automotive OEMs have production plants in SA [29]. • Developed transportation system with excellent accessibility to the entire Sub-Saharan region [29]. • Quality of internet and telecommunications is on a high level [29]. • Unreliable electricity supply as blackouts occurs often, complicating an efficient manufacturing process with high-technology machinery [29]. • Labour costs are low but since the efficiency of the workforce is also low the overall value of employee-intensive production time is limited [29]. • Financial resources are difficult to obtain especially for small companies in the tooling industry, since local banks operate very restrictive with regards to loans for SMEs [29]. • Covid-19 poses a significant threat to worldwide trade, economy, and finance due to continuous lockdown that halted production of many items in the tooling business [49]. **Social factors:** • Poverty and inequality are widespread [29]. • Level of qualification and overall level of education of employees is low [29].

					Technological factors: • Automation and digitalisation [9]. • Rapid growth in ICT [64]. • Growth of the automobile & mechanical industry and rising machine tool technologies are the key trends in the tooling market"[49]. **Environmental factors:** • The supply of tungsten is at risk as it is expected that worldwide tungsten reserves are going to be depleted in 40 years, making it one of the critical raw materials for the European Union [196]. • Rising focus on sustainability and creating sustainable products, processes and services [103]. **Legal factors:** • Changing legal regulations [103]. **Trends in the global TDM industry** [138]: • Independent tool making developed (larger companies sell or close tool-making activities to reduce "indirect labour") [138]. • Reduction in the need for manual labour skills through continuous investment in modern technologies [138]. • Countries with high labour costs find it difficult to compete against lower labour costs of emerging manufacturing economies [138]. • Global demand for series parts continues to increase, at the same time there is an increasing amount of derivates with a decreasing lot size and life-cycle duration per derivate. Growing markets and derivatization lead to an increasing demand for tools [29]. • High competitiveness in industry [29]. • Increasing competitiveness from emerging markets (benefit from lower costs) [29]. **Trends in the South African TDM industry** [138]: • High compliance costs in SA to start a business and hiring labour. • Low investment levels, resulting in lower quality products at lower prices for products that have lower production runs compared to international counterparts. • High production costs, because of low levels of investments in necessary technology. • Severe skills shortage in the SA TDM industry. • Domestic demand for TDM products increases (expanding automotive industry). • Tool rooms are small with little capacity.

			1.3.2 Operating environment analysis	*Identify real-world limits or constraints in the South African environment.*	**Challenges in South African TDM industry** [138]:
					• Shortage of skills and the lack of skills development infrastructure.
					• Attitude towards collaboration (attitude of independent competition within domestic industry).
					• Attitude towards investment (technologies mostly obsolete, very little investment in new technology).
					
					Main constraints faced by TDM industry in SA [64]:
					• Financial constraints (SMEs lack finance to invest in required technology).
					• Technological constraints (due to lack in finance, use aging technology and equipment).
					    • Design technology (long order processing times due to a lack of a proper design depository for speedy quoting of jobs; most tool rooms lack the required software for simulation, design analysis, failure mode analysis and stress analysis).
					    • Machining technology(most firms use old equipment that compromise delivery time).

					• Molding technology (most tool rooms machine own mould cavities, it has cost benefits but compromise delivery lead times). • Testing technology (lack of appropriate metrological and measurement equipment for conducting conformance tests on finished products). • Capacity constraints (limited resource capacity base, lack of sufficient resources and capacity) • Human resource constraints (due to lack of capital, tool rooms cannot afford necessary expertise required to manage big projects). • Global trade and pricing constraints (size of firms prohibit them from attaining power, local firms can pay double the international price for the material and components). • Fluctuating raw material prices of raw materials are the effecting factor for tooling market [49].
				Identify real-world limits or constraints in the SMME environment.	**SMEs in SA face the following challenges** [116]: • "Limited access to low- and medium-cost funding is constraining business growth; • Even when funding is available, low awareness of opportunities and a lack of financial knowledge remain major barriers to SMEs accessing the required support; • Slowing demand has led to SMEs having to limit expansion plans and identify alternative channels to sell products, • Accessing the right markets to sell products is a challenge; • Owners and founders struggle to empower staff to lead and drive the business; and • Liquidity and cashflow management are limited."
		1.4 Business opportunity identification and analysis	1.4.1 Business opportunity identification	*Identify possible business opportunities based on the current value proposition and analyses.*	**Upstream:** • Customer integration begins upstream by actively supporting the product development process and thereby influencing the product and tool design to guarantee the production feasibility of series parts [29]. **Current:** • Time-to-market can be improved through services at the interface with the product development [29]. • Offering additional services to customers [29]. • Product-service systems offer the potential for tool and die companies to widen their existing range of products through combining tools as their core products with value-adding services [203] • The use of 3D design software and simulation programs provide a sound preparation of the production process [29]. • An online platform for customers, where the customer is able to see the progress of the ordered tool, increasing the transparency of manufacturing process and creating confidence in on time deliveries [29]. **Downstream:** • Introduce services at the interface with series production, including support during the start-up of tools in series production and their repair and maintenance [29]. • Offering try-out cycles to test the tool in terms of function and efficiency is one option of integration before delivery [29]. • Utilise cyber-physical systems to track the tool condition in the series production with sensors and offer tailored services [29]. **AM tooling fabrication opportunities** [55]: • Identify low-volume use cases where tooling performance could be improved through tool redesign. The redesign should take advantage of AM's ability to create complex geometries. • Evaluate where the fabrication of tooling involves a high percentage of material loss. • Using AM, tooling design cycles can keep pace more easily with the demands of the product design cycles. • Explore new opportunities throughout tool's entire life cycle, not just the tool-makers traditional field (tool design, tool production, tool try-out and prototypes/ pre-series) [103].

					• Adapt a more or less informal application of lean manufacturing practices, combined with a strong and continuous innovation effort [103].
				Assess and prioritise business opportunities according to product's lifecycle.	‼ *To be completed by user.*
				Identify possible offerings to address business opportunities.	**Possible products:** • Smart tool equipped with sensor technology (technological enabler for the related services) that permit constant measurements of process parameters such as temperature, pressure, tool acceleration, sound profile, tool torsion) [203]. • Complex geometrical products manufactured using AM. • AM allows for the production of highly customised and personalised products [26]. • AM must be used for niche customer products [198]. • Conformal cooling channels in production tool inserts. **Possible services:** • Guaranteed productive availability of the tool [203]. • Optimisation of the production process based on real-time process data [203]. • Real-time monitoring of the production process [203]. • Total cost/ lifecycle assessment of the tool [203]. • Offering of operational models for the tool in production (pay-per-x models) [203]. • Digital tool log book: production process data [203]. • Ensured spare-part availability [203]. • Preventative maintenance based on monitored condition of the tool [203]. • Provision off 3D datasets including trouble shooting instructions [203]. • Digital log book: handling and maintenance data [203]. Note: For PSS, aligning physical product characteristics with service is important [3].
				Identify value-in-context elements (define value for the customer).	Note: Defining value for the customers is the starting point of PSS design [3]. Note: Evaluate the customer's willingness-to-pay to evaluate the potential of offering profitable PSS [203]. ‼ *To be completed by user.*

			1.4.2 Customer profile	*Identify the customer target-segment(s).*	Target-segments by end-user **industry** [49]: • Automotive • Electronics and electrical • Aerospace, marine and defense • Plastics industry • Construction and mining • Others • Automotive sector • Machine tools • Gauges Target-segments by **product type [49]**: • Dies and molds • Forging • Jigs and fixtures Target-segments by **region [49]**: • North America • Europe • Asia-Pacific • LAMEA (Latin America, Middle East, Africa) The automotive segment is projected to dominate the global tooling market during the forecast period (2021-2030) [49]. Selected industry: Automotive sector Selected product-type: Dies and molds Selected region: Africa
				Identify the customer needs.	• Differentiation for the customer is achieved through the product [29]. • With core products, tools, or dies, the TDM industry has to ensure a reliable series production according to the specifications required by the customer [29]. • Quality is the critical requirement, need to be addressed by the highest precision regarding geometry and surfaces [29]. • Customers expect more than just the delivery of a reliable tool at the agreed date. Customers want to buy an efficient production with a high output rate and a high reliability [29] • Studies have shown that customers appreciate short lead times, a high due date reliability and the responsiveness of tool shops higher than the price of the tool. The time it takes for a tool shop to submit an offer is directly linked to customer satisfaction and moreover the likelihood of getting an order is contingent on the speed of the quotation process [29]. • Customers rapidly change their needs [64], constant evaluation is needed. • Conversely, in those contexts where demand is volatile and the customer requirement for variety is high, “agility” is needed which is concerned with responsiveness. [26]
				Refine the identified joint offerings according to the customer needs.	‼ *To be completed by user.*
				Determine customer involvement and interaction (where, how).	• Customer integration begins upstream by actively supporting the product development process and thereby influencing the product and tool design [29]. • AM technologies allows for digital interaction with customers [26]. • AM enable personalised production for customers [26]. • Shop-floor management system (digitalisation process) proposed by [64] could be extended to customers (and suppliers). ‼ *To be completed by user.*
			1.4.3 Industry and market analysis	*Identify the key competitive drivers of the industry.*	TDM industry key competitive performance objectives (competitive performance measures) [64]: • *“Product quality* • *Due date conformance* • *Product cost* • *Speed to market [64]*

					• *Delivery reliability* • *Volume flexibility* • *Brand presentation"* • The productivity of a tool is represented by the tool price and the efficiency that the tool enables in the series production. The value of a tool for the series production is thereby displayed by the total-cost of ownership for the customer in series production [29].
				Analyse the competitors within the industry.	**Key international players** [49]: • *"Bharat Forge* • *Carlson Tool & Manufacturing Corp.* • *Doosan Machine Tools Co., Ltd.* • *Godrej & Boyce Manufacturing Co. Ltd.* • *Omega Tool Corp* • *Parpas S.p.A (GRUPPO PARPAS)* • *Samvardhana Motherson Group* • *Unique Tool & Gauge Inc.* • *Sandvik AB* • *Yamazaki Mazak Corporation"* ***Porter's five forces:** **Supplier power:** • Powder suppliers have the power in AM. **Buyer power:** • Customers have the power to allocate orders to selected tool rooms. **Threat of substitutes:** • AM used in other industries may reduce the need for tooling products. **Threat of new entry:** • New entrepreneurs enter the AM market. • New players in global markets. **Competitive rivalry:** • The global tooling market is analysed across four geographical regions, which include North America (the U.S., Canada, and Mexico), Europe (Germany, France, the UK, Italy, and rest of Europe), Asia-Pacific (Japan, China, Thailand, India, and rest of Asia-Pacific), and LAMEA (Latin America, the Middle East, and Africa). Europe is expected to hold the largest market share throughout the study period and Asia-Pacific is expected to grow at the fastest rate. [49] • International market pressure introduced by increasingly competitive tooling markets in emerging countries in Asia and Eastern Europe [29].
				Analyse the target market.	**Automotive sector:** • The automotive industry that accounts for more than 12% of South Africa's manufacturing exports is a key factor of ensuring innovation for the country's tooling industry [29]. • The South African automotive industry is one of the most important manufacturing industries for the country. The majority of international automotive OEMs have production plants in South Africa. Examples include BMW, Daimler, Volkswagen, General Motors, Nissan, PSA and Toyota with own production plants [29]. • Additionally, many component manufacturers have established a production base in South Africa [29].

					• Because of the strong presence, the internationally driven automotive industry is a key factor for ensuring continuous innovation of the entire manufacturing industry [29]. • Automotive industry contribute 6,8% to the South African GDP with 110,000 people employed across vehicle and component manufacturers [39]. • The automotive industry also faces tough challenges in the form of accelerating localisation and developing a future-proof supply chain [39]. • Localisation, the process whereby an increased percentage of the parts and costs of a motor vehicle are either assembled or manufactured in SA rather than important provides significant opportunities [39]. • The South African Automotive Master Plan 2021 – 2035 could see the automotive industry growing from 600,000 to 1.4 million vehicles a year in production [39]. • As part of the South African Automotive Master Plan a proposed solution to grow the automotive industry is to increase local content in South African assembled vehicles from around 37% [2015] to 60% by 2035 [39]. • This include the creation of 485 new businesses in Tier 2 automotive products by 2035 of which 50% needs to be locally and black owned [39]. • The automotive segment of the market accounted for over half of the global tooling market share in 2020, owing to increase in production of light vehicles followed by growing focus of manufacturers to increase different varieties of tool production in automotive industry. The electronics & electrical industry is expected to be the fastest growing segment by 2030, owing to increased consumption of electronics in normal household activities [49]. Note: The AM market for tungsten carbide-based products is not known yet as the sector doesn't exist yet, however a few assumptions can be made to estimate a market size.
				Identify government structures (policies, programmes, legislation) which can influence the technology and potential business opportunities.	• To deal with skills shortage problem, the Department of Trade and Industry initiated a National Skills Fund [64]. • The National Tooling Initiative is a partnership between industry and government, which is a turnaround programme aimed at the rehabilitation and growth of the TDM sector. • The Department of Science and Innovation (DSI) commissioned the development of the National Advanced Manufacturing Technology Strategy for South Africa (AMTS) for the period 2014-2023 to speed the adoption rates up [60].

				Benchmark the local industry with industries in other countries.	Currently, the overall tooling capabilities in terms of products, processes and resources are well below those of developed tooling countries such as Germany [29].
					• **Product** [29].
					    • Overall tool complexity and innovative capacity of tools manufactured is low.
					    • Product range in terms of services is very limited.
					    • Upstream or downstream customer integration is uncommon.
					• **Process** [29].
					    • Process speed is low.
					    • Real net output ratio is very high.
					    • Neither a planning systematic nor planning system is in place.
					• **Resources** [29].
					    • Machinery and other technical equipment are not comparable to international best practices.
					    • Financial resources are limited, restraining growth and enhancements of tool shops.
					
					Other factors:

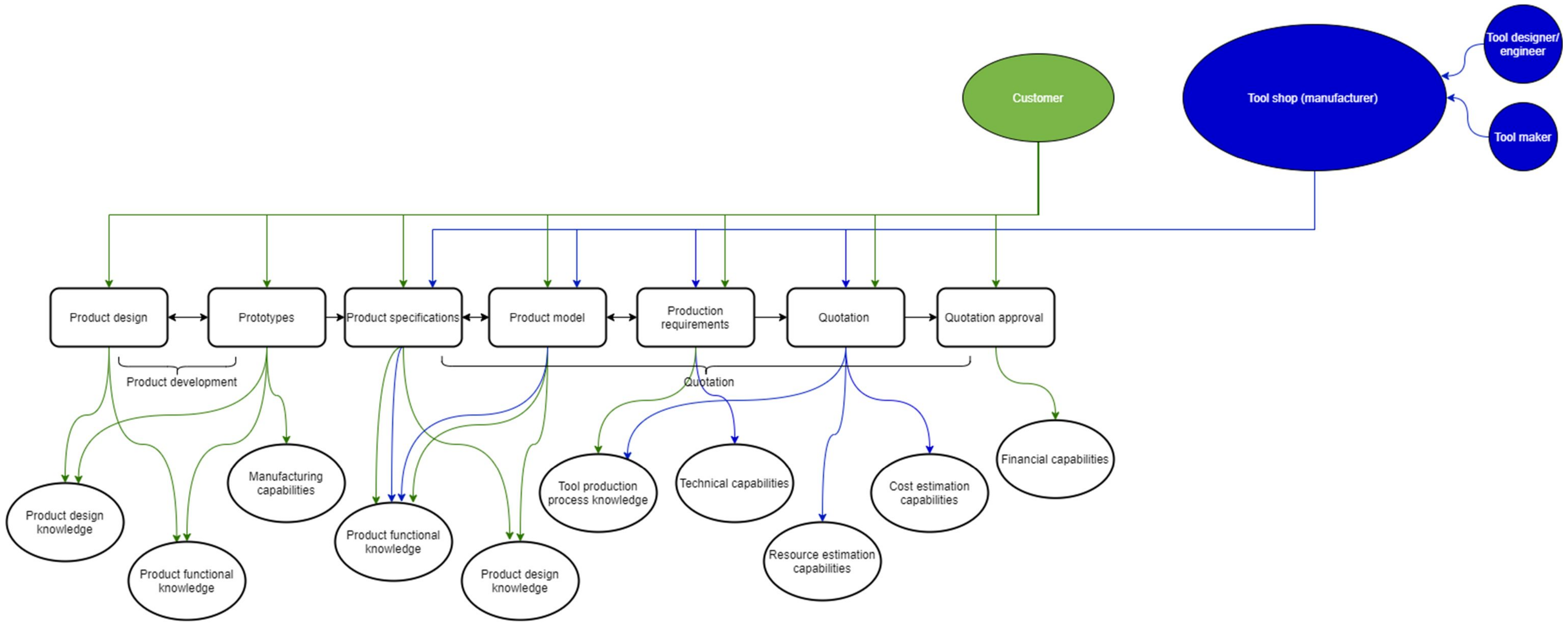
					• Many competitors in the market adopted product launch as their key developmental strategy to expand their product portfolio [49].
				Identify specific (best) practices within the industry.	• Offering additional services to tool shop clients besides selling tools [29]. • Some of the best practice tool shops dispatch their designer to the product design department of the customer to guarantee the producibility of the developed product from the tool shop's perspective [29] • Offering try-out cycles to test the tool in terms of function and efficiency is one option of integration before delivery [29]. • International best practice tool shops go even further and offer their customers a measurement of their presses with an intelligent and self-adjusting tool to compare the results of the try-out cycles with the series production. Ramp up monitoring as well as repair and maintenance work are common services offered by German tool shops [29]. • On the shop floor the high point of an industrialized tool shop is a synchronised production with a visible and structured material flow through the production [29]. • The indirect departments of best practice tool shops put a lot effort in planning and work preparation [29]. • The pursuit of highly efficient production is achieved by avoiding waste like waiting, overproduction or inefficient movements [29].
			1.4.4 Realisation requirements/ enablers	*Identify the requirements/ enablers to realise the identified business opportunities.*	• Selecting the correct suppliers and technologies is critical [189]. • Some industries have specific requirements / standards that need to be adhered to. • Establishing trust between value network partners. • Common technical language to simplify communication between management and shop-floor workers [103], as well as between partners. Required systems: • Product data management systems [103]. • Database management systems [103]. • Production planning and scheduling systems [103]. Digitalisation instruments for coordination and co-operation with suppliers [202]: **Basic:** • Supplier management. • Online bidding. • Production partner collaboration. **Advanced:** • Co-innovation platform. • Knowledge sharing platform. • Collaborative manufacturing enterprise system. • Supplier collaboration platform. • SLM: Though the technique looks simpler, it is imperative to precisely control the process parameters to avoid possible defects like pores, micro-cracks, layer delamination, warping, and degradation in the final

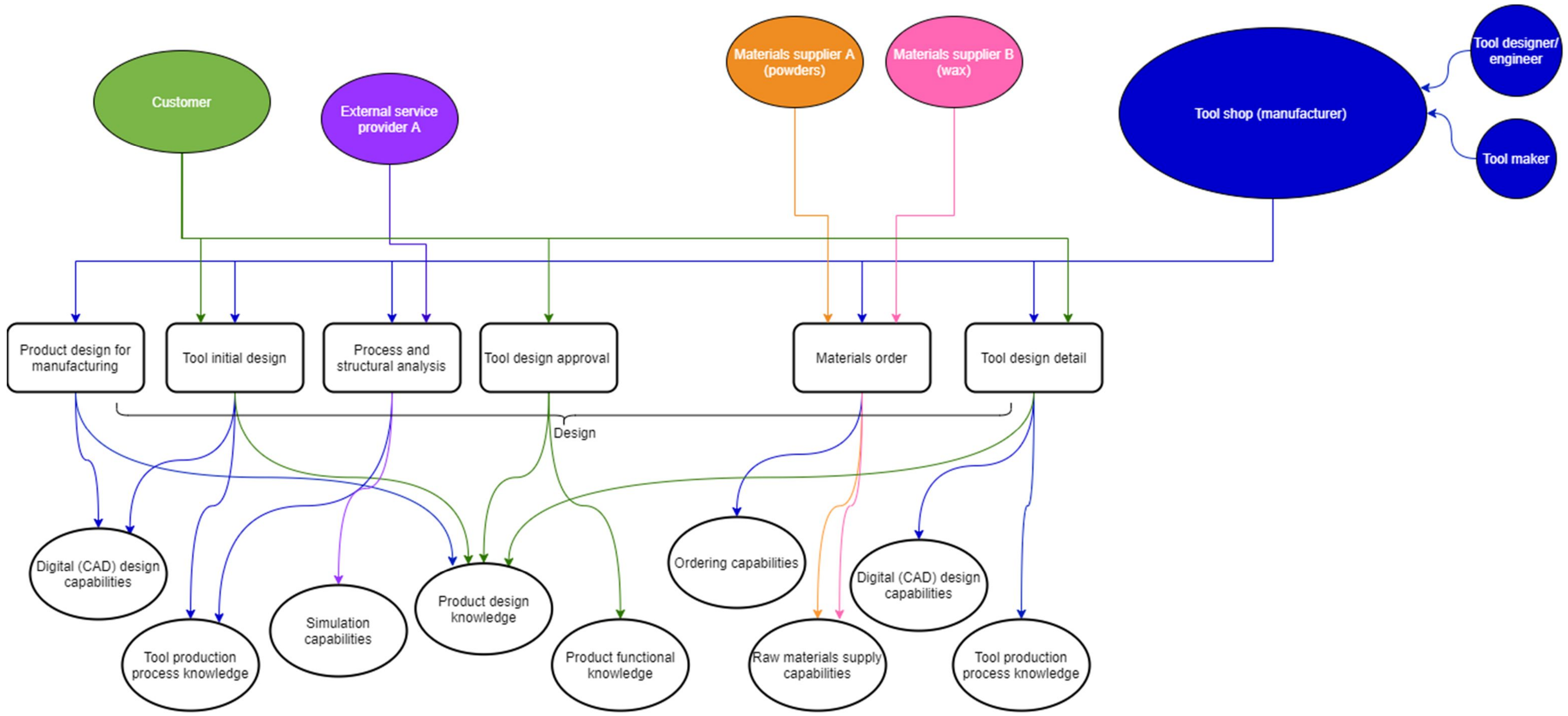
					property of the manufactured part [33]. Especially, proper control of laser parameters is the key to achieve high-quality parts. [175] ‼ *To be completed by user.*

			1.4.5 Strategy formulation	*Formulate appropriate strategies to realise business opportunities.*	Areas where SMEs can take action to mitigate challenges during the crisis [116]:
					• "Leverage technology to reach new customers or provide a distinctive value proposition;
					• Develop clearer market access strategies;
					• Drive efficiency as well as sales;
					• Develop team skills and capabilities and empower leadership."
					
					• AM can be used as a business strategy that can help manufacturers tackle challenges such as time-to-production pressures, adaptability, customisability and costs for new tooling [189].
					• Knowledge is understood to be the new competitive advantage in the TDM industry [103].
					• Since competitive advantage cannot be won by price over the Asian tooling industry, the focus need to be on providing and demonstrating a higher value by innovation (in terms of engineering, materials, and production technologies) [103].
					• Take on focused, specialised work. But focusing on core competences and special tools is risky, because focused range of tools require a focused group of customers which cannot often be found in SA [29].
					• The domestic TDM industry should aim to increase collaboration with regard to niche activities in the process. This will provide the domestic industry with a competitive advantage through the opportunity to focus and build experience in specific activities [138].
					• To increase the average process maturity of South African tool shops a rethinking of process design and value creation in terms of value creation networks needs to be done [29].
					• The automation of the manufacturing process is a possibility to enhance the overall efficiency of the tool shop [29].
					• Innovation cannot be considering only in the field of production technologies, it should be seen as a new strategic business approach also including capacity to enter new markets and operate and think globally, to handle new supply chains and networking partnerships, to provide tailored engineering solutions to client needs and perceived problems that low cost competition is not able to do [103]. Within this context, there are three distinct BMs:
					    ◦ *"Buy primarily on price: reduce costs through process improvement and get excellence in operations.*
					    ◦ *Buy primarily on service: get an intimate relation with clients and provide engineering solutions.*
					    ◦ *Buy primarily on innovation: leading edge technology and focus on 'lead tool users'."*
					• Strategies [103]:
					    ◦ Be a local and low-price player (conventional strategy).

					• Conquer a larger share on value in the supply chain (service providing – prototypes, pre-series and tool delivery or service, tools, and parts providing or from product design to parts providing). • Provide highly complex and innovative tools Strategic purpose [198]: • Improve service offering, build on technology and deepen customer relations. ‼ *To be completed by user.*
				Ensure alignment and coherence among formulated strategies.	‼ *To be completed by user.*
		1.5 Strategic business net establishment	1.5.1 Strategic business net need	*Define the need for the establishment of a strategic business net.*	• The focus on competences and collaboration with external partners are also key to innovation and productivity in tooling because it allows the specialisation and continuous development in strategically selected aspects of tools [29]. • Providing services adds several new tasks to company operations [9], for which companies need to develop networks and partnership infrastructures. Therefore, it is important to understand the network of suppliers and partners that make a business model work in practice [3]. • It has been established that value creation itself within the TDM industry is developing towards a balance between internal manufacturing and a strong network of partners [202]. • PSS enable SME tooling companies to integrate themselves into the value chain of their customers [203]. Collaboration among tool rooms is necessary to uplift competitiveness of the industry. Four main reasons for clustering can be identified [238]: • Small enterprises do not have the capacity to invest in the required technologies and skills development. Clustering offers the opportunity to share technologies and training programmes. Benefits from the establishment of independent tooling clusters with tool rooms as members will increase the efficient use of resources throughout the industry. • The lack of capacity in a single tool room to conduct large commissions forces clients to order from large international tooling organisations. Clustering to share capacity will increase the benefit to large tooling consumers, given local content requirements, especially for the automotive and packaging industries. • Tool rooms can gain knowledge and experience by focusing on specific processes in cluster formations. Specialisation, in which one commission is sectioned according to the capabilities of various tooling organisations, will increase efficiency. • Combined bids in joint ventures can be proposed, making it possible to undertake larger projects that would have gone elsewhere otherwise.
			1.5.2 Objectives	*Define the objective(s) of the*	• The objective of all network actors should be to satisfy, internal or external, customers [104].

				strategic business net.	• The network should work together to deliver the product or service to the customer at the right time, to the right place and at the right price [104]. • Manufacture a requirements-oriented tool for the customer [29]. • The goal is to implement the toolmaker as the network manager that coordinates all elements of the industrial product-service- system performed by him or by local partners, acting as the single point of contact towards the customer [203]. **TDM cluster objectives** [238]: • *"Innovation (products, services, processes).* • *Cluster Expansion (settlement of new firms, incubators, attractiveness of the region).* • *Business Development (promotion of operations, higher productivity and efficiency, higher quality).* • *Commercial Co-operation (joint purchasing policy, interactions between firms, cost savings).* • *Business Environment (physical/technical infrastructure, Legal/institutional settings).* • *Human Resources (workforces/employees, education, attractiveness for students, social attractiveness)."* ‼ *To be completed by user.*
			1.5.3 Boundaries	*Identify and classify all stakeholders.*	**Stakeholders/actors needed in AM** [9]**:** • Machine supplier. • Material (powder) supplier. • Software supplier. • Component manufacturers (service bureaus). • Post processing suppliers or service providers. **Actors in tooling cluster** [238]: • *"Industry (clients, suppliers, related industries, SMEs).* • *Public bodies (regional authorities, agencies).* • *Academia (universities, colleges, tech transfer offices, laboratories, technology parks).* • *Organisations for collaboration (formal and informal networks, trade associations, cluster organisations).* • *Finance (banks, venture capital, business angels).* • *Media."*
				Determine which stakeholders are included in the strategic business net.	For the tool making industry a network consists of a tool making company and its suppliers and customers [202]. • Industrial clients. • Suppliers (design, machine, material, software, scanning, post-processing, experts). • Manufacturer (Tool room/ focal actor).


Customer
Tool shop (manufacturer)
Tool designer/ engineer
Tool maker
Product design
Prototypes
Product specifications
Product model
Production requirements
Quotation
Quotation approval
Product development
Quotation
Product design knowledge
Product functional knowledge
Manufacturing capabilities
Product functional knowledge
Product design knowledge
Tool production process knowledge
Technical capabilities
Resource estimation capabilities
Cost estimation capabilities
Financial capabilities


Customer
External service provider A
Materials supplier A (powders)
Materials supplier B (wax)
Tool shop (manufacturer)
Tool designer/ engineer
Tool maker
Product design for manufacturing
Tool initial design
Process and structural analysis
Tool design approval
Materials order
Tool design detail
Design
Digital (CAD) design capabilities
Tool production process knowledge
Simulation capabilities
Product design knowledge
Product functional knowledge
Ordering capabilities
Raw materials supply capabilities
Digital (CAD) design capabilities
Tool production process knowledge

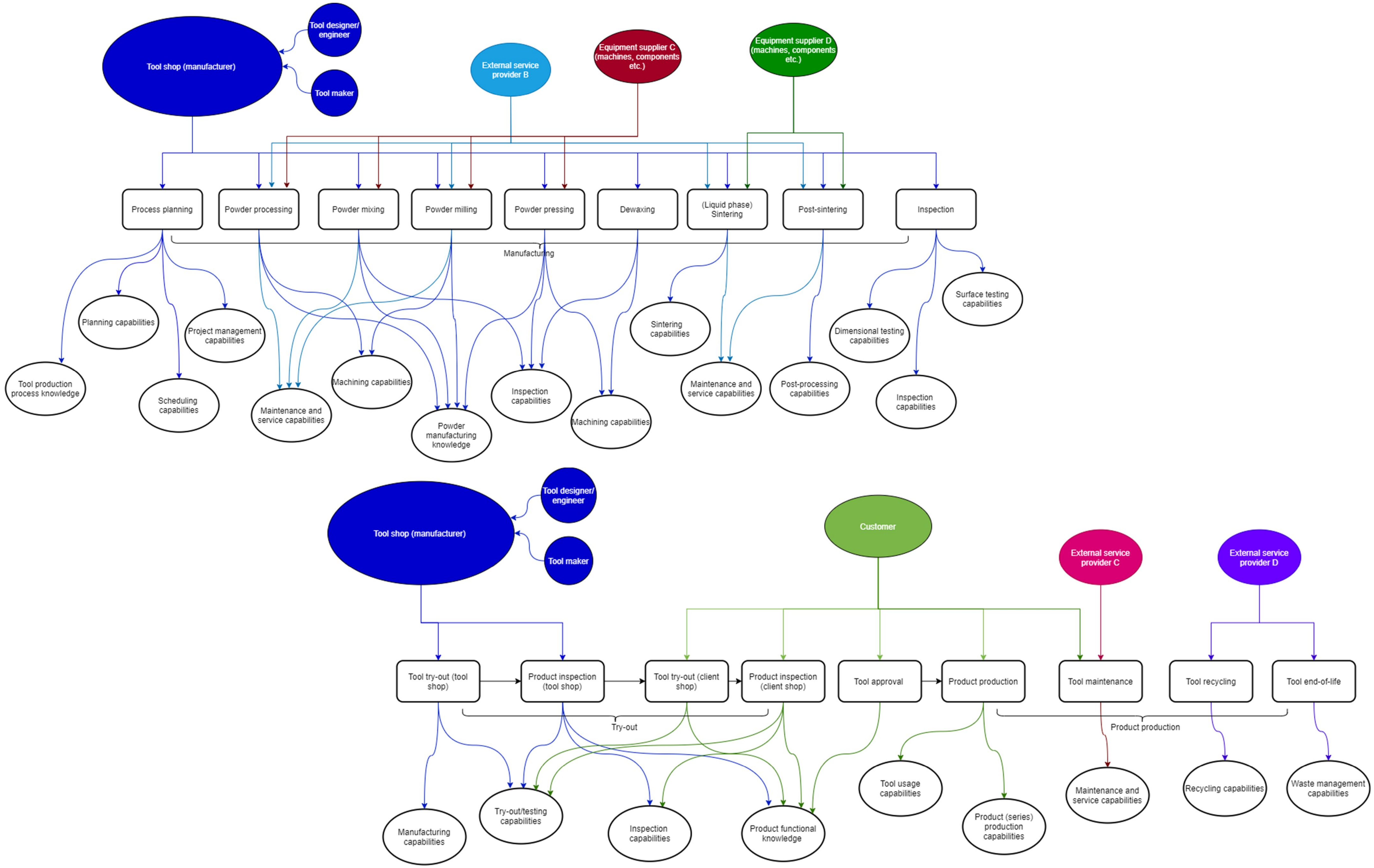


Figure 7.4: Contextual application: Overview of the potential configuration of the as-is value network

7.5.2 Ideation sub-phase

Table 7.2: Contextual application: Ideation sub-phase

<table>
<tr><th>Phase</th><th>Sub-phase</th><th colspan="3">Steps</th><th>Application</th></tr>
<tr><td rowspan="3">Sensing</td><td rowspan="3">2. Ideation</td><td rowspan="3">2.1 AM technology opportunities</td><td>2.1.1 Part-material-process analysis</td><td>Identify possible parts to be manufactured using AM (part of the joint offering).</td><td>‼ To be completed by user.</td></tr>
<tr><td>2.1.2 AM manufacturing process and technology selection</td><td>Select the required process and AM manufacturing technologies based on the part-material-process analysis.</td><td>SLM [175]:
• Advantages: “high dimensional accuracy, high geometric freedom, fewer steps, and high hardness.”
• Disadvantages: “high residual stress, uneven microstructure, evaporation of cobalt and carbon imbalance.”
BJ3DP [175]:
• Advantages: “uniform microstructure, high toughness, low cost and low residual stress.”
• Disadvantages: “complicated process, large shrinkage, low hardness, and moderate strength.”

• SLM is used in the TDM industry to produce final parts in small batches of approximately one to eight [31].
• Because of the almost infinite geometrical freedom, SLM is applied to manufacture tooling inserts containing conformal cooling channels, resulting in reduced cycle times and improved part quality [31].
• SLM offers massive cost saving in combination with better functionalities despite the higher manufacturing costs for small batch production [31].

Selected technology (assumption for illustration purposes): SLM</td></tr>
<tr><td>2.1.3 AM process chain analysis</td><td>Identify typical functions within the selected AM process chain.</td><td>Typical steps for metal LPBF (SLM) AM process:
Design for AM
3D CAD volume model/ topology optimisation [9]
Finite element simulation [9]
Final design/slicing [9]
Manufacturing:
Material build process [9]
Support structures [9]
Post-processing:
Stress relieving [9]
Support structure removal [9]
Heat treatment [9]
Machining [9]
Surface treatment [9]
Testing and inspection:
Dimension analyses [9]
Surface analyses [9]
Non-destructive testing [9]</td></tr>
</table>

					Quality assurance [9] Maintenance [9]
				Identify process chain requirements.	**AM process parameters or variables in SLM/SLS** [175]: • Scanning speed • Spot size • Laser power • Scan line spacing (hatch spacing) • Laser energy density • Layer thickness • Laser type • When compared to polymer powders, metallic powders are highly susceptible to contamination as they are highly reactive to moisture, absorbed gases, and formation of oxide and nitride layers which can affect the microstructure and degrade the properties [175]. • Properties like purity, morphology, and size of the metal powders also play a critical role in defining the final properties of the manufactured parts [175]. ‼ *To be completed by user.*
				Identify the required roles within the process chain.	• Systems manufacturers (original equipment manufacturers of AM machines, most offer related software, materials and services) [118]. • Materials producers (raw materials for AM) [118]. • Software developers (design, process simulation, workflow and CAD-model slicing) [118]. • 3D scanning and reverse engineering companies (focus on the reverse process of scanning existing products, to digitalise or further engineer/process them) [118]. • AM service provider (AM contract manufacturing, design, engineering or technical consulting) [118]. The most important roles within the value network are designers, manufacturers, processors, distributors, communicators, project manager, customers. The most important actors within the VN are the focal actor or manufacturer (including designers, service delivery), suppliers (powder, software, machine), post-processing partners, and customers
				Identify the required capabilities within the process chain.	• Powder manufacturing capabilities • Design capabilities (design software and optimisation methods for AM, metallurgical knowledge) • Post-processing capabilities (metal cutting, sintering, heat treatment, hot isostatic pressing) • Scanning capabilities • Project management capabilities • Accreditation (standardisation) capabilities ‼ *To be completed by user.*

			2.1.4 Business impact analysis	*Identify possible applicable AM benefits.*	**Benefits of using AM for tooling:** • Lead time reduction [55]. • Cost reduction [55]. • Improved functionality [55]. • Increased complexity of shapes [189]. • Increased ability to customise [55]. • Enormous design and manufacturing freedom [189]. • Improve efficiency [118]. • Enable the r(red)design and creation of end-use products with improved functionality or ones that could not be made previously, leading to growth as unmet customer needs can be satisfied and thereby winning new markets [118]. • AM provides the opportunity for companies to extend or change their BMs, reposition themselves in the value chain, or gain competitive advantage from the technology by becoming an AM vendor [118].
				Identify possible applicable AM challenges.	**Challenges of using AM** [9]: • Intellectual property rights. • Standards and certification. • Education and training. • Liability. • Need for new business models . • Environmental impact. • Health, safety, and environment.
			2.1.5 Value network impact analysis	*Determine the impact on the value network (strategic business net).*	• The use of AM within the tooling industry will not revolutionise the supply chain [55]. • The use of AM within the tooling industry will not revolutionise the end product as it will not differ greatly to products manufactured using conventional tooling [55]. • AM enables (i) localised manufacturing, and (ii) user manufacturing [225]. • The end customer will acquire CAD files from original equipment manufacturers or through business-to-customer and customer-to-customer marketplaces [225]. • If distributed AM supply networks are adopted, more manufacturing will take place downstream in the supply chain [225]. • The CAD file flows will also replace more product flows from upstream and mid-stream to downstream levels [225]. • Distributed manufacturing will decrease supply chain complexity, lead to shorter supply networks, decrease transportation needs, and reduce overall lead times [225].
		2.2 Business opportunity development	*2.2.1 Refinement*	*Refine the identified business opportunities (and joint offerings) based on the AM technology analysis.*	‼ *To be completed by user.*
			2.2.2 Selection and prioritisation	*Select the best business opportunities and prioritise them according to short, medium, and long-term.*	‼ *To be completed by user.*
			2.2.3 Risk management	*Identify the main risks associated with the selected AM process.*	Current properties of Additive Manufactured Tungsten carbide that make production challenging [175]: • *"Cracks and pores.*

					• *Lower density.* • *Changes in microstructure.* • *Dimensional inaccuracies.* • *Poor mechanical properties."* ‼ *To be completed by user.*
				Identify company risks and develop a risk management plan.	• Selecting wrong suppliers [189]. • Selecting wrong partners [189]. • *"The tool industry has not attracted venture capital because returns have not been commensurate with the risk of investment in what is perceived to be a mature and fragmented industry. There have been some extensive discussions between banks, some OEMs, tooling companies and others on how to create new financing mechanisms that simultaneously meet the desire of tool owners to take the cost of tooling off their balance sheets and relieve the cash flow drains on tooling firms"* [103]. ‼ *To be completed by user*
				Identify joint risks and develop a risk management plan.	• Data security • Communication • Lack of trust • Traceability ‼ *To be completed by user.*
		2.3 Strategic business net development and configuration	*2.3.1 Initiation features*	*Determine the scope of the networked BMI initiative.*	‼ *To be completed by user.*
				Identify the vision and mission of the BMI initiative.	‼ *To be completed by user.*
				Determine how the innovation process will be facilitated and implemented.	‼ *To be completed by user.*
				Determine how the process will be integrated with existing systems and/or processes.	‼ *To be completed by user.*
			2.3.2 Strategic business net configuration	*Configure the future strategic business net based on the functions, roles and capabilities associated with the AM process chain.*	► **See Section 7.5.3**
			2.3.3 Strategic business net features	*Consider the impact of the strategic business net features.*	‼ *To be completed by user.*
			2.3.4 Key success factors	*Identify key success factors for the strategic business net.*	**Success factors for a tool room to achieve global competitiveness** [138]: • Focus ability (concerning a specific industry or industries and production technologies and methods).

					• Technology base (the level of modern technologies utilised). • Skills (level of experience and expertise). • Efficiency (cost of input to the value of output for manufacturing a tool or die). • Motivation (satisfaction of employees within their work environment).
		2.4 Networked BM development	*2.4.1 Value network elements*	*Provide possible configurations/ ideas for the value network BM elements.*	►**See Section 7.5.4**
			2.4.2 Value proposition elements	*Provide possible configurations/ ideas for the value proposition BM elements.*	►**See Section 7.5.4**
			2.4.3 Value architecture elements	*Provide possible configurations/ ideas for the value architecture BM elements.*	►**See Section 7.5.4**
			2.4.4 Value finance elements	*Provide possible configurations/ ideas for the value finance BM elements.*	►**See Section 7.5.4**
		2.5 Business case rationale	*2.5.1 Customer profile*	*Refine the customer profile based on joint offerings enabled by AM.*	‼ *To be completed by user.*
				Identify potential brand ambassadors / lead customers among existing customers.	‼ *To be completed by user.*
			2.5.2 Network completion	*Ensure the network is complete and all aspects of the business opportunity and customers' needs are addressed.*	‼ *To be completed by user.*
			2.5.3 Business case	*Ensure a comprehensive business case that address the business opportunities are created.*	‼ *To be completed by user.*

7.5.3 SBN configuration process

Although the mapping of the strategic business net was originally proposed to be done in the feasibility sub-phase after actors were selected, it is acknowledged that it might be too late. Therefore, it is rather proposed to be done as part of the ideation sub-phase (*step 2.3.2*), as the configuration of the future strategic business net directly impact the possible configurations of the networked BM elements. The tables associated with the configuration are presented in Appendix E, Tables E.4 and E.5.

To elaborate a bit more, during *step 2.3.2*, the current VN configuration developed in *step .1.2* (Figure 7.4) were used, together with the functions, roles and capabilities associated with the LPBF process, identified within *step 2.1.3*. The aim was to visualise how a possible future VN or strategic business net would look like for the prospective use of AM within the cemented tungsten carbide manufacturing industry.

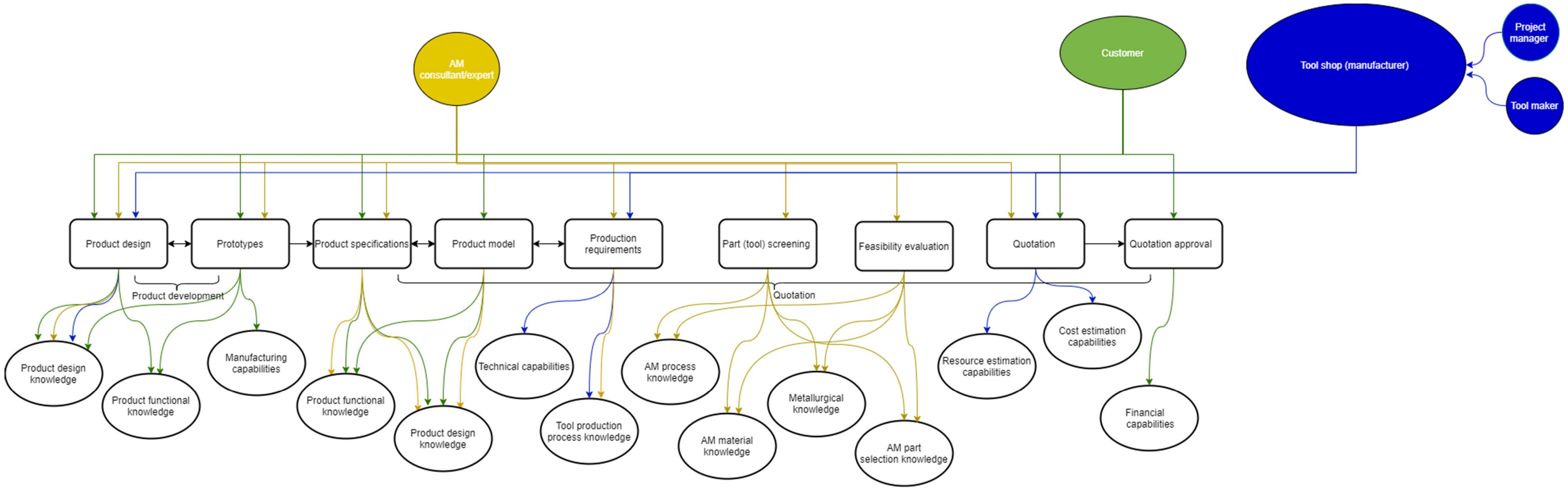
The strategic business net was thus configured using these aspects as well as a few additional assumed capabilities (fictionalised) and assumed possible roles and involvement in functions (fictionalised). However, some of the functions and capabilities associated with the conventional manufacturing method (powder metallurgy) were replaced by LPBF manufacturing functions and capabilities. For existing users within the tooling industry, using a hybrid approach (the use of traditional methods together with AM) might however be the most feasible solution. The logic and sequence of these functions were evaluated by the AM expert. Again, to ensure the map read easy, some capabilities were repeated along with the network.

The proposed mapping illustrates the potential configuration of a future strategic business net, i.e., which possible roles are required, possible functions, and possible capabilities to fulfil the functions. As with the current VN, the proposed configuration can also be used by a network actor that wants to enter the VN, or integrate their functions upstream or downstream, an overview can be acquired of what is needed (as it is not a simple move). The main aim was to illustrate the functionality and applicability of the process, as well as creating a ‘base case’ or a ‘mental picture’ for the industry that may be built on in future research or be used by potential users within the industry. The proposed configuration can provide an initial understanding of the VN regarding the possible adoption of AM in the tooling industry, but the configuration will however frequently change (as noted by subject-matter expert I). It is furthermore acknowledged that the strategic business net’s configuration might not be completely comprehensive, nor accurate, but it might be an acceptable representation to begin with.

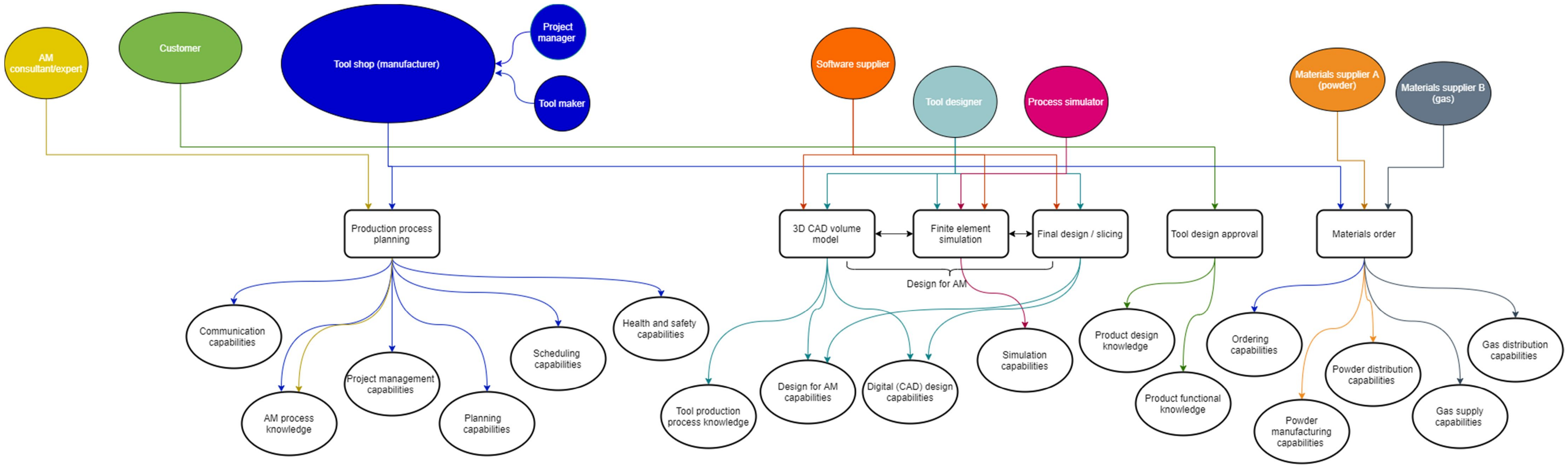
Within the proposed configuration, the *tool shop* remains the focal actor, but the customer now partakes in the value creation being involved in more functions. The customer is vital as AM enables customised products, and therefore with every decision made, the customer need to be considered (including customer-centric BMs). Furthermore, additional roles are involved along the network, which can either be fulfilled by existing actors, or new actors entering the marketplace. This increase in the number of actors, and consequently these increased dependencies emphasise the need for SMMEs to start focusing on how to establish trust with all network actors. It is important to note that proposed configurations will however constantly change because of changes in actors’ capabilities, causing the roles in the network to change, and consequently the network’s offerings and BM.

During the configuration, it was clear that within the tooling industry collaboration is necessary since no individual actor can fulfil all the functions. Since the AM industry is very small, competitors need to form part of one’s value network, as their capacities may be needed, therefore they were included in the configuration. Due to this small market, relationships and the management thereof are extremely important as one cannot afford to burn bridges.

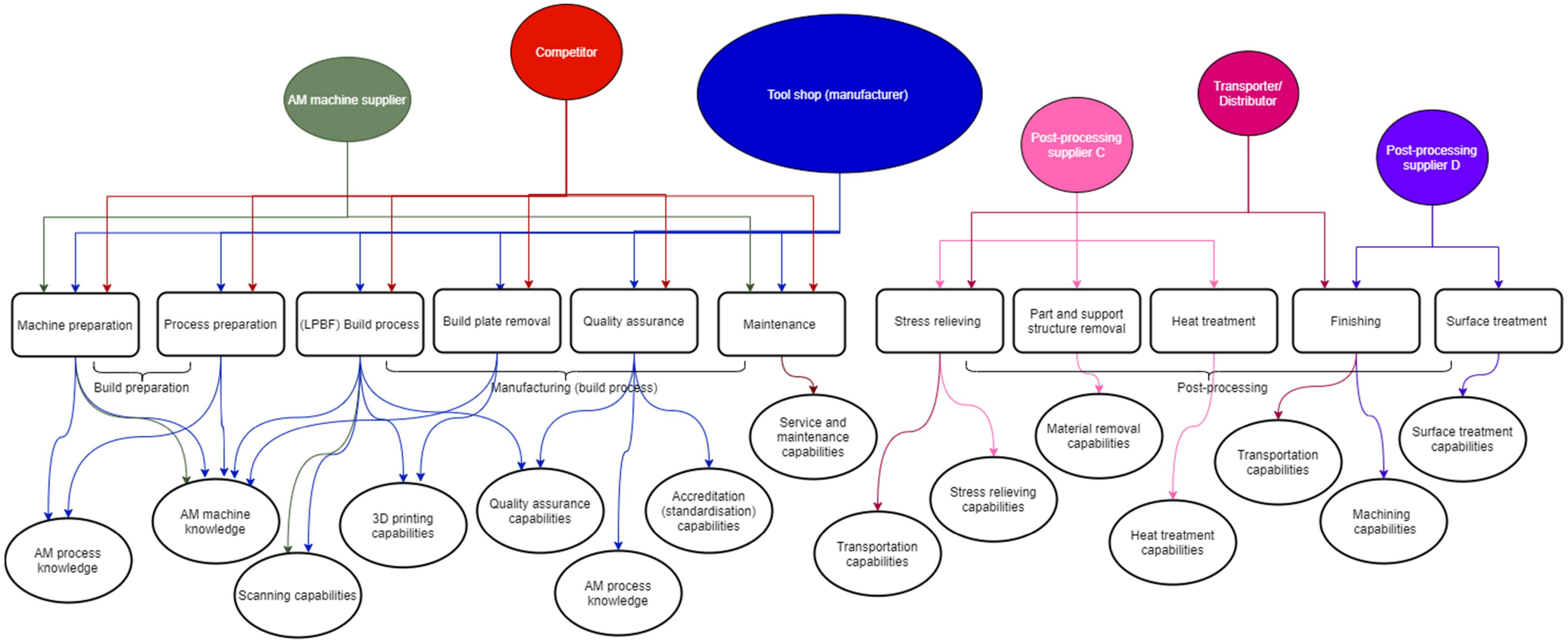
Due to the lack of in-depth knowledge with regards to the physical operations of the tooling network or industry, only two functions were mapped on the tactical level to demonstrate applicability and functionality to the contextual application area. These functions and flow are mapped on assumptions and are therefore fictional. However, these steps applicability and potential value within the contextual application area were adequately demonstrated.

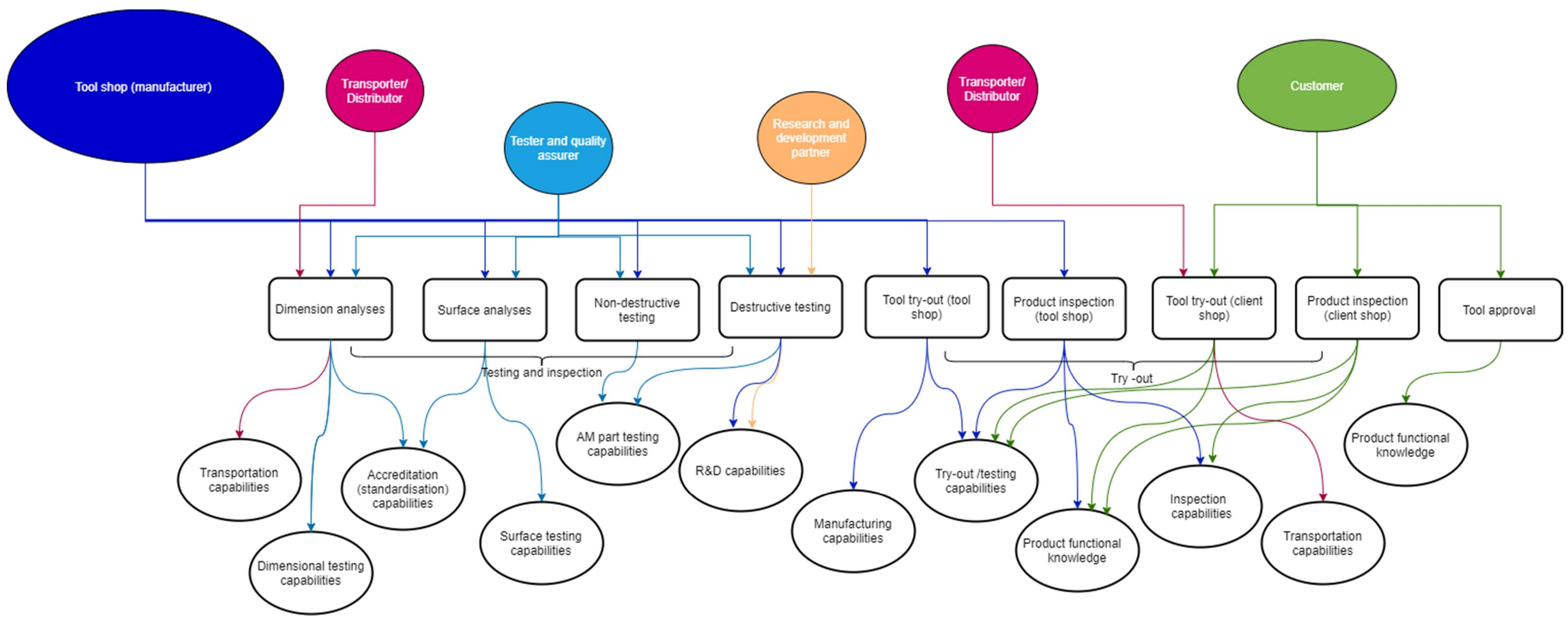


AM consultant/expert
Customer
Tool shop (manufacturer)
Project manager
Tool maker
Product design
Prototypes
Product specifications
Product model
Production requirements
Part (tool) screening
Feasibility evaluation
Quotation
Quotation approval
Product development
Quotation
Product design knowledge
Product functional knowledge
Manufacturing capabilities
Product functional knowledge
Product design knowledge
Technical capabilities
Tool production process knowledge
AM process knowledge
AM material knowledge
Metallurgical knowledge
AM part selection knowledge
Resource estimation capabilities
Cost estimation capabilities
Financial capabilities



AM consultant/expert
Customer
Tool shop (manufacturer)
Project manager
Tool maker
Software supplier
Tool designer
Process simulator
Materials supplier A (powder)
Materials supplier B (gas)
Production process planning
3D CAD volume model
Finite element simulation
Final design / slicing
Tool design approval
Materials order
Design for AM
Communication capabilities
AM process knowledge
Project management capabilities
Planning capabilities
Scheduling capabilities
Health and safety capabilities
Tool production process knowledge
Design for AM capabilities
Digital (CAD) design capabilities
Simulation capabilities
Product design knowledge
Product functional knowledge
Ordering capabilities
Powder manufacturing capabilities
Powder distribution capabilities
Gas supply capabilities
Gas distribution capabilities


Competitor
AM machine supplier
Tool shop (manufacturer)
Post-processing supplier C
Transporter/ Distributor
Post-processing supplier D
Machine preparation
Process preparation
(LPBF) Build process
Build plate removal
Quality assurance
Maintenance
Stress relieving
Part and support structure removal
Heat treatment
Finishing
Surface treatment
Build preparation
Manufacturing (build process)
Post-processing
Service and maintenance capabilities
Material removal capabilities
Surface treatment capabilities
Transportation capabilities
AM machine knowledge
3D printing capabilities
Quality assurance capabilities
Accreditation (standardisation) capabilities
Stress relieving capabilities
Machining capabilities
AM process knowledge
Scanning capabilities
AM process knowledge
Transportation capabilities
Heat treatment capabilities


Tool shop (manufacturer)
Transporter/ Distributor
Tester and quality assurer
Research and development partner
Transporter/ Distributor
Customer
Dimension analyses
Surface analyses
Non-destructive testing
Destructive testing
Tool try-out (tool shop)
Product inspection (tool shop)
Tool try-out (client shop)
Product inspection (client shop)
Tool approval
Testing and inspection
Try -out
AM part testing capabilities
R&D capabilities
Product functional knowledge
Transportation capabilities
Accreditation (standardisation) capabilities
Try-out /testing capabilities
Inspection capabilities
Surface testing capabilities
Manufacturing capabilities
Transportation capabilities
Dimensional testing capabilities
Product functional knowledge

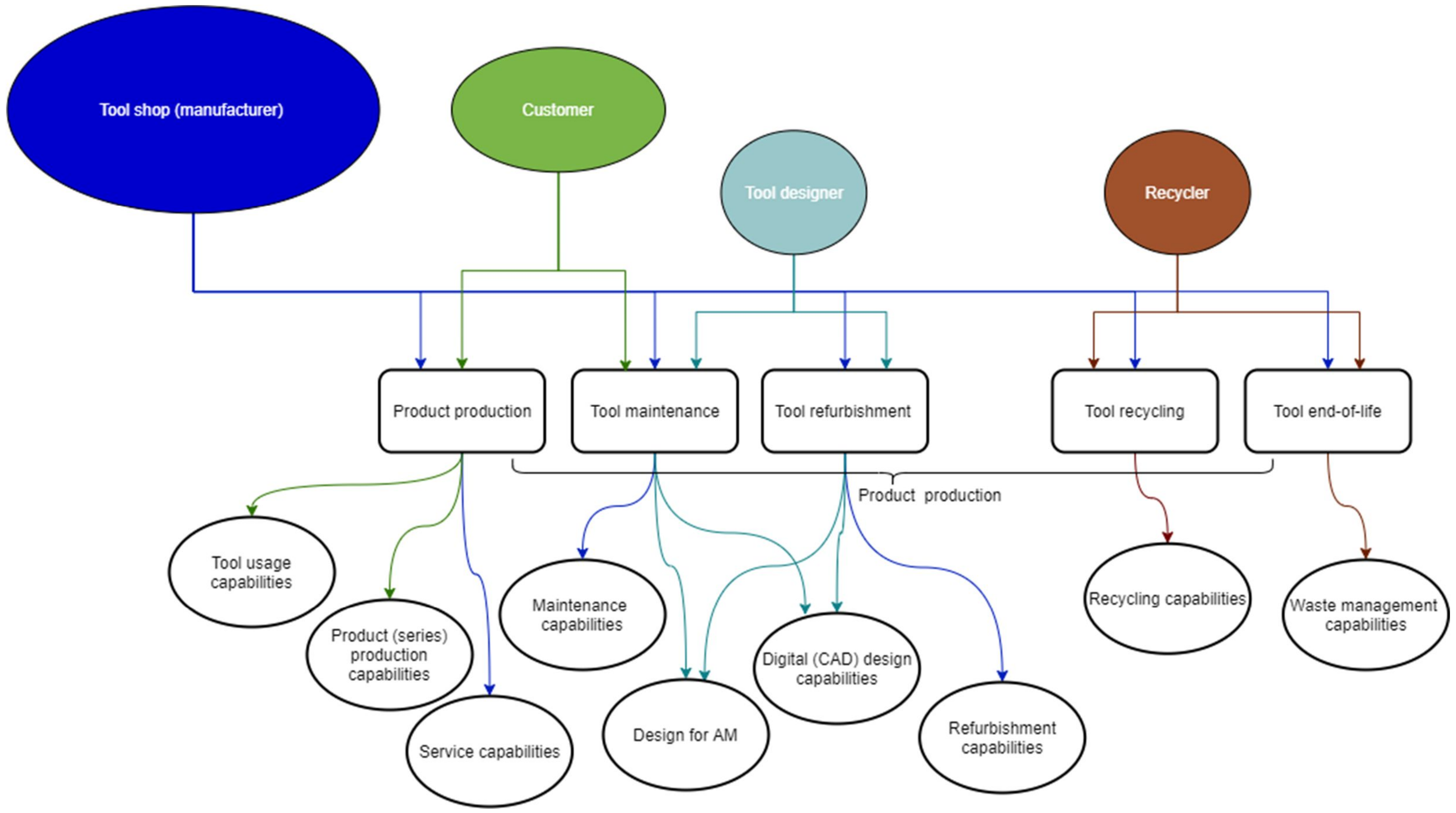


Figure 7.5: Contextual application: Overview of the configuration of the future potential strategic business net

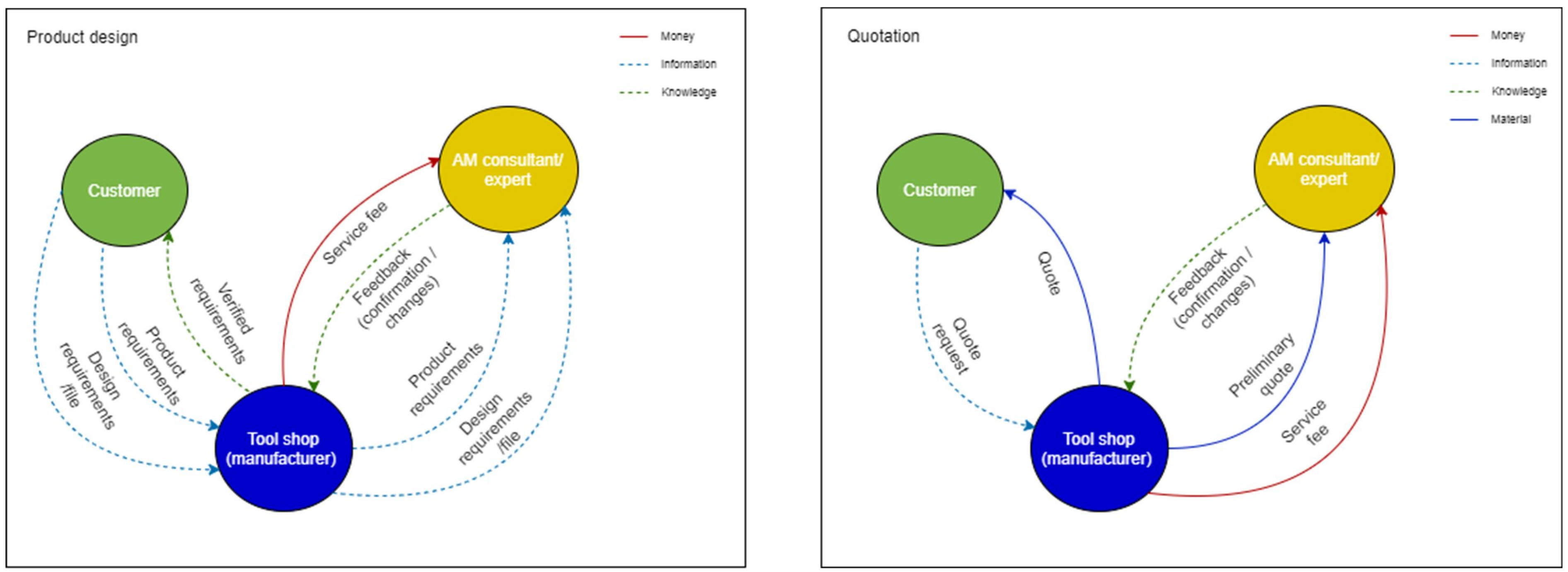


Figure 7.6: Contextual application: Overview of two functions of the future strategic business net

7.5.4 Networked BM elements

The following section presents the results of step 2.4 of the ideation sub-phase, regarding the possible configurations of the networked BM elements. Based on the insights obtained through the completion of the activities and configuration of a possible future strategic business net, possible configurations and ideas for the networked BM elements are proposed below in Tables 7.3 - 7.6.

For this specific case, a combination of the BM for 'In-house 3D printing' and '3D printing service' proposed by Dukat [65] (discussed in Section 3.6.4) are used as basis to inform the configurations for the network. Furthermore, a customer-centric approach is taken, and need to be taken by potential users (as discussed in Section 3.6.3). It is however important to note that the proposed configuration for the strategic business net, as well as the networked BM elements are just one possible configuration (containing fictionalised elements), but many are possible that can be configured and weighed against each other. The configuration can easily change if one actor or partner's role(s) are moved sideways which in turn will also directly influence their firm-level BM's 'length' if more or less functions are fulfilled by a certain actor [192]. Since the configuration of the firm-level BMs can easily be moved up and down or sideways, depending on the configuration of the strategic business net, it enables the firm-level BMs to become fully 'mobile' [192] (discussed in Section 3.6.4). Due to a lack of knowledge, some of the networked BM elements could not be configured adequately and were indicated accordingly.

Table 7.3: Possible configurations for the elements of the value network dimension

Value network dimension	Configuration
Roles	• Customers • Manufacturer (AM) • AM consultant or expert • Designer • Software supplier • Process simulator • Powder suppliers • Gas supplier • AM machine supplier • Post-processing partners • Testers and quality assurers • Recycler • R&D partners (academic and or companies) • Value network integrator • Platform developer • Competitors • Distributor (transport)
Actors / Partners	‼ *To be completed by user (select actors to fulfil roles).*
Relationships	Strategic, collaborative partnerships between the AM manufacturer, AM consultants or experts, designers, post-processing suppliers, simulators, as well as testers and quality assurers. (All organisations remain independent organisations.) Transactional relationships between the AM manufacturer and the material, software, and machine suppliers. Co-operative relationship between the AM manufacturer and the R&D partners to continuously develop and improve offerings. Strategic partnerships between the AM manufacturer and selected competitors that may help when capacity limits are reached.
Governance	A flat governance structure is followed where all actors or partners within the network share costs and risks, depending on their contribution and role in the network.
Communication	Communication upstream to customers and downstream to partners and suppliers are of utmost importance to enable value co-creation. It is important to establish what information and data need to be communicated to which actor or partner and when. Communication channels between network actors can include electronic communication systems and other channels (including electronic platforms).

Value network dimension	Configuration
Communication channel	Interaction with clients will follow a hybrid approach, including intermediaries and direct selling approaches, such as: • Online advertisements • Events, tradeshows • E-mail • Social media channels • Web-page • Online platform
Control	The AM manufacturer (focal actor) has control within the network, directly communicate and interact with customer. The manufacturer is also in control of the planning and management of the production process that must be followed for each order.
Push/pull	A pull, on-demand production paradigm is used, rather than forecast-driven production. Agile production principles will be needed to produce these niche market products.
Customisation	Primarily, highly individualised (personalised), customised products are manufactured. In addition, pre-designed products with little to no personalisation can also be manufactured.

Table 7.4: Possible configurations for the elements of the value proposition dimension

Value proposition dimension	Configuration
Target-segment	Niche market (for example in the automotive industry). Local market. Product segments: • Dies and moulds. • Cutting tools.

Product-service	• Pre-designed (designer or customer, or other 3rd party) products.
	• Customised products.
	• Product life-cycle services
	  • Installation
	  • Delivery
	  • Maintenance
	  • Support
	  • Reparations
	‼ *To be completed by user.*

Joint offering	In addition to the product-service, the total offering include: • Expertise • Flexibility • Customer service • Product quality • Due date conformance • Variety • Differentiation ‼ *To be completed by user.*
Distribution channel	• E-commerce website. • Platform.
Customer relationships	High customer interaction is required for customised, build-to-order products. Production is based on customer's needs and requirements; with value co-creation the customer continuously need to provide input and feedback. For other, predesigned products or AM printing services, low customer interaction is required, as it is mostly a transactional relationship.
Development and design	Development and design of parts to be manufactured (pre-designed and customised products) using AM to be done by a network partner, in close collaboration with tool manufacturer and the customer to obtain input and ensure alignment with the product to be series produced.
Value-in-context	The value-in context (value offer) elements are closely associated with the joint-offering and needs to be defined accordingly. ‼ *To be completed by user.*

Table 7.5: Possible configurations for the elements of the value architecture dimension

Value architecture dimension	Configuration	
Functions	**Product development** Product design Prototypes **Quotation** Product specifications Product model Production requirements Part (tool) screening Feasibility evaluation Quotation Quotation approval Production process planning **Design for AM** 3D CAD volume model Finite element simulation Final design/slicing Tool design approval Materials order **Build preparation** Machine preparation Process preparation **Manufacturing (build process)** (SLM) build process Build plate removal[9]	Quality assurance Maintenance **Post-processing:** Stress relieving Part and support structure removal Heat treatment Finishing Surface treatment **Testing and inspection:** Dimension analyses Surface analyses Non-destructive testing Destructive testing **Try-out** Tool try-out (tool shop) Parts inspection (tool shop) Tool try out (client shop) Parts inspection (client shop) Tool approval **Product production** Product production Tool maintenance Tool recycling Tool end-of-life
Capabilities	Product design knowledge Manufacturing capabilities Product functional knowledge Tool production process knowledge Technical capabilities AM process knowledge AM part selection knowledge AM material knowledge Resource estimation capabilities Cost estimation capabilities Financial capabilities Communication capabilities Project management capabilities Planning capabilities Scheduling capabilities Health and safety capabilities Metallurgical knowledge Design for AM capabilities Digital design capabilities Simulation capabilities Product design knowledge Ordering capabilities	Powder manufacturing capabilities Gas supply capabilities Gas distribution capabilities AM machine knowledge 3D printing capabilities Accreditation (standardisation) capabilities Quality assurance capabilities Service and maintenance capabilities Stress relieving capabilities Material removal capabilities Heat treatment capabilities Machining capabilities Surface treatment capabilities AM part testing capabilities R&D capabilities Inspection capabilities Try-out/testing capabilities Series production capabilities Tool usage capabilities Refurbishment capabilities Recycling capabilities Waste management capabilities Distribution capabilities
Resources	**Physical resources:** • Machinery (including 3D printing machine). • Equipment. • Production facility. • ICT infrastructure. • Post-processing auxiliary equipment.	

Value architecture dimension	Configuration
	• Software. • Material (including powder, gas etc.) • Energy. **Human resources:** • Competent personnel. • Technology know-how. • Industry know-how. **Intellectual resources:** • Intellectual property linked to technology and industry know-how. **Financial resources:** • Capital to invest in machines, software, training, personnel, etc. • Funding to sustain running cost at the beginning.
Information flow	Timely and accurate information flow and exchange between partners, suppliers, and customers becomes crucial as it is the foundation for knowledge and enable networked operations. This information relates specifically to the operations of the network. Information can be shared via an online platform, email, or other software solutions. ‼ *To be completed by user (what information needs to be shared with whom, when).*
Data analytics	The customer's data regarding needs, usage, performance, requirements etc, are the source of high-value data that have a direct impact on the operations of the strategic business net.
Platform	A merchant only digital platform is required to enable communication and collaboration between the manufacturer and customer.

Table 7.6: Possible configurations for the elements of the value finance dimension

Value finance dimension	Configuration
Revenue structure	Primary revenue streams for the network: • Customised parts. • Pre-designed parts. Revenue sources: • Sales (specific sales by specific actors e.g., materials, machine, equipment, products etc.) • Services (specific services delivered by specific actors e.g., design, processing, printing, distribution, maintenance, repair etc.) Payment methods: • Bank transfer (EFT) • Cash • Credit card • PayPal Payment process: • Payments received from customer according to fixed milestones; allocated to partners who have already completed their functions. Distribution of revenues are done among all actors who contribute to the delivery of the product and/or service i.e., distributed among actors according to contribution for specific part or order. ‼ *To be completed by user.*
Cost-structure	Cost distribution as a percentage of internal costs associated with each function in the network: • Personnel • Depreciation • Interest payable • External services • Material

Value finance dimension	Configuration
	• Overheads Distribution of costs are done among all actors who contribute to the delivery of the product and/or service i.e., distributed among actors according to contribution for specific part or order. ‼ *To be completed by user.*
Profit-formula	A profit % need to be allocated to the quote for each part or order based on the costs and revenues associated with the specific part or order. Each partner within the network gets their profit accordingly. ‼ *To be completed by user.*
Pricing method	Pricing is very order specific, and case dependent, however it might be based on one of the following options: • Option 1: Unique quote for customised order. • Option 2: A set price per part, depending on dimensions with additional charges. • Option 3: A set price for a standardised product. ‼ *To be completed by user.*
Total-cost-of-ownership	The overall costs with respect to all core arrangements that are needed to create, provide, market, deliver, and maintain the solution throughout its lifespan (including development, support, maintenance, collaboration costs). ‼ *To be completed by user.*
Sales model	The customer pays for ownership of the joint offering the strategic business net creates, as well as service delivery, depending on the customer's needs.
Continuity	Revenue will have a mixed continuity. The biggest amounts will be received upfront, during or after the production process, then as services are delivered throughout the product's lifespan, more revenues will be generated.
Metrics	Profitability and performance of value network. Following metrics or measurements might be applicable to the firm/ strategic business net [138]: • *"Annual turnover generated per employee/network partner;* • *Turnover profitability, i.e. operating profit as a percentage of turnover;* • *Return on capital employed, i.e. operating profit as a percentage of all assets;* • *Capital turnover, i.e. turnover as a percentage of capital assets;* • *Investment expenditures as a percentage of costs; and* • *All costs for the production phases expressed as a value per employee/partner."*

7.6 Tooling industry reflection

The aim of the theoretical application of the framework's first two sub-phases was to demonstrate the framework's application potential to the AM industry, specifically to produce cemented tungsten carbide hardmetal parts (real-life problem). Furthermore, the application aimed to use existing and available literature studies to create a potential 'first draft' of the activities for potential future users to build on through the evaluation and revision of the application and the addition of practical and industry knowledge. Figure 7.7 below illustrates the proposed next steps for a potential user in future.

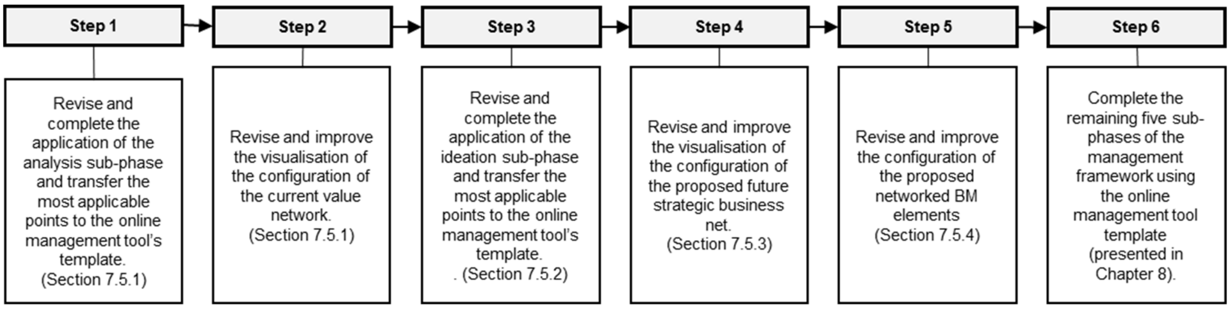


Figure 7.7: Next steps for a potential user in the tooling industry

Reflecting on the selected contextual application area after the application of the first two sub-phases, the following notes were made:

- The introduction and adoption of emerging technologies such as AM is no simple, overnight task, but require thorough research, analysis and planning due to all the risks associated with these technologies.
- The strategic business net and networked BM must be planned carefully and thoroughly to ensure alignment and to prevent unnecessary stumbling blocks.
- The adoption of AM technologies in the hardmetals tooling industry has a lot of potential if the market is approached correctly, together with the identification of value-in-context elements associated with the joint offerings to create a 'niche'.
- The formation of partnerships in the tooling industry (including customers, suppliers, and competitors) are extremely important for commercial feasibility due to the high cost associated with investments and the specific know-how associated with every function within the AM process chain.
- Due to the small existing AM market, know-how (knowledge) drives the market and is a requirement to be an early adopter and leader within the industry.
- Existing manufacturers and potential entrepreneurs need to carefully consider their position in the network and plan, structure, and develop accordingly.
- Due to increased competition from other emerging economies, the South African government will need to implement more structures to help SMMEs to obtain funding for research, development, and implementation of AM technologies.
- A comprehensive analysis and proposed configurations could not be done due to a lack of industry and tooling operations knowledge; however, any potential user could use the results as a starting point to build and add on.

7.7 Outcomes of the contextual application

The findings and outcomes of the application of the first two sub-phases (analysis and ideation), including the configuration of a possible strategic business net on the strategic level, as well as the formulation of possible configurations for the networked BM elements, have been divided into three sub-categories. The first category highlights where the findings are directly aligned with the content of the research artefacts. The second category contains all the additions to the research artefacts based on the application. The third category summarises where the application highlighted inadequate aspects which required modifications to the research artefacts. The consideration and implementation of the outcomes described in Table 7.7 form part of Design Cycle 6.

Table 7.7: Outcomes after contextual application

	Aspect	Modification
Validations	Management framework	The steps and activities contained in the framework need not necessarily be executed in chronological order.
		Although not all concepts and aspects were addressed iteratively throughout the framework, it is important to iterate through the activities as the process progress and as new knowledge become available to ensure the most relevant information is captured.
	Tools	Some of the proposed tools and templates are not as easy to use theoretically, due to the lack of insight into the business, therefore some of the tools might be more useful in practice than in theory and therefore some steps or activities might need to be more generalised or simplified. For example, value opportunity mapping is difficult to complete if one does not have insight into the business and industry, therefore the activity needs to be more generalised regarding the identification of value opportunities for a potential user that is not comfortable with the proposed tool.
	Networked BM and SBN configuration process	There is indeed a very close interrelationship between the configuration of the strategic business net and the networked BM elements. The configuration of the strategic business net needs to visually depict and portray the networked BM.
		The configuration of the strategic business net must be used by each network partner to focus their own operations and to determine their position in the network as the roles, capabilities and functions fulfilled within the strategic business net, directly correlate to the firm-level BM of each partner.
	SBN configuration process	Without insight into the operations of the business, it is difficult to visualise and map value flow and value exchange on the tactical level. However, these visualisations remain valuable and applicable, as demonstrated in the real-life scenario in Chapter 5 as well as with the two examples regarding the contextual application.
Additions	Activity	The addition of a separate step to ensure alignment between the configuration of the strategic business net and the configuration of the BM elements due to the close interrelationship.
Modifications	SBN configuration process	The modification of the indication of precedence and interrelationships on either level of visualisation, instead of only on the tactical level.
	Concept map of theory	The contextual application confirmed the importance of roles before actors can be allocated. Therefore, within the concept map of theory, the 'roles' and 'actors' labels were switched around.
	Tools	The simplification and generalisation of steps and activities containing tools and templates.
	Management framework	The inclusion of the mapping of the strategic business net in the ideation phase (already modified in the application). It is important to visualise and understand the configuration of the net, before actors are approached, and before BM elements are configured, therefore, changing the mapping to be done in the second stage after roles have been identified, it is easy to later just add the actor names into the configuration, after actors were selected as partners for the network.
	Management framework	Where applicable, changing the steps regarding the 'configuration' of the strategic business net features, to 'consider' the strategic business net features as it was found that for all elements 'possible configurations' were not possible. Instead of explicitly proposing configurations for these features, the features rather need to be carefully considered throughout the application of the networked BMI framework.
		Based on the knowledge obtained from the execution of the first two sub-phases, the activities and steps of other phases were re-evaluated, and the necessary changes were made.

7.8 Conclusion: Chapter 7

This chapter presented the results from the partial application of the first two sub-phases as well as the strategic business net configuration process on a strategic level and the configuration of the networked BM elements for the tungsten carbide based hardmetals AM industry in South Africa. The application of the framework helped to gain more insights into the relevance and applicability of the framework itself, as well as the steps, activities and tools contained within the framework. It was found that the is applicable and relevant to the industry and would prove to be even more valuable if more insight into the industry and business could be used to complete the activities and configurations.

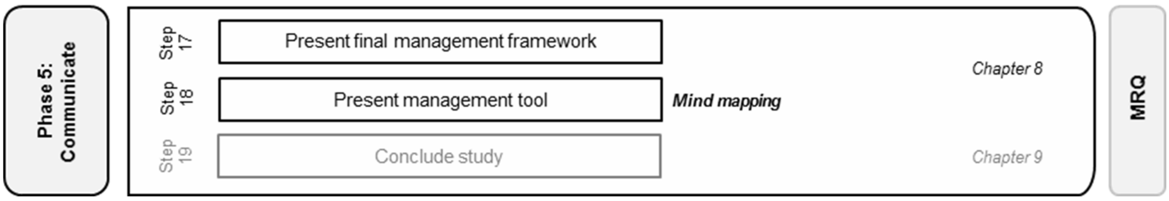
The changes and modifications proposed within this chapter were implemented to complete the last design cycle iteration. The final management framework, as well as the final configurations of the other research artefacts developed throughout this study, are presented in the following chapter. Chapter 8 concludes with the presentation of the management tool which is an interactive representation of the final management framework designed and developed up until this point.

Chapter 8: Management tool

This chapter aims to transform the management framework into a management tool. The aim of the networked BMI process, as well as the management tool, is to support SMMEs to configure strategic business nets and develop appropriate networked BMs in their business transformation process. The focus of this transformation process includes the introduction and adoption of an emerging AM technology in South Africa. A summary of the motivation for the tool's development and its intended purpose is provided. Thereafter, an overview of the development approach is provided together with the final configurations of the various research artefacts, answering the study's main research question. Lastly, the management tool is presented as well as a procedure for facilitating the implementation of the tool.

Chapter 8 key objectives:

- Provide background on the motivation for the tool's development (Section 8.1).
- Present an overview on how the development and evaluation of the management framework (Section 8.2)
- Present the final networked BM elements (Section 8.3).
- Present the final strategic business net features (Section 8.4).
- Present the final networked BMI hierarchical taxonomy (Section 8.5).
- Present the final concept map of theory (Section 8.6).
- Present the final SBN configuration process (Section 8.7).
- Present an overview of the final management framework (Section 8.8).
- Present the management tool (Section 8.9).
- Describe the facilitation process of the tool (Section 8.10).



8.1 Motivation and purpose of the management tool

The Department of Science and Innovation commissioned the development of the National Advanced Manufacturing Technology Strategy for South Africa for the period 2014-2023 to increase the adoption rates of emerging technologies [60]. *"AM for impact on traditional manufacturing sectors"* is identified as one of the four key industrial focus areas of the strategy. The vision of this focus area is to establish advanced AM technology within the traditional manufacturing technology sector. There is a rising need in South Africa to find alternative solutions to manufacturing challenges that require custom solutions, therefore it is imperative to explore the possibility of producing functional components, such as cutting inserts, using AM [232].

The introduction and adoption of these emerging technologies which are associated with I4.0 is however no easy task for SMMEs in South Africa, which make up the largest percentage of the manufacturing sector. These manufacturers face numerous constraints and challenges and cannot compete on their own and are therefore required to form part of collaborative and co-operative VNs, referred to as strategic business nets. Therefore, a need was identified to develop a self-explanatory framework for SMMEs, which contains appropriate processes, steps, activities, tools, and considerations, on how to holistically approach business model innovation from a VN perspective, referred to as networked BMI. This management tool is needed to provide guidance to SMMEs regarding the configuration of strategic business nets that are in line with the networked BM to guide the transformation process when adopting AM into their traditional manufacturing environment.

The proposed tool's purpose is to provide business and management guidance to traditional manufacturing SMMEs or entrepreneurs that want to adopt or implement an AM process (or an emerging technology associated with I4.0) and therefore need to focus on network-level developments. The tool aims to aid in the configuration of the strategic business net and associated networked BM through a semi-structured process. Due to close interactions among various business levels, the tool could not be developed in isolation, and therefore aims to create a holistic view on various aspects to consider (using the identified six development dimensions) when considering or implementing the transformation process. The tool is however not a recipe for success, but rather gives an overview of what needs to happen during the BMI endeavour, from a VN perspective. In line with Wirtz and Daiser [245], the proposed networked BMI process is a blueprint, which needs to be adapted by users according to their specific needs. As this serves as a 'management' tool, the tool's purpose is to facilitate business and management activities that can be conducted in-house without having to pay for external consulting services.

A further important conclusion made by Wirtz and Daiser [245], is the multi-directional character of the BMI process. Instead of being a sequential, unidirectional, standardised procedure, the BMI process is rather a semi-structured flow of activities that need to be matched with the specific requirements of the respective BMI initiative. Thus, it is not an essential prerequisite that each BMI initiative covers each of the BMI process phases. Depending on the requirements of the BMI initiative, some BMI process phases may be passed several times and some not at all. However, the initial planning of the BMI initiative should start with the extensive process, taking into account each possible BMI process phase, and each decision concerning deviations from this plan or upcoming variances from the course of the BMI initiative should always be based on a holistic BMI process perspective. [245]

8.2 Summary of the tool's development approach

The development of the management tool was done systematically and in a stepwise manner, discussed throughout this document. Figure 8.1 below provides an overview of the research process followed. As illustrated, in addition to the management framework, various research artefacts were developed throughout the process, based on the existing knowledge base, which was also continuously considered and modified throughout the study. This section provides a more detailed summary of the development process of the tool based on the various research artefacts.

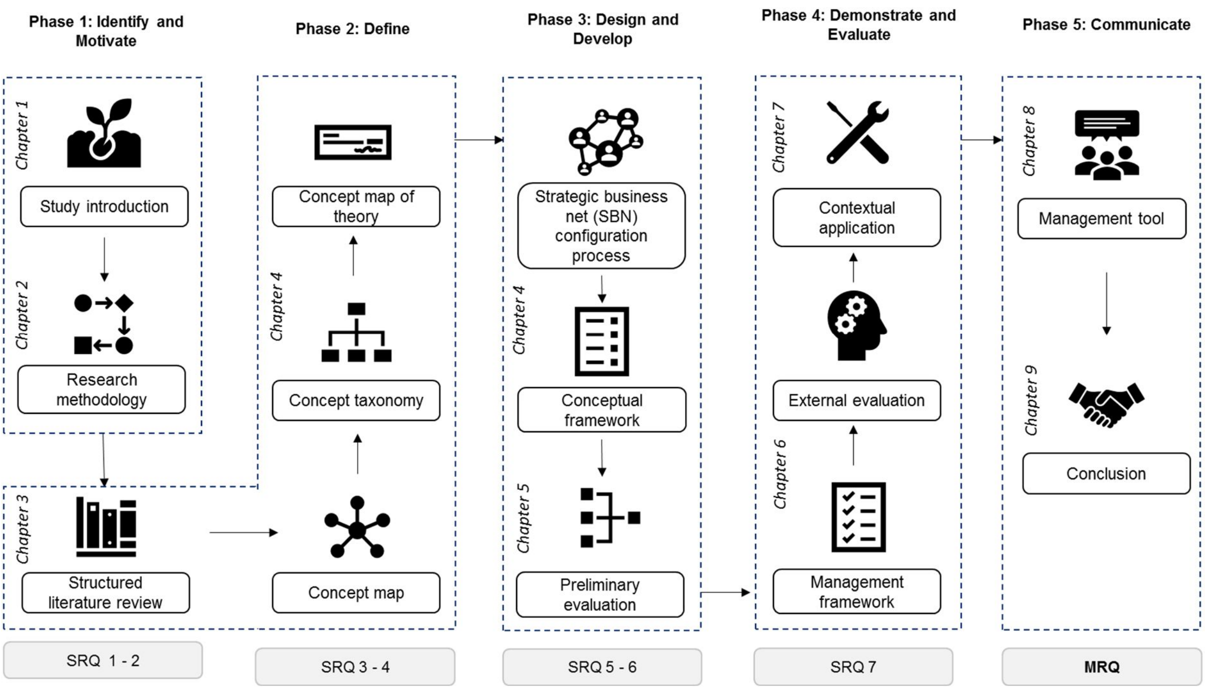


Figure 8.1: Overview of the approach followed throughout this study

The management tool's development is based on the DSR framework and consisted of six design cycle iterations. These iterations comprised of development and evaluation components which respectively draw insight from the application environment (AM, SMME, SA) as well as the central knowledge base (BM, BMI, VN) to ensure the relevance and rigour of the management tool. The relevance of the framework, and consequently the tool, was concerned with the appropriateness, applicability, and implementation potential within the identified application environment. The rigour of the framework, and consequently the tool, was concerned with the grounding of the framework in existing knowledge and the entire research process showing integrity and legitimacy. To support the development and evaluation of the framework, as well as aiding in the rigour thereof, several research methods were incorporated in the six design cycle iterations.

The evaluation component of the design cycles aimed to appraise the relevance, rigour, and utility of the existing elements and activities of the framework which were developed in former design cycles and to adapt these elements and aspects accordingly. The development component consisted of the formulation, design, and building of the framework's elements and activities based on insights gained from the application environment and knowledge base.

To develop the management tool, Figure 8.2 below depicts the information to describe what was developed and/or evaluated in the corresponding design cycles, how the relevance and rigour were established, and what research methods were incorporated in each of the design iterations.

Figure 8.2: Design cycle iterations 1-6

The result of the six design cycles is the final management framework that is converted into the management tool. Before the final framework and management tool is however presented, the final research artefacts are presented and briefly discussed below.

8.3 Final networked BMI hierarchical taxonomy

The initial hierarchical taxonomy presented in Section 4.3 were slightly adapted with the addition of another four development dimensions, as described in Section 4.6. Furthermore, based on the findings and additional knowledge gained throughout this study, the descriptions of each class were adapted and improved. The hierarchical taxonomy aims to provide guidelines and structure (a set of requirements) to the networked BMI concept which were under investigation in this study. Table 8.1 provides the descriptions of the final classes contained in the networked BMI hierarchical taxonomy and Figure 8.3 below visually depicts the final taxonomy.

Table 8.1: Final networked BMI hierarchical taxonomy description

Facet	Class	Description
Networked BM elements	**(1) Value proposition**	A way that demonstrates the business logic of creating value for the end-customer, for each network actor involved, as well as for the strategic business net, through the production and delivering of a joint offering. This includes an overall synergistic view of the actors' bundle of products, services, and knowledge, to satisfy the needs of their target segments.
	(2) Value network	A way in which the entrepreneurial/focal actor configure the net on a strategic level to enable collaborative value exchanges through the coordination of functions and complementary capabilities among the network actors and the customer. It also includes the design, configuration and functioning of the strategic business net in the wider business ecosystem.
	(3) Value architecture	A way that describes the value configuration of the strategic business net on a tactical level, in terms of value exchanges and value flows between roles/actors to complete functions that enable value co-creation in the production and delivering of the joint offering.
	(4) Value finance	A way in which the strategic business net manages the value capture logic related to costing, pricing, and revenue breakdown between network actors to sustain and improve its competitive position. It also includes key metrics to evaluate the performance of the network and individual actors.
Development dimensions	**(5) Business opportunity**	A way to identify possible business opportunities to be pursued by the strategic business net, the development thereof, as well as the selection and prioritisation for short, medium, and long-term realisation.
	(6) Network-level strategy	A way to guide the strategic decision-making process regarding the strategic business net's strategy and the alignment thereof with the configuration of the strategic business net, networked BM, and other aspects.
	(7) Strategic business net	A way to systematically develop and design the strategic business net regarding its configuration, features, value creation levels and performance (including the performance of individual partners).
	(8) Networked BM	A way to systematically consider and develop the identified networked BM elements, categorised into the four value dimensions, and ensuring the alignment thereof with the configuration of the strategic business net, as well as the firm-level business processes.
	(9) Firm-level business	A way to consider high-level aspects pertaining to processes that must happen on the firm-level (either applied to the focal actor or other network partners), although not detailed, it emphasises the connection and alignment of the network-level with the firm-level.

Facet	Class	Description
	(10) (Additive Manufacturing) Technology	A way to systematically consider the development of an emerging technology (in this case AM technology) in line with the development of the networked BM and the strategic business net's configuration to ensure alignment and successful implementation when the technology is commercially ready.
Functions	**(11) Shared mental model**	A way to facilitate the creation of a strategic vision shared by all network actors regarding what the strategic business net aims to achieve.
	(12) Alignment	A conceptual way to facilitate the consideration of alignment issues to ensure configurational fit between development dimensions, aspects, elements, values, and objectives internally and externally.
	(13) Collaboration	A way to establish inter-organisational collaboration (a process in which entities share information, resources, and responsibilities to jointly achieve a common goal), between all network actors to enable value co-creation and the successful delivery of the joint offering.
	(14) Complementarity	A way to ensure the network actor's resources and capabilities are complementarity to each other. It also includes ensuring the value contributions and offerings of partners are complementary to each other.
	(15) Knowledge	An intangible and tactical information/knowledge asset useful in portraying the underlying business logic of the strategic business network and supporting strategic decision-making functions to create and sustain a competitive advantage.
	(16) Synergy	A way value and benefits are created together by the network of actors which are greater than the value that can be created by each actor individually.
BM reach	**(17) Inter-organisational**	The focus is on the interrelationship of the entrepreneurial/focal actor with the other network actors to ensure they share the same mental model to participate in the value co-creation effort to achieve the value proposition.
	(18) Intermediate layer	An interface or a theoretical intermediate layer between both the network's strategy and the firm-level business processes performed by each individual actor.
Modelling principles	**(19) Holistic**	A holistic (but not exhaustive) way to develop a feasible BM and configure a strategic business net to adequately address the business opportunity by considering internal as well as external factors.
	(20) Conceptual	A conceptual tool, an abstraction, and a blueprint of the existing business and VN and/or the future planned business and strategic business net.
	(21) Modular	A modular (or granular) controllable way of designing and evaluating business as the concept is subdivided into manageable elements.
	(22) Structured	A semi-structured and organised flow of activities (or steps) that need to be matched with specific requirements of the respective BMI initiative, to design and develop the constituent elements.
	(23) Dynamic	A dynamic concept as BMI is regarded as a dynamic process. Furthermore, the BM and strategic business net configurations and design change over time reflecting adjustments made according to the internal and external environments.
	(24) Coherent	A coherent way of depicting the logic and operations of a particular strategic business net while entirely taking into consideration the interlinks between its different aspects. This includes the interlinks between aspects within the networked BM, as well as the interlinks between firm-level aspects.

Facet	Class	Description
Mapping levels	**(25) Actors/Roles**	A way to identify the required actors needed to partake in the strategic business net and to analyse their connections (actor bonds), value exchanges and contributions in achieving the value proposition.
	(26) Functions	A way to identify the required functions (including the main functions and sub-functions) and how they are connected to each other (links), performed by the various selected actors, to enable the production and delivering of the joint offering.
	(27) Capabilities	A way to identify the required capabilities that actors need to have to perform the identified functions required to deliver the joint offering.
Value creation levels	**(28) End-customer value**	A way to address customer needs by creating value, monetary and non-monetary, for the end-user, which is strongly related to the value proposition.
	(29) Business value	A way to create value for and help individual actors to maximise their own value through participation in the strategic business net, thus helping them to build value for their own stakeholders.
	(30) Collaborative value	A way to create value for the strategic business net through collaboration, and simultaneously improve the actor's business value. Short-term returns may decrease but long-term returns may increase through proper network positioning.
Systemic development phases	**(31) Sensing**	A way in which threats and opportunities are identified based on internal and external analyses (business, technology, ecosystem, market, customer) and the translation into possible business opportunities ideas and strategies (including the need for a strategic business net and networked BM).
	(32) Seizing	A way in which relevant business opportunities can be operationalised through the systematic development (feasibility and prototyping) of the networked BM, strategic business net elements and possible joint offerings enabled by emerging technologies.
	(33) Transforming	A way in which selected business opportunities are pursued through adequate decision-making and implementation of the decisions to build new competencies and to implement organisational renewal throughout the strategic business net, as well as the continuous development to ensure the sustainability of the networked BM and strategic business net.
Innovation phases	**(34) Research and Development**	A way to consider the innovation phase where the emerging technology, service, and product is developed.
	(35) Pilot	A way to consider the innovation phase where the emerging technology, service, and product is introduced and tested in the market.
	(36) Market	A way to consider the innovation phase where the emerging technology, service, and product is ready for commercial use in emerging markets.

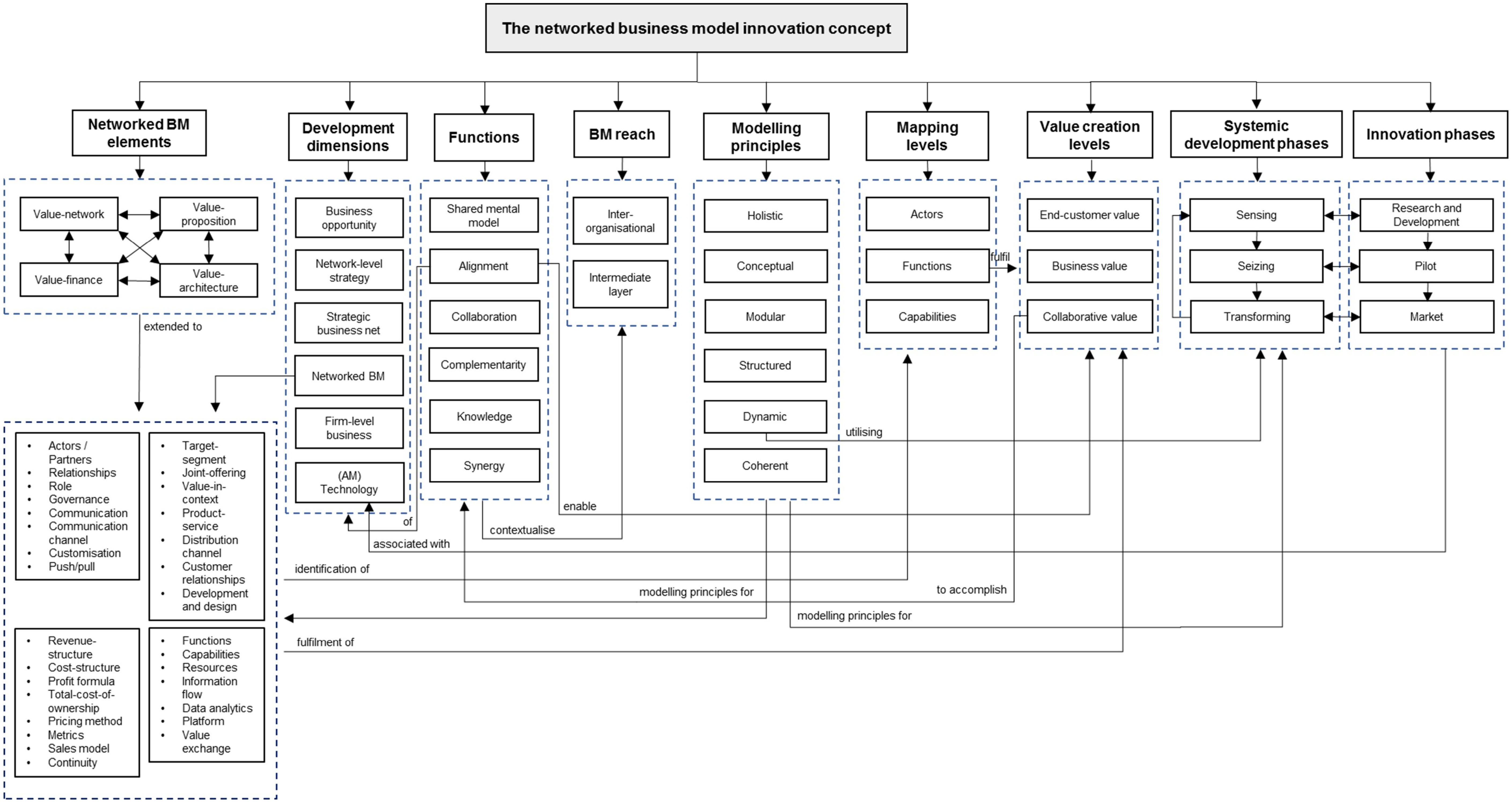


Figure 8.3: Final networked BMI hierarchical taxonomy

8.4 Final networked BM elements

For this study, the view of the BM as a set of linked activities or functions, to explain value creation and value capture [255] (including strategic, market, and customer components [246]) but expanding it to value co-creation [161], where new customer value creation is co-shaped by organisations and other key players [236] to achieve a competitive advantage, was adopted. The initial set of networked BM elements presented in Section 4.2, that formed part of the initial hierarchical taxonomy, were slightly adapted based on the findings made throughout this study. The final set of networked BM elements, divided into the four value dimensions, as presented as part of the final hierarchical taxonomy in the section above, are presented and described in Table 8.2 below.

Table 8.2: Final networked BM elements descriptions

Value dimension	Element	Description
Value network	Actors / Partners	It refers to legal and economic independent entities representing an organisation, company, customer, person, or research institution that partake in the strategic business net.
	Roles	It describes how a specific actor contributes to the fulfilment of a particular function within the strategic business net.
	Relationships	It describes the type of links established between actors within the strategic business net.
	Governance	It refers to who within the strategic business net has control and power over what kind of objects and resources e.g., data, relationships, channels, functions, patents, brands, and transactions. It can either be hierarchical where one or few actors dominate the power or flat where all actors share costs, risks, knowledge, and capabilities more equally.
	Communication	It refers to the exchange of information between actors, functions, or resources through a medium or channel. It also includes determining what must be communicated to whom and when.
	Communication channel	It refers to the communication mediums or ports used to communicate materials and information among actors (including customers) as a result of their established relationships. Channels could be physical or electronic and can range from manual to fully automated.
	Customisation	It refers to how individualised the product-service is (mass production/ mass customisation/ mass individualisation).
	Push/pull	It describes the kind of production paradigm used (pull, on-demand/ push and pull).
Value proposition	Target-segment	It refers to the clustering of the strategic business net's customers into different groups based on shared common properties and characteristics.
	Product-service	It describes the product(s) and service(s) provided to customers which form part of the joint offering produced and delivered by the strategic business net.
	Joint offering	It refers to the total offering provided to the customers, which are created by the group of actors that form part of the strategic business net, including factors such as availability, technical support, quality of service.
	Distribution channel	It refers to how the joint offerings are going to reach the customers.
	Customer relationships	It describes the type of relationship established with customers.

Value dimension	Element	Description
	Development and design	It refers to who develops and designs the products (hired or employed experts/ customer or user designed/ development community or crowdsourcing). It includes who owns the CAD design files and products.
	Value-in-context	It refers to how the value associated with the joint offering is unique in the specific context (closely associated with unique selling points and value-added benefits or value offer to the customers).
Value finance	**Pricing method**	It refers to how different joint offerings delivered by the strategic business net are priced (e.g., fixed, dynamic, or a mixture).
	Revenue structure	It refers to the type of revenue sources utilised, e.g., reselling consumables/ sale/ leasing/ rental partner. It also includes how the profitability of different joint offerings are split among customer segments.
	Total-cost of ownership	It refers to the overall costs with respect to all core arrangements that are needed to create, provide, market, deliver, and maintain the joint offering throughout its lifespan (including development, support, maintenance, collaboration costs).
	Cost structure	It refers to the allocation of costs within the strategic business net.
	Profit formula	It refers to the financial benefit which is realised when revenues gained exceeds that of expenses, costs, and taxes needed to sustain the activities conducted as part of the strategic business net.
	Sales model	It refers to what the customer is paying for (ownership/service delivery or use/ availability or result).
	Continuity	It refers to how continuous the revenues are (once/mixed/continuous).
	Metrics	It refers to the standard measurements to evaluate or measure the profitability and performance of the strategic business net and individual partners.
Value architecture	**Functions**	It refers to the actions performed by the actors within the strategic business net to produce and deliver the joint offering, using different, complementary capabilities and resources, usually motivated by a potential profit.
	Capabilities	It refers to the ability to do something through the integration of knowledge and skills and adapting and flexing to meet future needs, or the fulfilment of future functions which form part of the future strategic business net.
	Resources	It refers to the tangible, static resources that require some action to make them valuable (e.g., people, facilities, equipment, materials, infrastructure, tools), as well as the intangible, dynamic resources that can create value (e.g., knowledge, time, energy, skills, attitude, capacity).
	Information flow	It refers to the flow of timely, real-time, and accurate information (including facts, data, knowledge) between network actors to enable close partnerships, the exploitation of network benefits, and overall network performance.
	Data analytics	It refers to the source of high-value data (internal data/ customer's data).
	Platform	It refers to the kind of digital platform, if any, that forms an essential part of the BM (IoT/ merchant only/ innovation only/ merchant and innovation).
	Value exchange	It refers to the transfer of tangible or intangible values from one actor to another and how the value flow between the functions and actors to enable value co-creation within the strategic business net.

8.5 Final strategic business net features

The focus of this study was on intentionally formed VNs with a finite set of parties that can be partially managed and controlled to be efficient, in this study referred to as *strategic business* *nets*, that aim to collaborate to achieve joint goals. The strategic business net aims to gain or sustain a competitive advantage [154] through collaboration among competitors to increase capacity, co-operation with customers to develop focused competencies, and collaboration with partners that provide access to complementary competencies and resources [103]. The actors involved within these networks co-operate for business strategic development, and the companies involved remain legally and economically independent [103].

The initial set of strategic business net features presented in Section 4.2 were slightly adapted based on the findings made throughout this study. In addition to the elements identified to form part of the value network dimension, these features were selected and included as they need special consideration or attention from the user(s) during the networked BMI endeavour, specifically regarding the formation and functioning of strategic business nets.

Table 8.3: Final strategic business net features descriptions

Strategic business net feature	Description
Boundaries	It refers to which actors are included to participate in the strategic business net as partners, which actors are only classified as potential stakeholders of the strategic business net and which actors are excluded.
Control	It refers to the power of one or more actors to influence or direct other actor's behaviour or the execution of functions or activities within the strategic business net.
Control points	It refers to areas in the strategic business net where power and control can be applied - functional and strategic (the more control points an actor have, the more important are they in the network).
Coordination	It refers to the organisation of the different actors and their roles, functions, capabilities, and resources within the strategic business net to enable collaboration and value co-creation.
Co-operation	It refers to the process of working with other actors towards the same goal.
Culture	Organisational culture refers to the cumulative deposit of knowledge, experience, beliefs, values. The cultures of the respective actors' need to be aligned and adaptable to ensure successful network operation.
Integration	It refers to the integration of the functions, capabilities, and resources of different network actors to deliver the joint offering and to reach the network's goal or objective. It also includes the integration of findings/ outcomes on the network-level into existing firm-level processes and structures.
Management	It refers to the process of dealing with or controlling functions, activities, and actors within the strategic business net.
Mode	It refers to the way in which the network is established and expanded (open/ close).
Power	Power dependence denotes the influencing forces where one actor can partially control and influence another actor, as the other actor needs those resources or competences held by the first actor.
Shared values	Shared values (tacit or explicit) provide a common ground or understanding among different actors.
Trust	It refers to the firm belief in the reliability, truth, or ability of strategic business net actors to fulfil their roles and to successfully perform their functions and activities.

8.6 Final concept map of theory

The initial concept map of theory presented in Section 4.4 was constantly evaluated and critically considered as the study progressed. Figure 8.4 below illustrates the final concept map of theory. A few adjustments were made, including the addition of the four extra development dimensions, and the addition of the innovation development phases associated with emerging technology development. The aim of the concept map of theory is to visually depict on a high-level of abstraction, what the networked BMI concept, as well as the management framework, consist of, through the synthesis of existing theoretical frameworks and models as well as a few additions as suggested by this study. A brief, overview description of the concept map of theory is presented below.

The concept map of theory consists of three systemic development phases namely *sensing, seizing and transforming* (or reconfiguring) [184, 219], which need to be aligned with each of the innovation development phases [177] namely *research and development, pilot and market phase.* This alignment ensures the simultaneous development of the networked BM with the associated strategic business net and the development of the emerging technology. Furthermore, each of the dynamic capability main phases is divided into sub-phases from the Generic BMI Process proposed by Wirtz and Daiser [245] to make it more structured and tangible. Thus, the sensing phase consists of *analysis and ideation*; the seizing phase consists of *feasibility and prototyping*, and the transforming phase consists of *decision-making, implementation, and sustainability.*

The networked BMI concept consists of six development dimensions that constantly needs to be aligned throughout the development phases. Two of the development dimensions were proposed by Palo and Tähtinen [177] as networked BM development dimensions, namely *strategic business net* development (adapted from strategic net development) which refers to the development of the configuration of the strategic business net, and the *business opportunity* development dimension which refers to the identification and development of possible opportunities to be pursued by the strategic business net.

To ensure a more structured and logical approach, another four development dimensions were added to the networked BMI concept. The first dimension includes the *networked BM* perse, adapted from Palo and Tähtinen [177], which refers to the development and configuration of the selected networked BM elements. The next development dimension, *network-level strategy*, refers to the development of concepts related to the strategy of the business net, which is on the strategic level of the network. The *firm-level business* development dimension and *AM technology* dimension refer to the operational view of the network and refers to the development of some high-level aspects and elements by network partners on the firm-level, including the development of the technology which is closely related and aligned with the innovation development phases. Therefore, these innovation phases which were previously not explicitly included (Section 4.4), are now forming part of the final concept map of theory.

From a VN perspective, the combination of these six development dimensions enables a strategic (*business opportunity* and *network-level strategy* dimensions), tactical (*networked BM* and *strategic business net* dimensions), and operational (*firm-level business* and *AM technology* dimensions) view of the strategic business net [201], with the primary focus on the tactical level. Furthermore, there are constant interactions and feedback between the steps, activities and outcomes associated with each dimension to ensure alignment and successful development. This alignment aims to include internal firm-level alignment, referring strategy, BM, business process and IT alignment [6, 59], internal network-level alignment, referring to alignment between the network-level BM and firm-level BMs and between all the firm-level BMs [59], and external alignment, referring to alignment with the customer needs, stakeholder priorities, and the external environment [209, 216].

Possible business opportunities can be identified through the analysis and understanding of the external environment. Different types of innovation have a direct impact on the environment and cause different trends and constant changes. The continuous development and improvement of technology is a main driver of innovation and provides new business opportunities which are associated with new product and service offerings. Furthermore, it is important that any business opportunity identified based on the analysis of the external environment (or based on internal analysis) must be aligned with the identified customer needs. In order to realise the business opportunity, a networked BM must be developed (part of the *networked BM* development dimension) that consist of four high-level value dimensions namely, the *value network, value proposition, value architecture and value finance* [7] with the constituent elements discussed in Section 8.4.

The business opportunity can however not be pursued and delivered by the focal (or entrepreneurial) actor alone, but a collaborative effort from various actors or partners is needed. Therefore, a strategic business net is required which is an intentionally formed VN. Within this strategic business net, the entrepreneur actor(s) can act as facilitators within the network, as they identify and create business opportunities [177]. The design and configuration of the strategic net need to be mapped on the strategic level (associated with the *value network* value dimension) using the three identified mapping levels (*roles, functions, and capabilities*) [22, 95]. Roles are fulfilled by specific *actors* in the strategic business net and therefore there is constant interaction between actors and roles. Functions are used on a higher abstraction level but consist of various *activities*; and then lastly capabilities that actors must have to fulfil the functions, are associated with tangible and intangible *resources* (part of the *strategic business net* development dimension).

To better enable the visualisation and understanding of how value is co-created between the *focal (entrepreneurial) actor*, the *customer* and other *network actors*, a lower (tactical) level of visualisation are needed. This visualisation effort is associated with the *value architecture* value dimension and refer to the mapping of the different *tangible and intangible values* that are exchanged between the network actors to fulfil each function. Tangible values include products, materials, natural resources, and money. Intangible values include knowledge, information, services, skills, and competencies. The successful development and implementation of a networked BM, as well as a strategic business net, will enable the production of a *joint offering* and include additional offerings such as flexibility, quality, and accessibility in addition to the product and service. Visualising and mapping the strategic business net on the strategic (value network) level as well as the tactical (value architecture) level, together forms the strategic business net.

The functions fulfilled by the actors to create the joint offering and the *value exchanges* between the different actors must create value, otherwise, it is nullified. Therefore, the perceived value must be evaluated. The value perceived can be in different levels for different actors namely *business value* (for an individual actor), *collaborative value* (for the network) and *end-customer value* (for the customer) [134]. Value conversion is only completed when the value offered by any role on any level is accepted or validated by another role in the VN [12], therefore the importance to evaluate the perceived value at the end to ensure value conversion was successful.

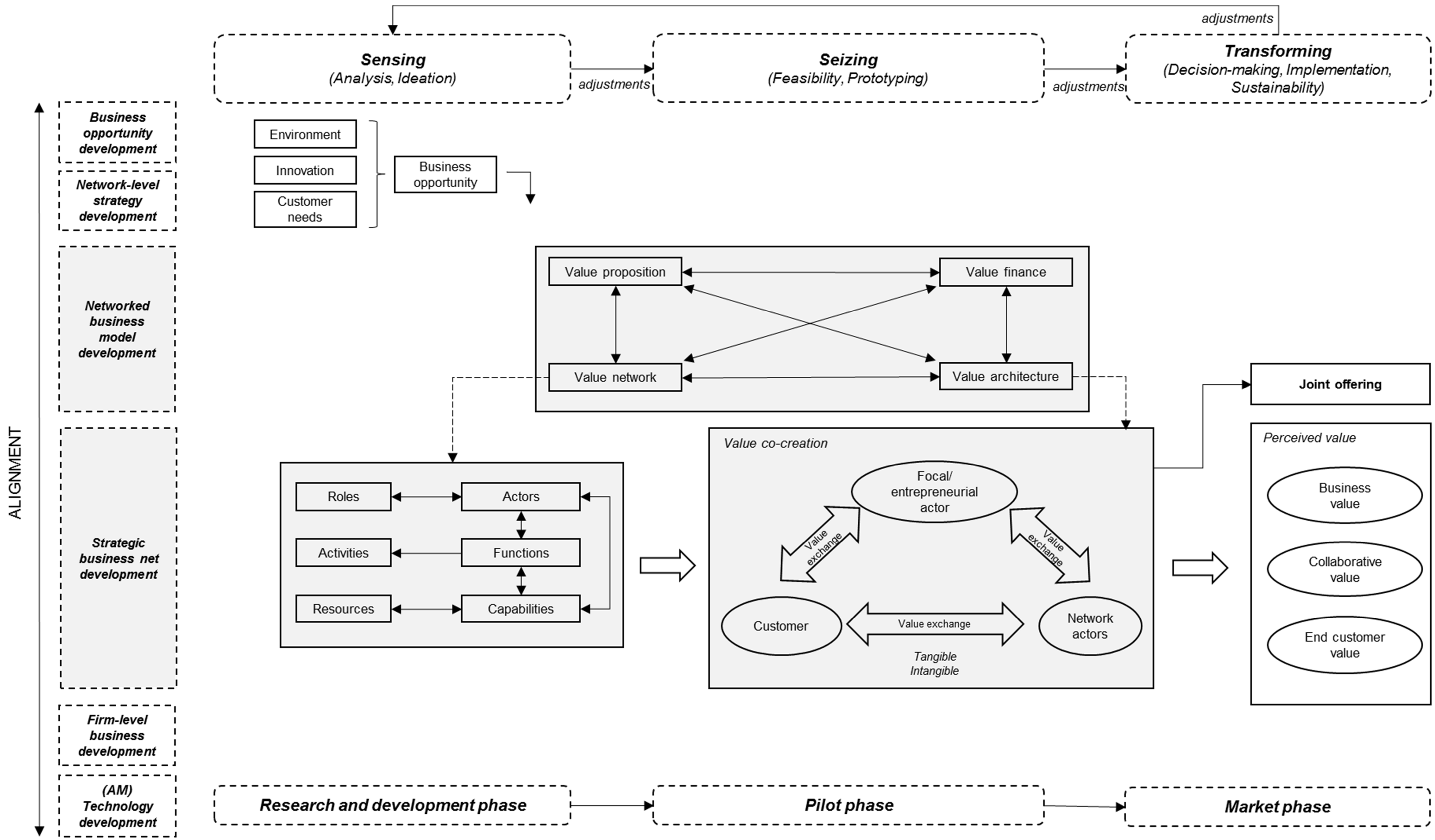


Figure 8.4: Final concept map of theory

8.7 Final SBN configuration process

Since the networked BM was viewed as a set of linked activities or functions, to explain value creation and value capture [255] for the strategic business net, viewed as an intentionally formed VN with a finite set of parties that can be partially managed and controlled to be efficient, that aim to collaborate to achieve joint goals, it was important to help users to easily link these two concepts (as their configurations directly influences each other) through a VN visualisation tool. As stated in Section 7.7, the configuration of the strategic business net needs to visually depict and portray the networked BM. Therefore, the SBN configuration process was developed to fulfil this role, and to address the identified gap in the literature body regarding network visualisation on a strategic and tactical levels.

Based on the findings and observations made during the evaluation and application of the proposed SBN configuration process, a few changes and additions were made to the process proposed in Section 5.2. Figure 8.5 below propose the final SBN configuration process, consisting of 12 guiding steps. These steps are incorporated into the management framework and management tool to map the current VN, as well as the future strategic business net, but can also be used as a separate management tool.

The first steps (steps 1-6) guide the user to identify the functions, capabilities and roles or actors associated with the current or future strategic business net, as well as to map the business net on the strategic level. Since the mapping process might take time, it is proposed to first use and revise the tables before the mapping (visualisation) is done to save time. Regarding step 6, it was found that it might sometimes be necessary to map an actor or role's involvement (providing knowledge or information for instance) in a function, without allocating any specific capabilities to the actor or role to just indicate involvement. Therefore, actor or roles may be mapped to a function, without associated capabilities per se.

The second group of steps (steps 7-11) guide the user to analyse and map each function individually regarding the value exchange and flow needed among the actors to fulfil the function. And lastly, step 12 involves the mapping of precedence and interrelationships, which may be done on either the strategic or tactical level of the business net.

STRATEGIC BUSINESS NET CONFIGURATION PROCESS

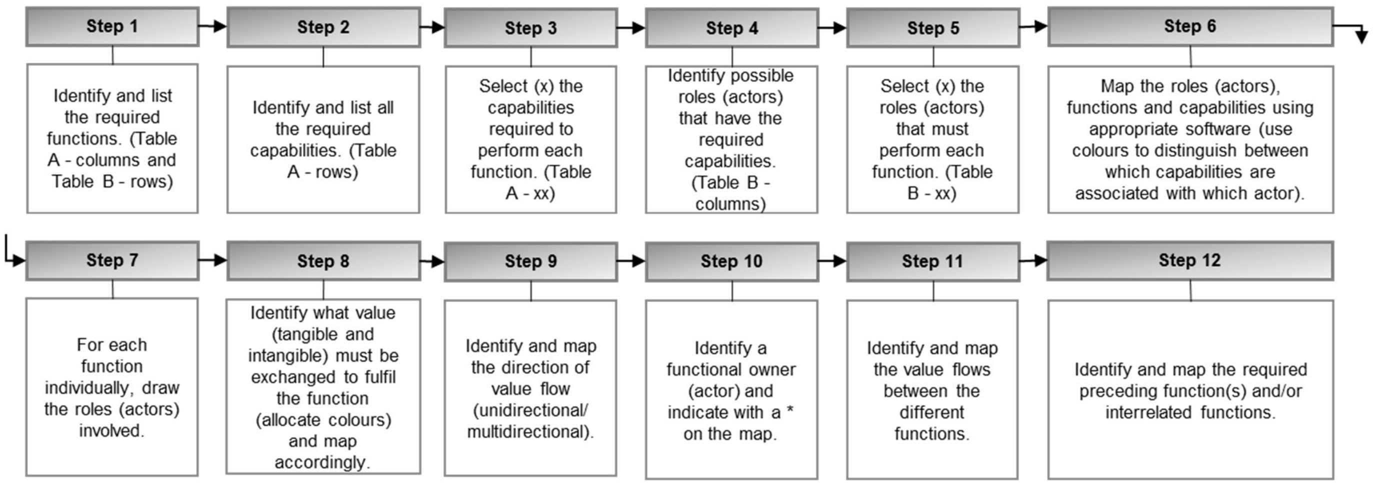


Table A: Function - Capability

	Function 1	Function 2	Function 3	Function 4
Capability a	x	x		
Capability b	x	x	x	
Capability c	x			x
Capability d			x	x

Table B: Role (Actor) - Function

	Role (Actor A)	Role (Actor B)	Role (Actor C)	Role (Actor D)
Function 1	x	x		x
Function 2		x	x	
Function 3	x	x		
Function 4			x	x

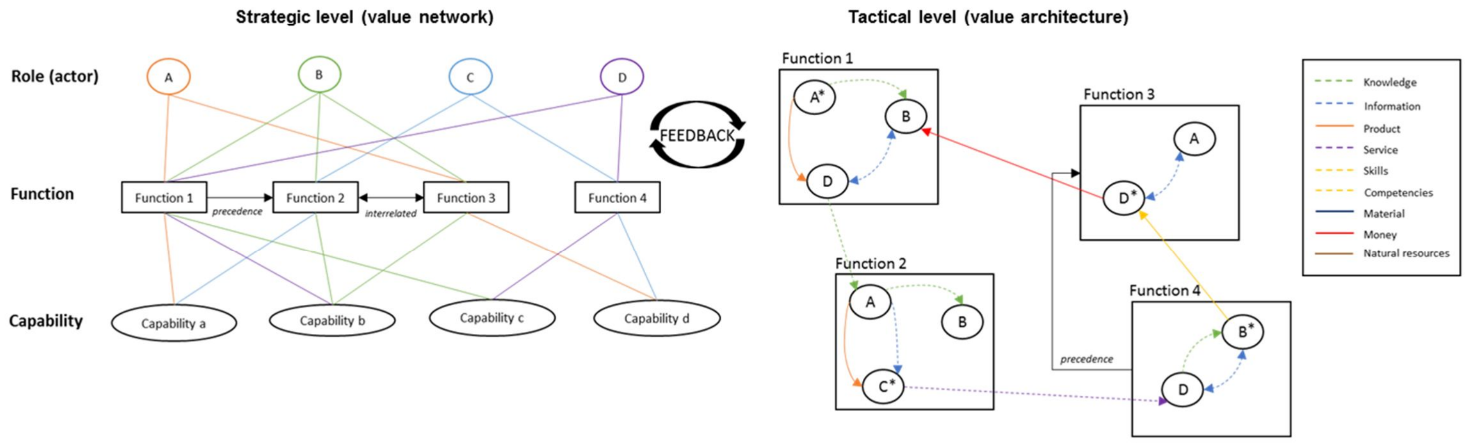
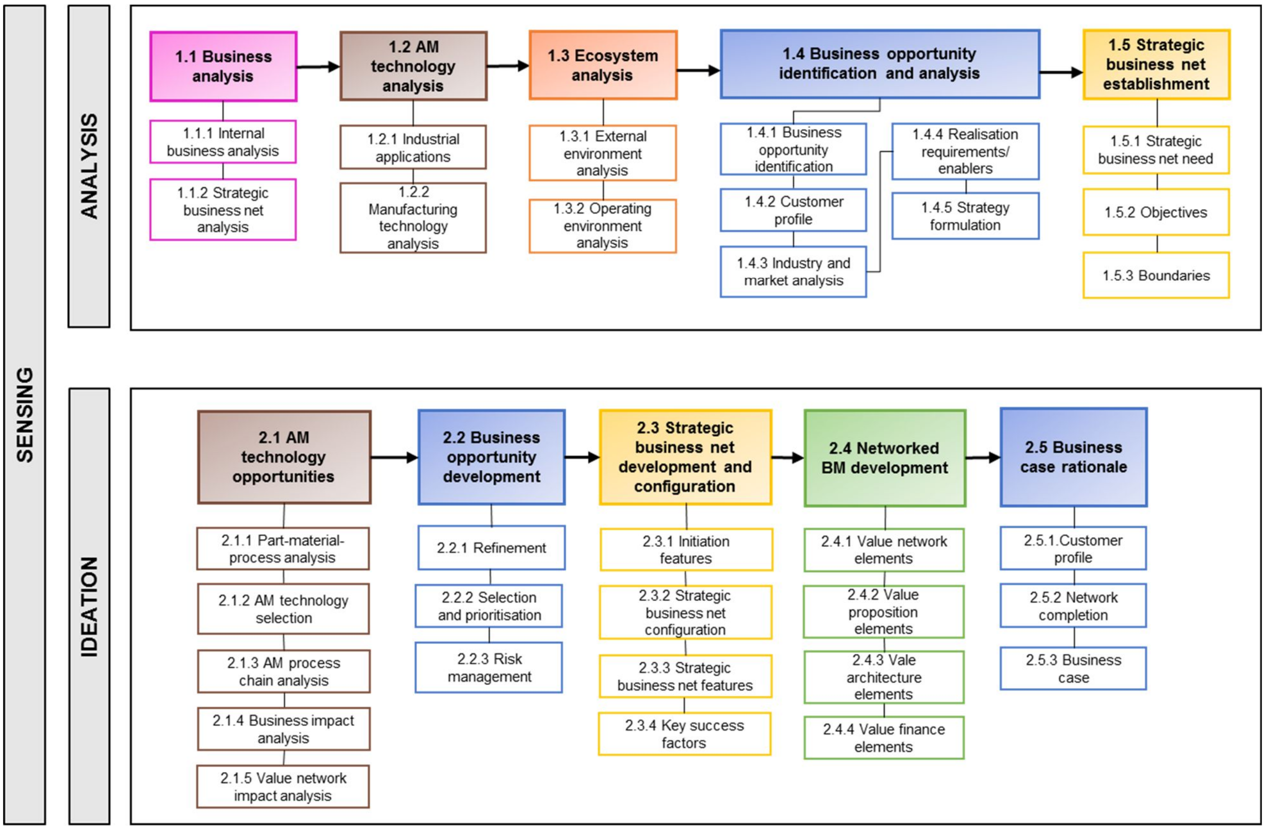
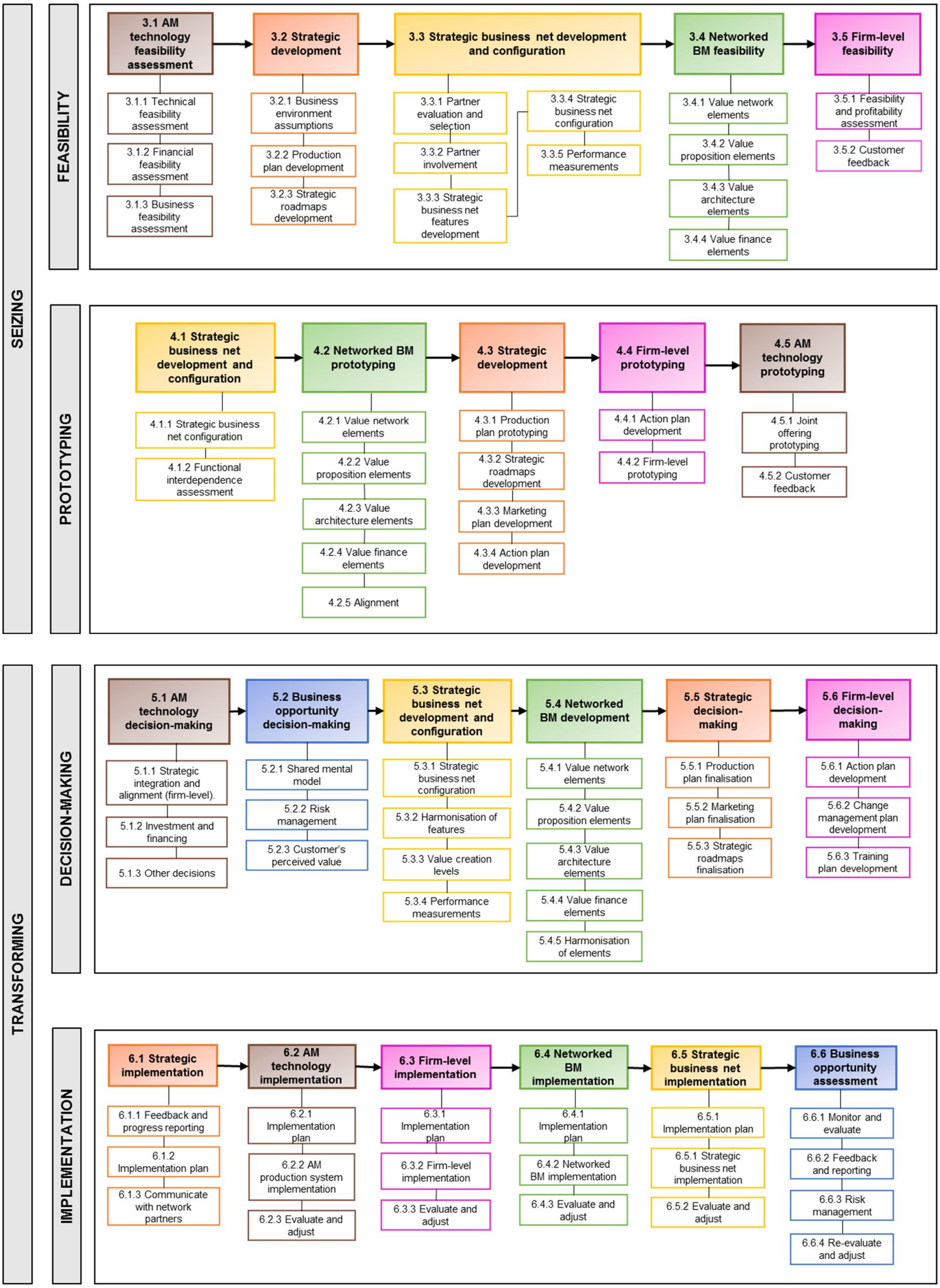


Figure 8.5: Final SBN configuration process

8.8 Part E-8: Final management framework

Throughout this study, the management framework was systematically developed and evaluated. The following section presents the overview of the final management framework, consisting of the key steps and activities. A high-level overview is presented in Figure 8.6, followed by an overview of the activities in Figure 8.7 and the presentation of the seven sub-phases. The detail of the final management framework, containing the guidelines and considerations is presented in Appendix F.




SEIZING
FEASIBILITY
3.1 AM technology feasibility assessment
3.1.1 Technical feasibility assessment
3.1.2 Financial feasibility assessment
3.1.3 Business feasibility assessment
3.2 Strategic development
3.2.1 Business environment assumptions
3.2.2 Production plan development
3.2.3 Strategic roadmaps development
3.3 Strategic business net development and configuration
3.3.1 Partner evaluation and selection
3.3.2 Partner involvement
3.3.3 Strategic business net features development
3.3.4 Strategic business net configuration
3.3.5 Performance measurements
3.4 Networked BM feasibility
3.4.1 Value network elements
3.4.2 Value proposition elements
3.4.3 Value architecture elements
3.4.4 Value finance elements
3.5 Firm-level feasibility
3.5.1 Feasibility and profitability assessment
3.5.2 Customer feedback
PROTOTYPING
4.1 Strategic business net development and configuration
4.1.1 Strategic business net configuration
4.1.2 Functional interdependence assessment
4.2 Networked BM prototyping
4.2.1 Value network elements
4.2.2 Value proposition elements
4.2.3 Value architecture elements
4.2.4 Value finance elements
4.2.5 Alignment
4.3 Strategic development
4.3.1 Production plan prototyping
4.3.2 Strategic roadmaps development
4.3.3 Marketing plan development
4.3.4 Action plan development
4.4 Firm-level prototyping
4.4.1 Action plan development
4.4.2 Firm-level prototyping
4.5 AM technology prototyping
4.5.1 Joint offering prototyping
4.5.2 Customer feedback
TRANSFORMING
DECISION-MAKING
5.1 AM technology decision-making
5.1.1 Strategic integration and alignment (firm-level).
5.1.2 Investment and financing
5.1.3 Other decisions
5.2 Business opportunity decision-making
5.2.1 Shared mental model
5.2.2 Risk management
5.2.3 Customer's perceived value
5.3 Strategic business net development and configuration
5.3.1 Strategic business net configuration
5.3.2 Harmonisation of features
5.3.3 Value creation levels
5.3.4 Performance measurements
5.4 Networked BM development
5.4.1 Value network elements
5.4.2 Value proposition elements
5.4.3 Value architecture elements
5.4.4 Value finance elements
5.4.5 Harmonisation of elements
5.5 Strategic decision-making
5.5.1 Production plan finalisation
5.5.2 Marketing plan finalisation
5.5.3 Strategic roadmaps finalisation
5.6 Firm-level decision-making
5.6.1 Action plan development
5.6.2 Change management plan development
5.6.3 Training plan development
IMPLEMENTATION
6.1 Strategic implementation
6.1.1 Feedback and progress reporting
6.1.2 Implementation plan
6.1.3 Communicate with network partners
6.2 AM technology implementation
6.2.1 Implementation plan
6.2.2 AM production system implementation
6.2.3 Evaluate and adjust
6.3 Firm-level implementation
6.3.1 Implementation plan
6.3.2 Firm-level implementation
6.3.3 Evaluate and adjust
6.4 Networked BM implementation
6.4.1 Implementation plan
6.4.2 Networked BM implementation
6.4.3 Evaluate and adjust
6.5 Strategic business net implementation
6.5.1 Implementation plan
6.5.1 Strategic business net implementation
6.5.2 Evaluate and adjust
6.6 Business opportunity assessment
6.6.1 Monitor and evaluate
6.6.2 Feedback and reporting
6.6.3 Risk management
6.6.4 Re-evaluate and adjust

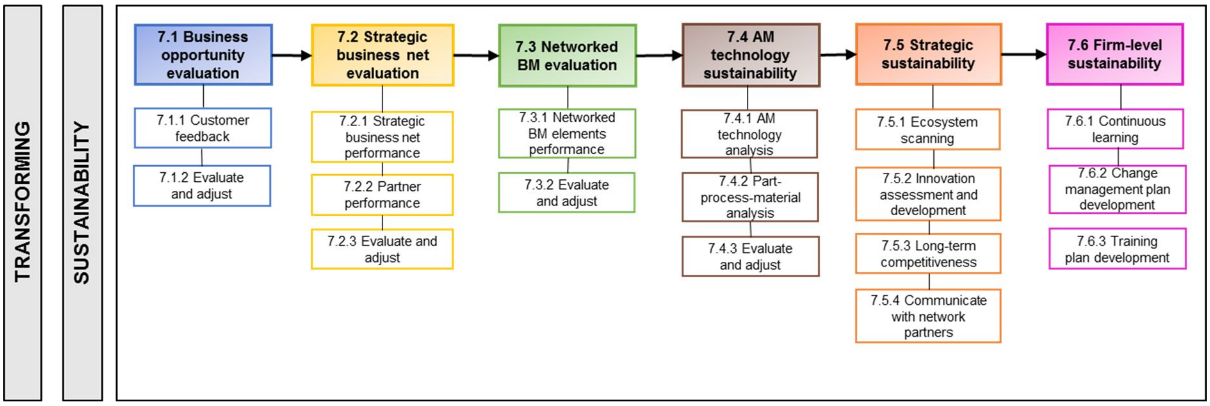


Figure 8.6: High-level overview of the final management framework

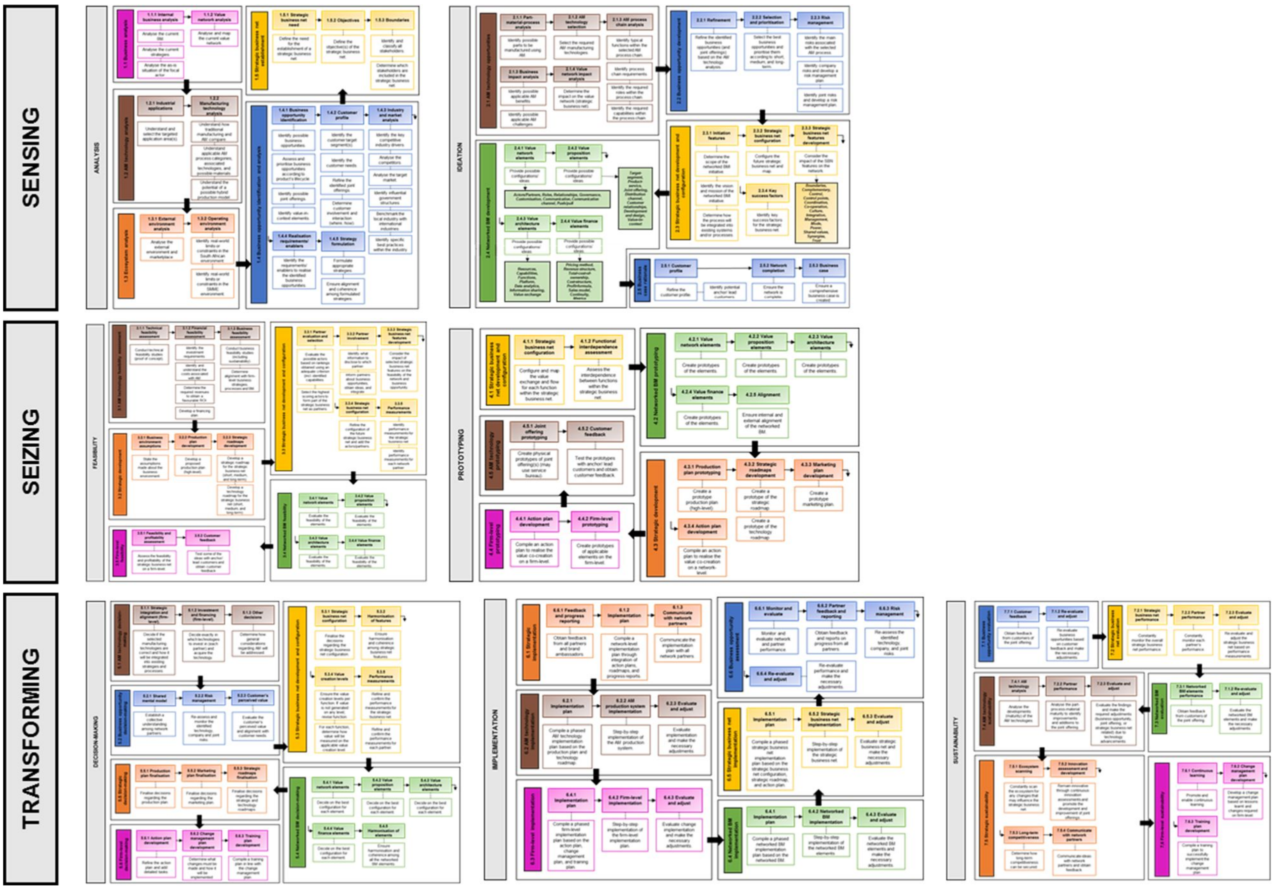
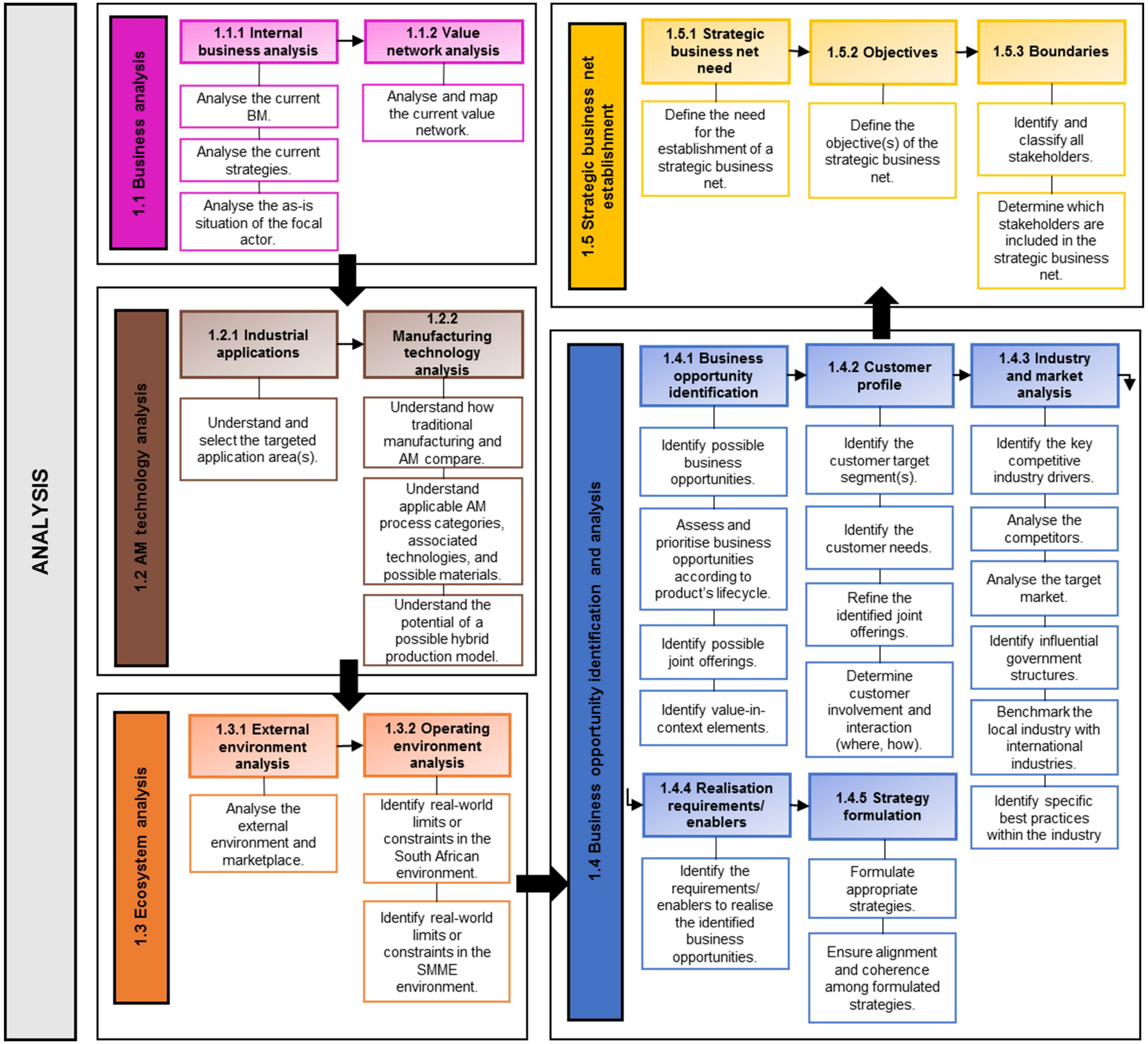
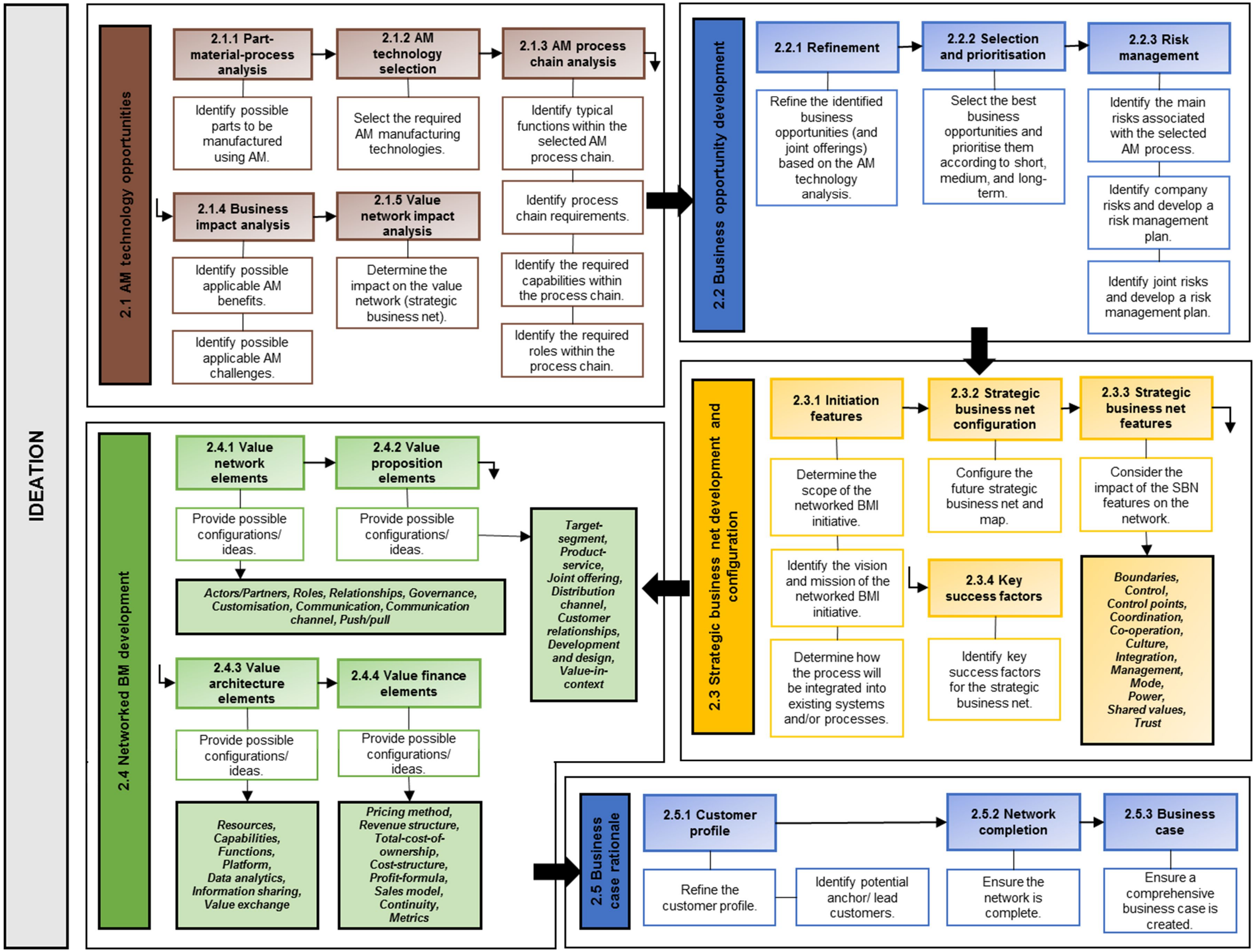
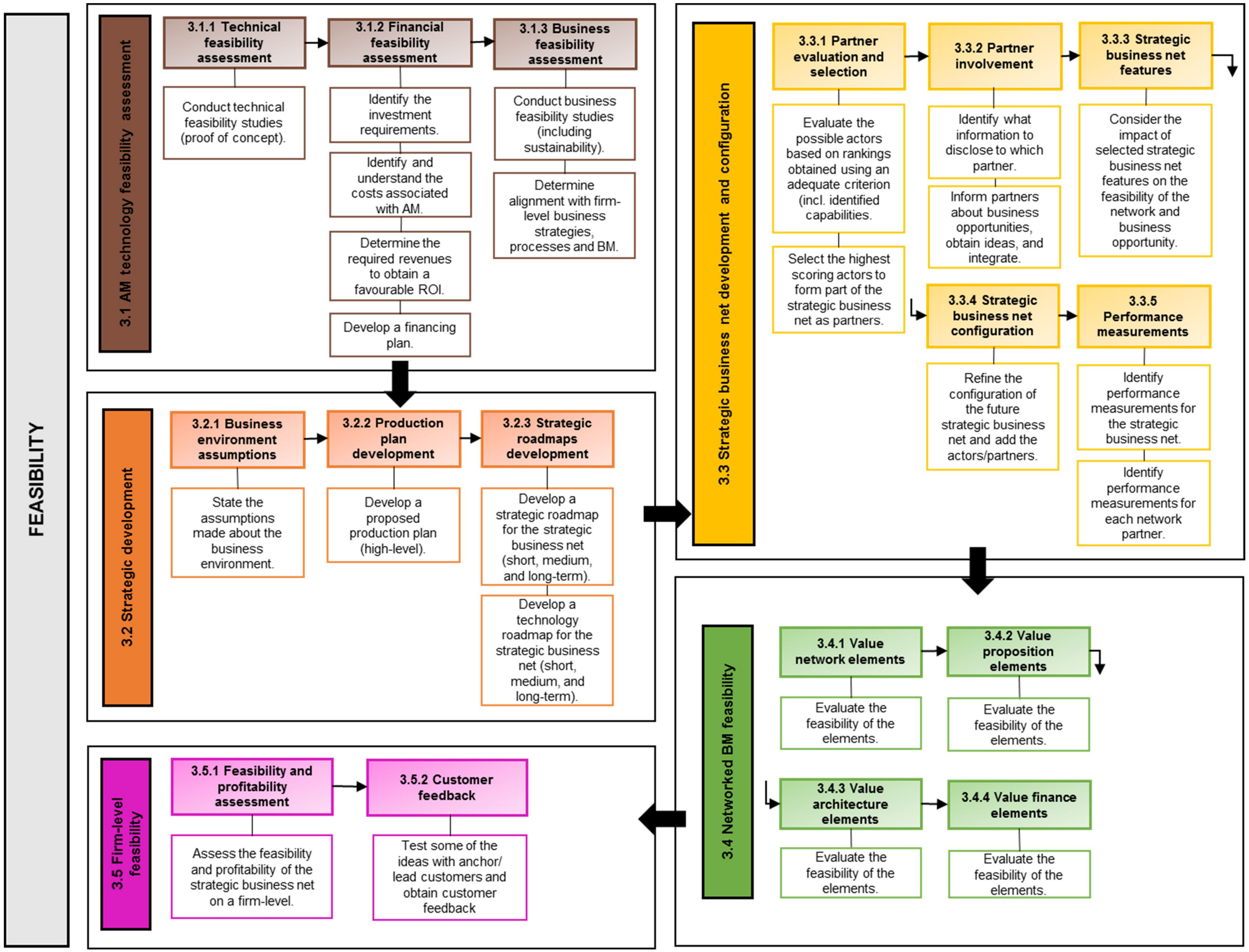
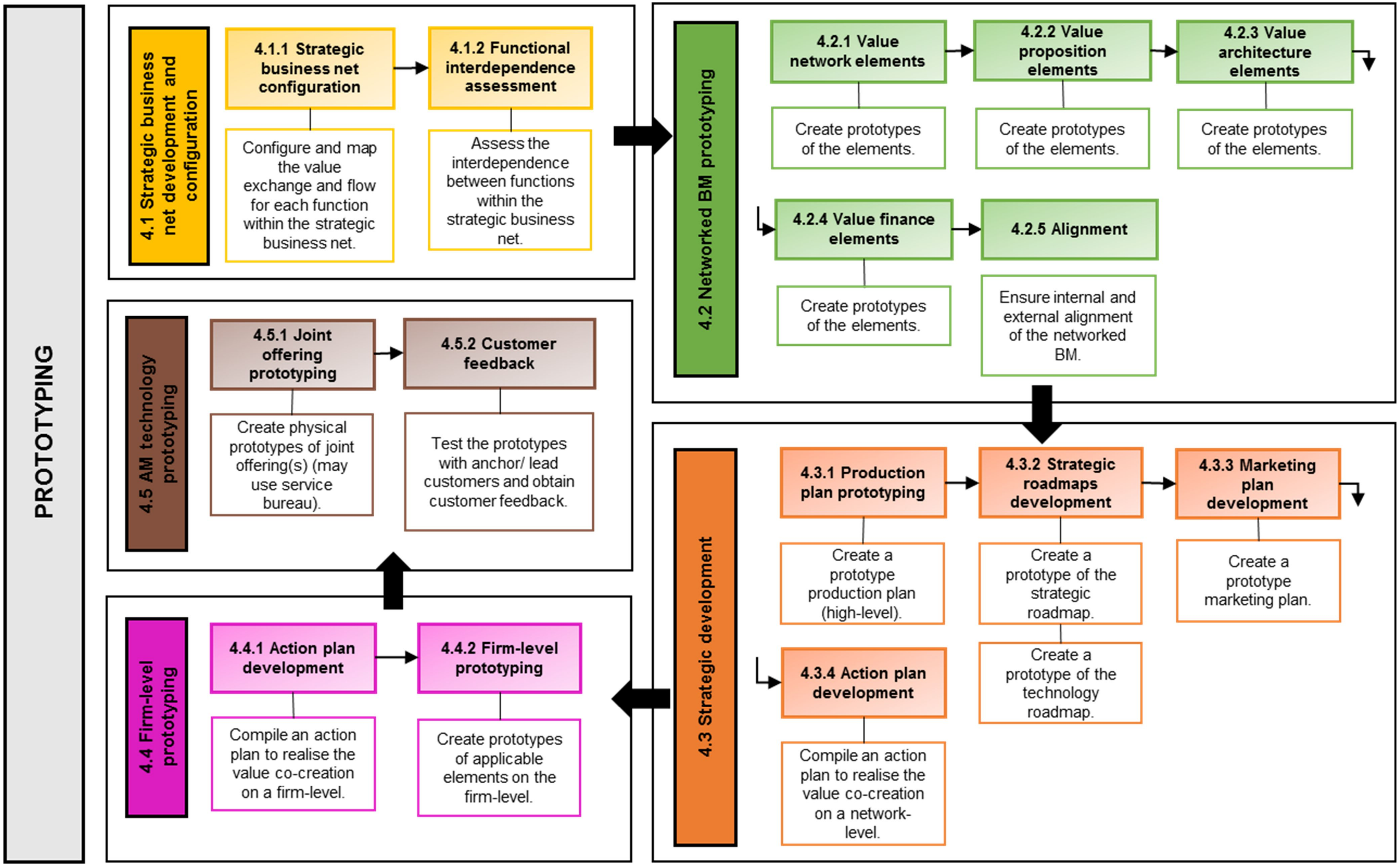


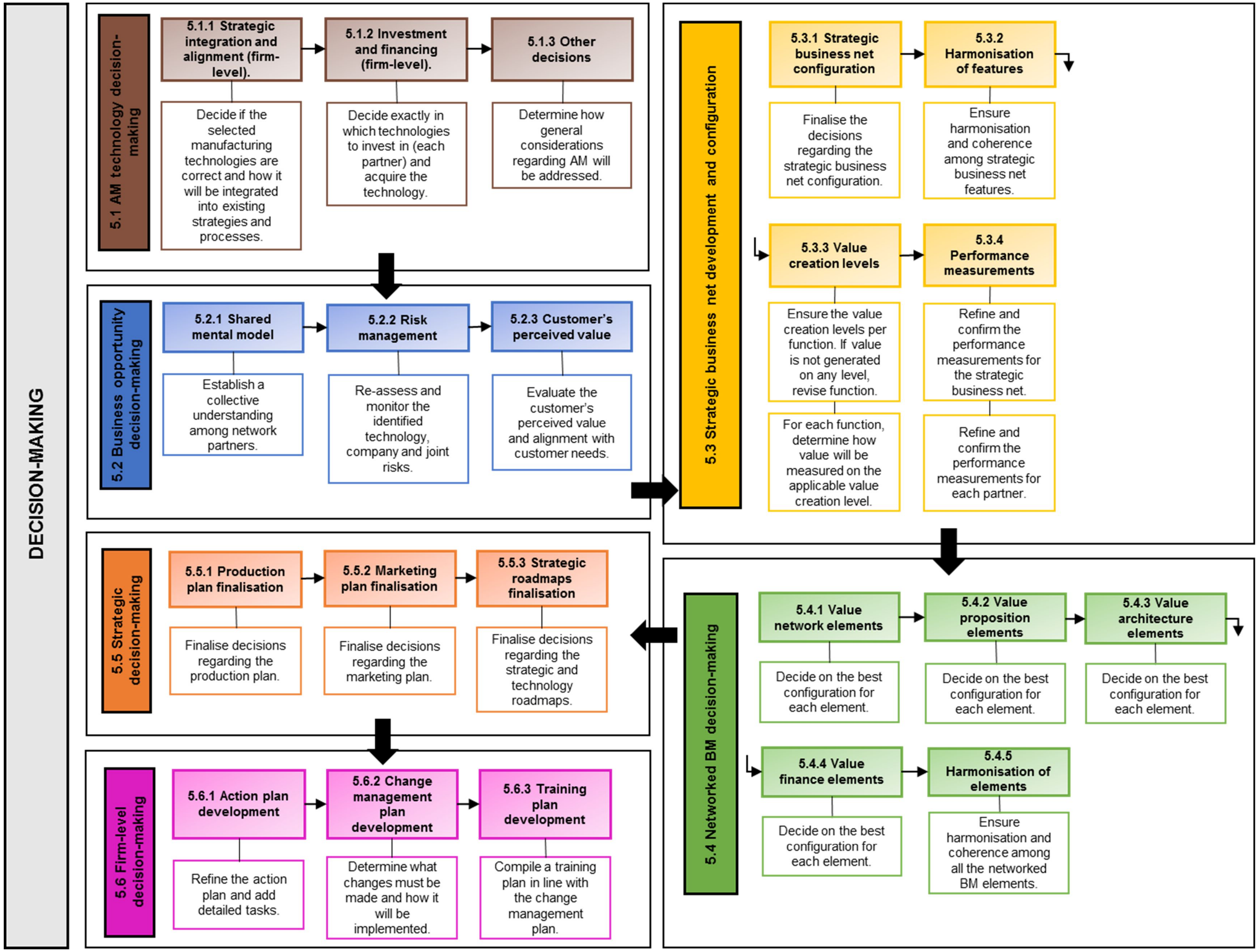
Figure 8.7: Overview of the phases and sub-phases of the final management framework


ANALYSIS
1.1 Business analysis
1.1.1 Internal business analysis
Analyse the current BM.
Analyse the current strategies.
Analyse the as-is situation of the focal actor.
1.1.2 Value network analysis
Analyse and map the current value network.
1.2 AM technology analysis
1.2.1 Industrial applications
Understand and select the targeted application area(s).
1.2.2 Manufacturing technology analysis
Understand how traditional manufacturing and AM compare.
Understand applicable AM process categories, associated technologies, and possible materials.
Understand the potential of a possible hybrid production model.
1.3 Ecosystem analysis
1.3.1 External environment analysis
Analyse the external environment and marketplace.
1.3.2 Operating environment analysis
Identify real-world limits or constraints in the South African environment.
Identify real-world limits or constraints in the SMME environment.
1.4 Business opportunity identification and analysis
1.4.1 Business opportunity identification
Identify possible business opportunities.
Assess and prioritise business opportunities according to product's lifecycle.
Identify possible joint offerings.
Identify value-in-context elements.
1.4.2 Customer profile
Identify the customer target segment(s).
Identify the customer needs.
Refine the identified joint offerings.
Determine customer involvement and interaction (where, how).
1.4.3 Industry and market analysis
Identify the key competitive industry drivers.
Analyse the competitors.
Analyse the target market.
Identify influential government structures.
Benchmark the local industry with international industries.
Identify specific best practices within the industry
1.4.4 Realisation requirements/ enablers
Identify the requirements/ enablers to realise the identified business opportunities.
1.4.5 Strategy formulation
Formulate appropriate strategies.
Ensure alignment and coherence among formulated strategies.
1.5 Strategic business net establishment
1.5.1 Strategic business net need
Define the need for the establishment of a strategic business net.
1.5.2 Objectives
Define the objective(s) of the strategic business net.
1.5.3 Boundaries
Identify and classify all stakeholders.
Determine which stakeholders are included in the strategic business net.

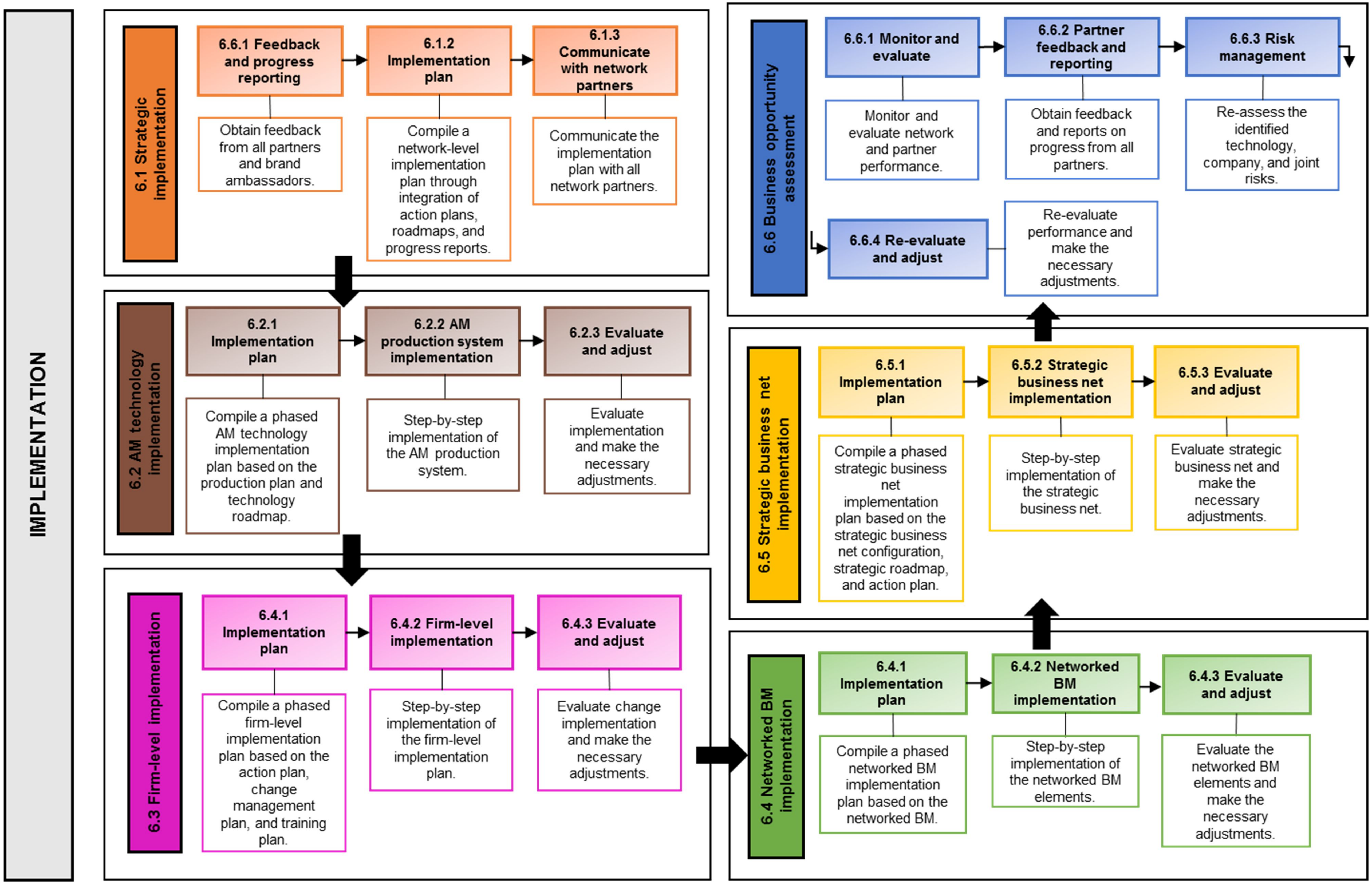

IDEATION
2.1 AM technology opportunities
2.1.1 Part-material-process analysis
Identify possible parts to be manufactured using AM.
2.1.2 AM technology selection
Select the required AM manufacturing technologies.
2.1.3 AM process chain analysis
Identify typical functions within the selected AM process chain.
Identify process chain requirements.
Identify the required capabilities within the process chain.
Identify the required roles within the process chain.
2.1.4 Business impact analysis
Identify possible applicable AM benefits.
Identify possible applicable AM challenges.
2.1.5 Value network impact analysis
Determine the impact on the value network (strategic business net).
2.2 Business opportunity development
2.2.1 Refinement
Refine the identified business opportunities (and joint offerings) based on the AM technology analysis.
2.2.2 Selection and prioritisation
Select the best business opportunities and prioritise them according to short, medium, and long-term.
2.2.3 Risk management
Identify the main risks associated with the selected AM process.
Identify company risks and develop a risk management plan.
Identify joint risks and develop a risk management plan.
2.3 Strategic business net development and configuration
2.3.1 Initiation features
Determine the scope of the networked BMI initiative.
Identify the vision and mission of the networked BMI initiative.
Determine how the process will be integrated into existing systems and/or processes.
2.3.2 Strategic business net configuration
Configure the future strategic business net and map.
2.3.3 Strategic business net features
Consider the impact of the SBN features on the network.
Boundaries, Control, Control points, Coordination, Co-operation, Culture, Integration, Management, Mode, Power, Shared values, Trust
2.3.4 Key success factors
Identify key success factors for the strategic business net.
2.4 Networked BM development
2.4.1 Value network elements
Provide possible configurations/ ideas.
2.4.2 Value proposition elements
Provide possible configurations/ ideas.
Target-segment, Product-service, Joint offering, Distribution channel, Customer relationships, Development and design, Value-in-context
Actors/Partners, Roles, Relationships, Governance, Customisation, Communication, Communication channel, Push/pull
2.4.3 Value architecture elements
Provide possible configurations/ ideas.
Resources, Capabilities, Functions, Platform, Data analytics, Information sharing, Value exchange
2.4.4 Value finance elements
Provide possible configurations/ ideas.
Pricing method, Revenue structure, Total-cost-of-ownership, Cost-structure, Profit-formula, Sales model, Continuity, Metrics
2.5 Business case rationale
2.5.1 Customer profile
Refine the customer profile.
Identify potential anchor/ lead customers.
2.5.2 Network completion
Ensure the network is complete.
2.5.3 Business case
Ensure a comprehensive business case is created.

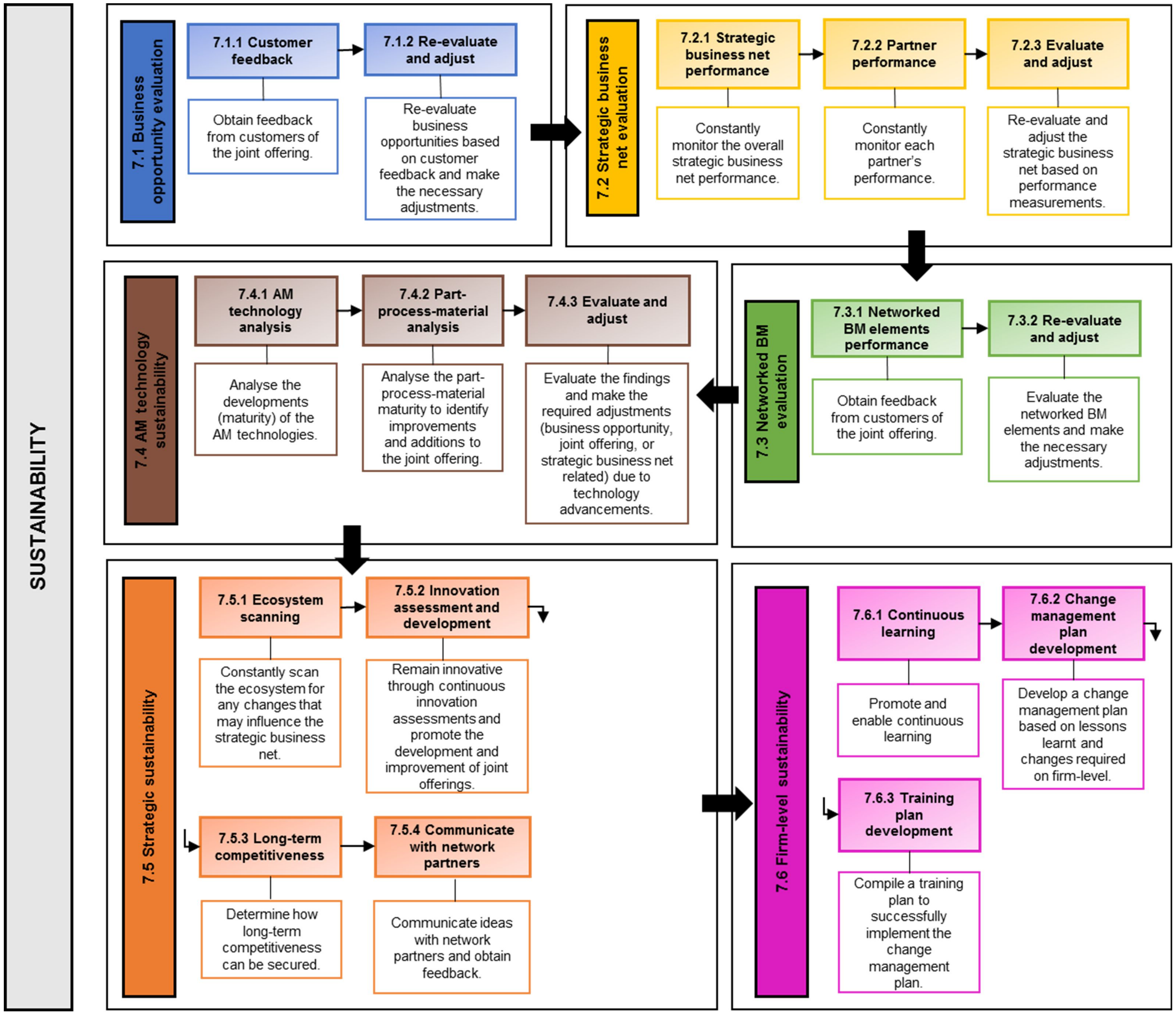

FEASIBILITY
3.1 AM technology feasibility assessment
3.1.1 Technical feasibility assessment
Conduct technical feasibility studies (proof of concept).
3.1.2 Financial feasibility assessment
Identify the investment requirements.
Identify and understand the costs associated with AM.
Determine the required revenues to obtain a favourable ROI.
Develop a financing plan.
3.1.3 Business feasibility assessment
Conduct business feasibility studies (including sustainability).
Determine alignment with firm-level business strategies, processes and BM.
3.2 Strategic development
3.2.1 Business environment assumptions
State the assumptions made about the business environment.
3.2.2 Production plan development
Develop a proposed production plan (high-level).
3.2.3 Strategic roadmaps development
Develop a strategic roadmap for the strategic business net (short, medium, and long-term).
Develop a technology roadmap for the strategic business net (short, medium, and long-term).
3.3 Strategic business net development and configuration
3.3.1 Partner evaluation and selection
Evaluate the possible actors based on rankings obtained using an adequate criterion (incl. identified capabilities.
Select the highest scoring actors to form part of the strategic business net as partners.
3.3.2 Partner involvement
Identify what information to disclose to which partner.
Inform partners about business opportunities, obtain ideas, and integrate.
3.3.3 Strategic business net features
Consider the impact of selected strategic business net features on the feasibility of the network and business opportunity.
3.3.4 Strategic business net configuration
Refine the configuration of the future strategic business net and add the actors/partners.
3.3.5 Performance measurements
Identify performance measurements for the strategic business net.
Identify performance measurements for each network partner.
3.4 Networked BM feasibility
3.4.1 Value network elements
Evaluate the feasibility of the elements.
3.4.2 Value proposition elements
Evaluate the feasibility of the elements.
3.4.3 Value architecture elements
Evaluate the feasibility of the elements.
3.4.4 Value finance elements
Evaluate the feasibility of the elements.
3.5 Firm-level feasibility
3.5.1 Feasibility and profitability assessment
Assess the feasibility and profitability of the strategic business net on a firm-level.
3.5.2 Customer feedback
Test some of the ideas with anchor/ lead customers and obtain customer feedback


PROTOTYPING
4.1 Strategic business net development and configuration
4.1.1 Strategic business net configuration
Configure and map the value exchange and flow for each function within the strategic business net.
4.1.2 Functional interdependence assessment
Assess the interdependence between functions within the strategic business net.
4.2 Networked BM prototyping
4.2.1 Value network elements
Create prototypes of the elements.
4.2.2 Value proposition elements
Create prototypes of the elements.
4.2.3 Value architecture elements
Create prototypes of the elements.
4.2.4 Value finance elements
Create prototypes of the elements.
4.2.5 Alignment
Ensure internal and external alignment of the networked BM.
4.3 Strategic development
4.3.1 Production plan prototyping
Create a prototype production plan (high-level).
4.3.2 Strategic roadmaps development
Create a prototype of the strategic roadmap.
Create a prototype of the technology roadmap.
4.3.3 Marketing plan development
Create a prototype marketing plan.
4.3.4 Action plan development
Compile an action plan to realise the value co-creation on a network-level.
4.4 Firm-level prototyping
4.4.1 Action plan development
Compile an action plan to realise the value co-creation on a firm-level.
4.4.2 Firm-level prototyping
Create prototypes of applicable elements on the firm-level.
4.5 AM technology prototyping
4.5.1 Joint offering prototyping
Create physical prototypes of joint offering(s) (may use service bureau).
4.5.2 Customer feedback
Test the prototypes with anchor/ lead customers and obtain customer feedback.



DECISION-MAKING
5.1 AM technology decision-making
5.1.1 Strategic integration and alignment (firm-level).
Decide if the selected manufacturing technologies are correct and how it will be integrated into existing strategies and processes.
5.1.2 Investment and financing (firm-level).
Decide exactly in which technologies to invest in (each partner) and acquire the technology.
5.1.3 Other decisions
Determine how general considerations regarding AM will be addressed.
5.2 Business opportunity decision-making
5.2.1 Shared mental model
Establish a collective understanding among network partners.
5.2.2 Risk management
Re-assess and monitor the identified technology, company and joint risks.
5.2.3 Customer's perceived value
Evaluate the customer's perceived value and alignment with customer needs.
5.3 Strategic business net development and configuration
5.3.1 Strategic business net configuration
Finalise the decisions regarding the strategic business net configuration.
5.3.2 Harmonisation of features
Ensure harmonisation and coherence among strategic business net features.
5.3.3 Value creation levels
Ensure the value creation levels per function. If value is not generated on any level, revise function.
For each function, determine how value will be measured on the applicable value creation level.
5.3.4 Performance measurements
Refine and confirm the performance measurements for the strategic business net.
Refine and confirm the performance measurements for each partner.
5.4 Networked BM decision-making
5.4.1 Value network elements
Decide on the best configuration for each element.
5.4.2 Value proposition elements
Decide on the best configuration for each element.
5.4.3 Value architecture elements
Decide on the best configuration for each element.
5.4.4 Value finance elements
Decide on the best configuration for each element.
5.4.5 Harmonisation of elements
Ensure harmonisation and coherence among all the networked BM elements.
5.5 Strategic decision-making
5.5.1 Production plan finalisation
Finalise decisions regarding the production plan.
5.5.2 Marketing plan finalisation
Finalise decisions regarding the marketing plan.
5.5.3 Strategic roadmaps finalisation
Finalise decisions regarding the strategic and technology roadmaps.
5.6 Firm-level decision-making
5.6.1 Action plan development
Refine the action plan and add detailed tasks.
5.6.2 Change management plan development
Determine what changes must be made and how it will be implemented.
5.6.3 Training plan development
Compile a training plan in line with the change management plan.


IMPLEMENTATION
6.1 Strategic implementation
6.6.1 Feedback and progress reporting
Obtain feedback from all partners and brand ambassadors.
6.1.2 Implementation plan
Compile a network-level implementation plan through integration of action plans, roadmaps, and progress reports.
6.1.3 Communicate with network partners
Communicate the implementation plan with all network partners.
6.2 AM technology implementation
6.2.1 Implementation plan
Compile a phased AM technology implementation plan based on the production plan and technology roadmap.
6.2.2 AM production system implementation
Step-by-step implementation of the AM production system.
6.2.3 Evaluate and adjust
Evaluate implementation and make the necessary adjustments.
6.3 Firm-level implementation
6.4.1 Implementation plan
Compile a phased firm-level implementation plan based on the action plan, change management plan, and training plan.
6.4.2 Firm-level implementation
Step-by-step implementation of the firm-level implementation plan.
6.4.3 Evaluate and adjust
Evaluate change implementation and make the necessary adjustments.
6.4 Networked BM implementation
6.4.1 Implementation plan
Compile a phased networked BM implementation plan based on the networked BM.
6.4.2 Networked BM implementation
Step-by-step implementation of the networked BM elements.
6.4.3 Evaluate and adjust
Evaluate the networked BM elements and make the necessary adjustments.
6.5 Strategic business net implementation
6.5.1 Implementation plan
Compile a phased strategic business net implementation plan based on the strategic business net configuration, strategic roadmap, and action plan.
6.5.2 Strategic business net implementation
Step-by-step implementation of the strategic business net.
6.5.3 Evaluate and adjust
Evaluate strategic business net and make the necessary adjustments.
6.6 Business opportunity assessment
6.6.1 Monitor and evaluate
Monitor and evaluate network and partner performance.
6.6.2 Partner feedback and reporting
Obtain feedback and reports on progress from all partners.
6.6.3 Risk management
Re-assess the identified technology, company, and joint risks.
6.6.4 Re-evaluate and adjust
Re-evaluate performance and make the necessary adjustments.


SUSTAINABILITY
7.1 Business opportunity evaluation
7.1.1 Customer feedback
Obtain feedback from customers of the joint offering.
7.1.2 Re-evaluate and adjust
Re-evaluate business opportunities based on customer feedback and make the necessary adjustments.
7.2 Strategic business net evaluation
7.2.1 Strategic business net performance
Constantly monitor the overall strategic business net performance.
7.2.2 Partner performance
Constantly monitor each partner's performance.
7.2.3 Evaluate and adjust
Re-evaluate and adjust the strategic business net based on performance measurements.
7.3 Networked BM evaluation
7.3.1 Networked BM elements performance
Obtain feedback from customers of the joint offering.
7.3.2 Re-evaluate and adjust
Evaluate the networked BM elements and make the necessary adjustments.
7.4 AM technology sustainability
7.4.1 AM technology analysis
Analyse the developments (maturity) of the AM technologies.
7.4.2 Part-process-material analysis
Analyse the part-process-material maturity to identify improvements and additions to the joint offering.
7.4.3 Evaluate and adjust
Evaluate the findings and make the required adjustments (business opportunity, joint offering, or strategic business net related) due to technology advancements.
7.5 Strategic sustainability
7.5.1 Ecosystem scanning
Constantly scan the ecosystem for any changes that may influence the strategic business net.
7.5.2 Innovation assessment and development
Remain innovative through continuous innovation assessments and promote the development and improvement of joint offerings.
7.5.3 Long-term competitiveness
Determine how long-term competitiveness can be secured.
7.5.4 Communicate with network partners
Communicate ideas with network partners and obtain feedback.
7.6 Firm-level sustainability
7.6.1 Continuous learning
Promote and enable continuous learning
7.6.2 Change management plan development
Develop a change management plan based on lessons learnt and changes required on firm-level.
7.6.3 Training plan development
Compile a training plan to successfully implement the change management plan.

8.9 Part F: Management tool

This section aims to convert the final management framework presented in the previous section, into an interactive management tool using a collaborative, free, online mind mapping software application, *MindMeister.* The sub-phases, steps and activities presented above were used to create the tool, with some of the important considerations, guidelines, tools, and definitions presented in the detailed management framework contained in Appendix F.

There are a few reasons for selecting the mind mapping method, and the specific software application. The first reason is to present the management tool in a user-friendly manner as a document containing a table, or an excel spreadsheet is not attractive to the potential audience and will most probably be ignored. Presenting the framework as an interactive mind mapping tool will enable potential users to get perspective and an overview of the process before commencing as well as throughout the BMI process. The tool furthermore enables collaboration among users; therefore, the facilitator can share the mind map with other key role-players (including management) within the company. It is however proposed that only one person must be responsible, the facilitator, and have permission to modify the map to reduce traceability issues that may occur. Using a mind map enables the informal documentation of certain aspects, ideas, or decisions and can be used in future for reference or can be used as guidance to create formal documents. The mind map furthermore enables customisation and users can easily add or delete activities to best suit their business requirements and needs. The software is open-source and free and therefore enables anybody to use it freely without any restrictions.

Regarding the proposed tools contained within the framework, it was decided not to include templates for the tools that are widely used in practice. For these tools, it was rather decided to only include a few headings, considerations, or guidelines to provide a starting point for potential users to build upon. However, some of the tools included in the framework, may not be well known for people working in the manufacturing industry, and therefore tool template suggestions were provided, which are included in Appendix F.

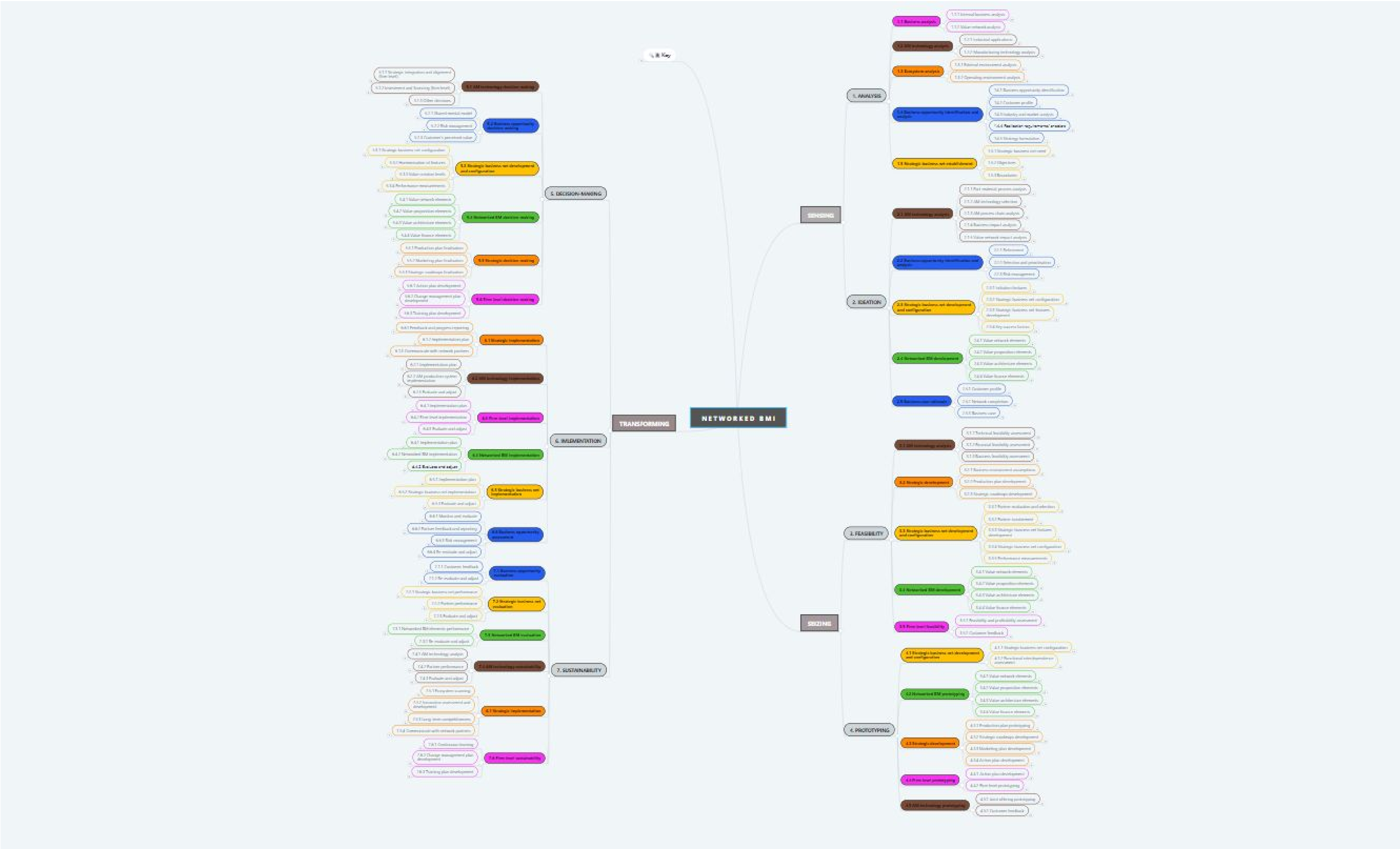
During the business subject-matter expert interviews (discussed in Section 6.4.4), a few framework requirements have been proposed. Table 8.4 below discusses how these requirements were addressed throughout the development of the management tool.

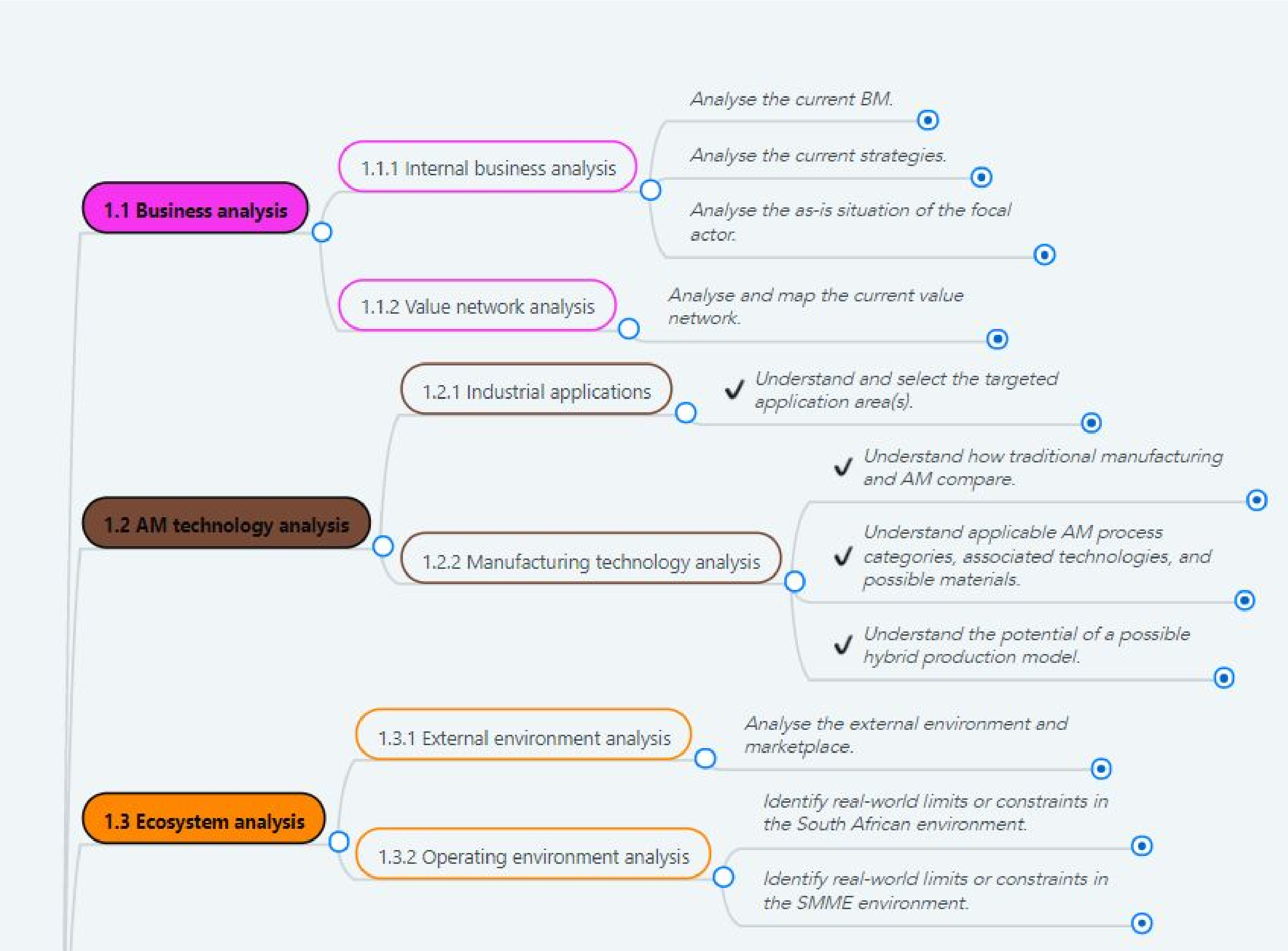
Table 8.4: Framework requirements discussion

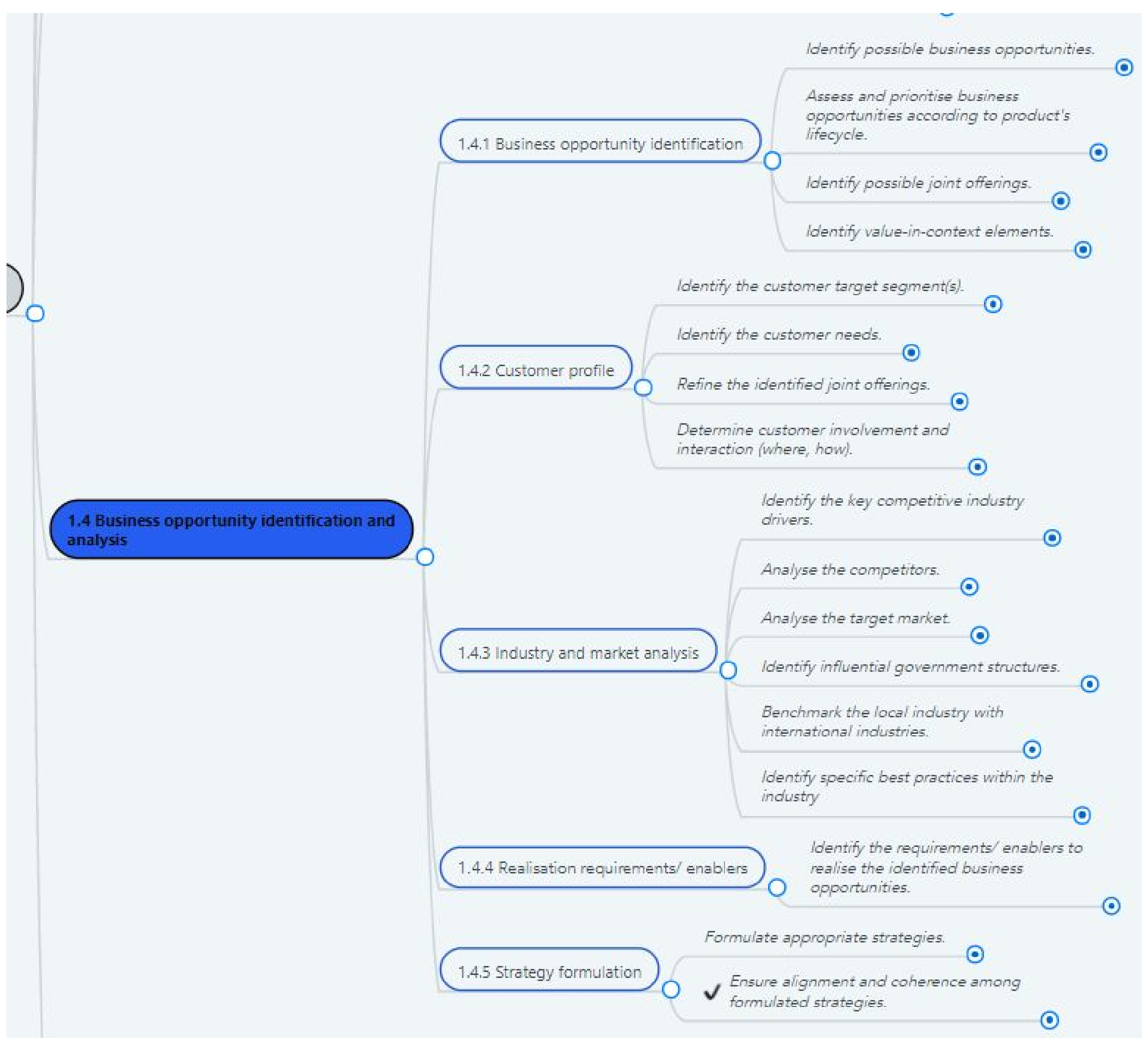
Framework requirement	**Discussion**	
Practical	√	The management tool includes steps and activities that are practical and action oriented. The proposed tools are widely known and practical to implement, and users could also include tools commonly used within their business. The use of a mind map to present the framework enables users to practically use the tool in the industry and present the tool and findings to all role-players within or outside of the organisation or SMME.
Easy to understand	√	The management tool includes a key to guide the user on what to do (discussed in the following section). The management tool is divided into the six development dimensions and accordingly indicated with corresponding colours to ease the understanding. Definitions, guiding questions and considerations are included to ease the understanding of what the specific activity requires the user to do. The use of a mind map also contributes to the understanding of the tool, instead of only tables.
Easy to use	√	The use of a mind map and open-source software make the tool easy to use.
Show value (or added value)	√	The inclusion of the SBN configuration process as a proposed network visualisation tool within the management tool, enable the user to visualise and see

Framework requirement		Discussion
		where value is created within the strategic business net and to configure the networked BM accordingly to enable the user to capture the value.
Easy interpretable results	√	The results or findings captured within the management framework is easy to understand and to interpret as it is focused and to the point.
Lead decision-making processes	√	The use of seven sub-phases within the management tool, guide the user to systematically develop, configure, and test aspects before final decisions are made. The management tool also includes considerations regarding what the user needs to typically think about before decisions are made.
Easy to amend	√	The use of collaborative software and a mind map makes it easy for users to add or delete activities according to the business requirements.
Comprehensive	√	The management tool includes steps and activities from the strategic, tactical, and operational view of the value network (discussed in Section 4.6.2).
Address all the functions of the business	√	In addition to the activities included from the strategic, tactical, and operational view of the value network, the selected networked BM elements that are developed throughout the tool, aim to address all the business functions of the network.

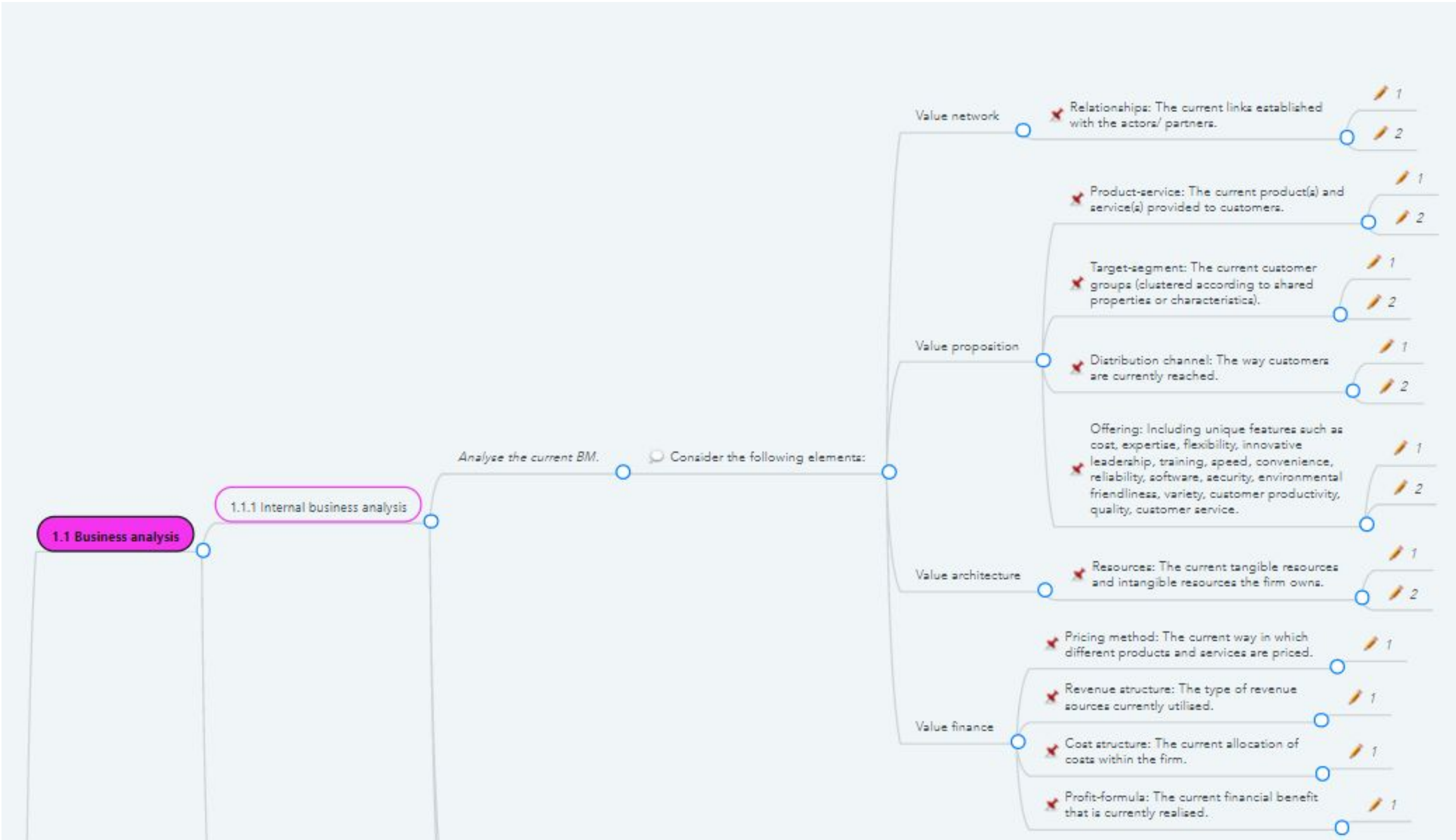
The following link can be followed to access and view the complete management tool https://mm.tt/1885184897?t=PT99aoKSaG. Furthermore, below are a few screenshots of the management tool itself to provide the look and feel of the tool.


NETWORKED BMI
SENSING
SEIZING
TRANSFORMING
1. ANALYSIS
2. IDEATION
3. FEASIBILITY
4. PROTOTYPING
5. DECISION-MAKING
6. IMPLEMENTATION
7. SUSTAINABILITY

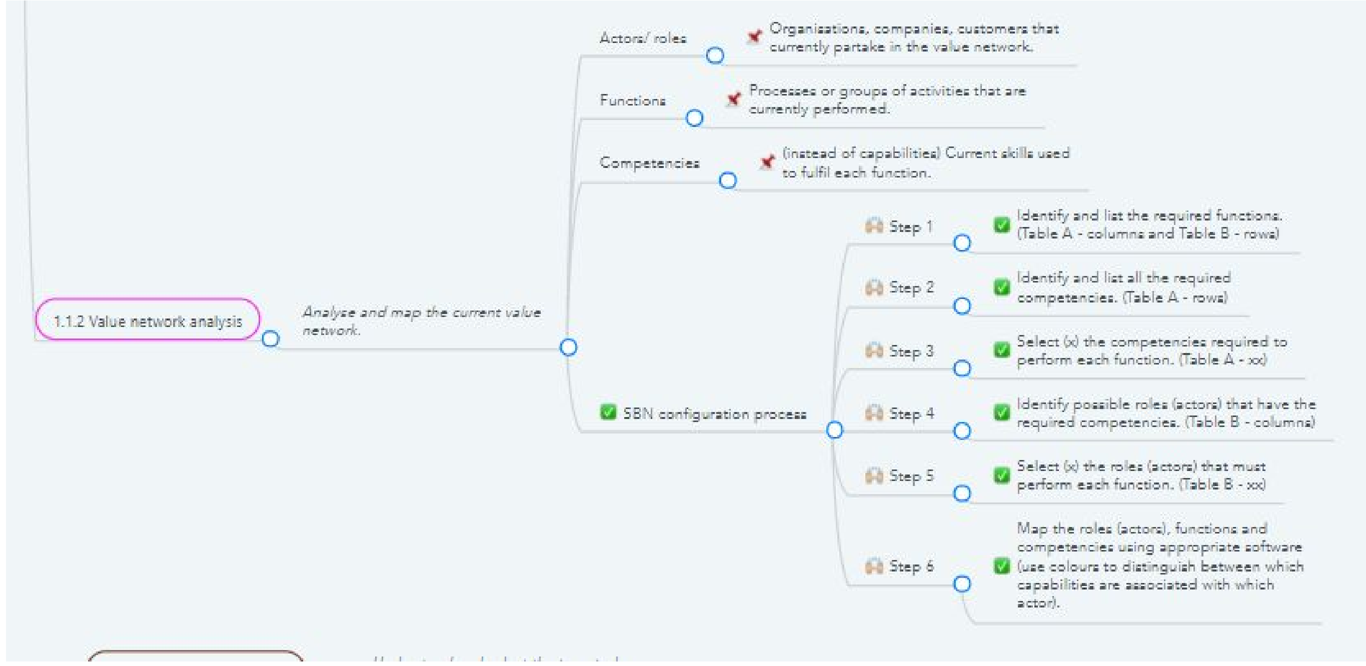

1.1 Business analysis
1.1.1 Internal business analysis
Analyse the current BM.
Analyse the current strategies.
Analyse the as-is situation of the focal actor.
1.1.2 Value network analysis
Analyse and map the current value network.
1.2 AM technology analysis
1.2.1 Industrial applications
Understand and select the targeted application area(s).
1.2.2 Manufacturing technology analysis
Understand how traditional manufacturing and AM compare.
Understand applicable AM process categories, associated technologies, and possible materials.
Understand the potential of a possible hybrid production model.
1.3 Ecosystem analysis
1.3.1 External environment analysis
Analyse the external environment and marketplace.
1.3.2 Operating environment analysis
Identify real-world limits or constraints in the South African environment.
Identify real-world limits or constraints in the SMME environment.


1.4 Business opportunity identification and analysis
1.4.1 Business opportunity identification
Identify possible business opportunities.
Assess and prioritise business opportunities according to product's lifecycle.
Identify possible joint offerings.
Identify value-in-context elements.
1.4.2 Customer profile
Identify the customer target segment(s).
Identify the customer needs.
Refine the identified joint offerings.
Determine customer involvement and interaction (where, how).
1.4.3 Industry and market analysis
Identify the key competitive industry drivers.
Analyse the competitors.
Analyse the target market.
Identify influential government structures.
Benchmark the local industry with international industries.
Identify specific best practices within the industry
1.4.4 Realisation requirements/ enablers
Identify the requirements/ enablers to realise the identified business opportunities.
1.4.5 Strategy formulation
Formulate appropriate strategies.
Ensure alignment and coherence among formulated strategies.

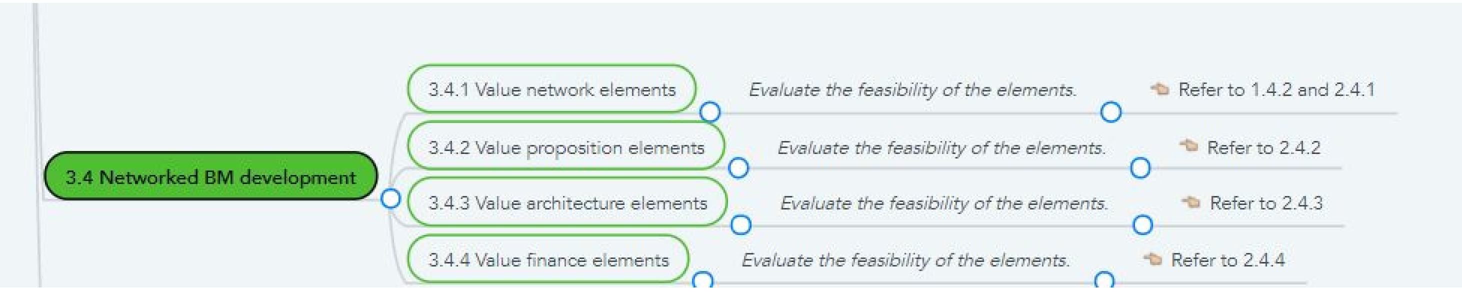

1.5 Strategic business net establishment
1.5.1 Strategic business net need
Define the need for the establishment of a strategic business net.
1.5.2 Objectives
Define the objective(s) of the strategic business net.
1.5.3 Boundaries
Identify and classify all stakeholders.
Determine which stakeholders are included in the strategic business net.



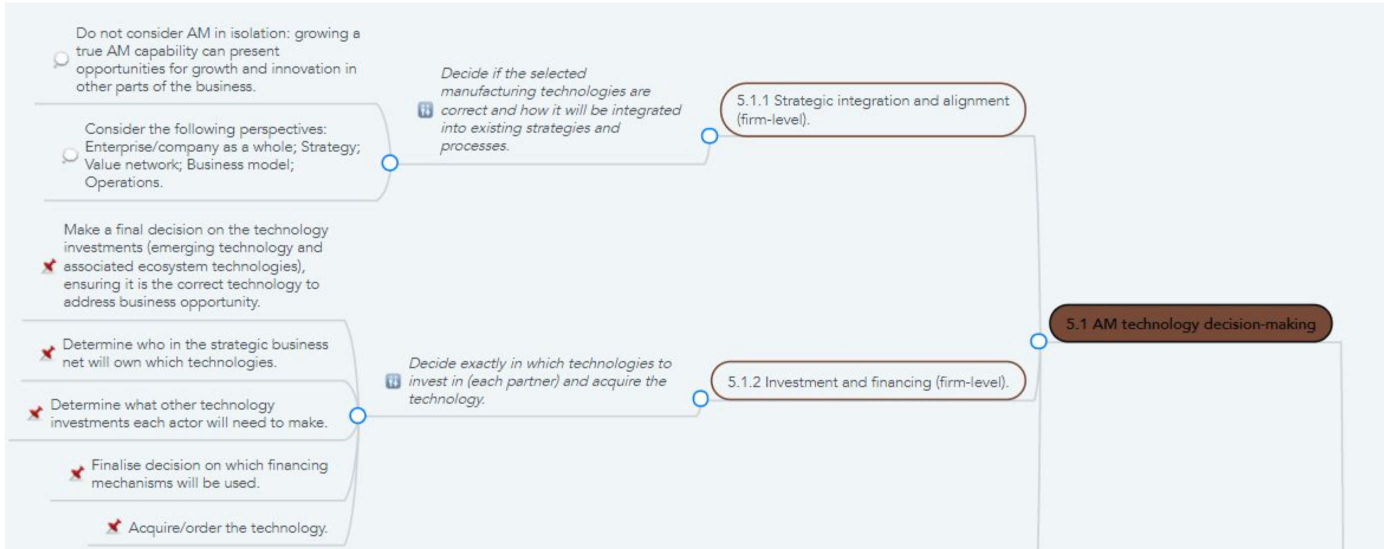
1.1 Business analysis
1.1.1 Internal business analysis
Analyse the current BM.
Consider the following elements:
Value network
Relationships: The current links established with the actors/ partners.
1
2
Value proposition
Product-service: The current product(s) and service(s) provided to customers.
1
2
Target-segment: The current customer groups (clustered according to shared properties or characteristics).
1
2
Distribution channel: The way customers are currently reached.
1
2
Offering: Including unique features such as cost, expertise, flexibility, innovative leadership, training, speed, convenience, reliability, software, security, environmental friendliness, variety, customer productivity, quality, customer service.
1
2
Value architecture
Resources: The current tangible resources and intangible resources the firm owns.
1
2
Value finance
Pricing method: The current way in which different products and services are priced.
1
Revenue structure: The type of revenue sources currently utilised.
1
Cost structure: The current allocation of costs within the firm.
1
Profit-formula: The current financial benefit that is currently realised.
1



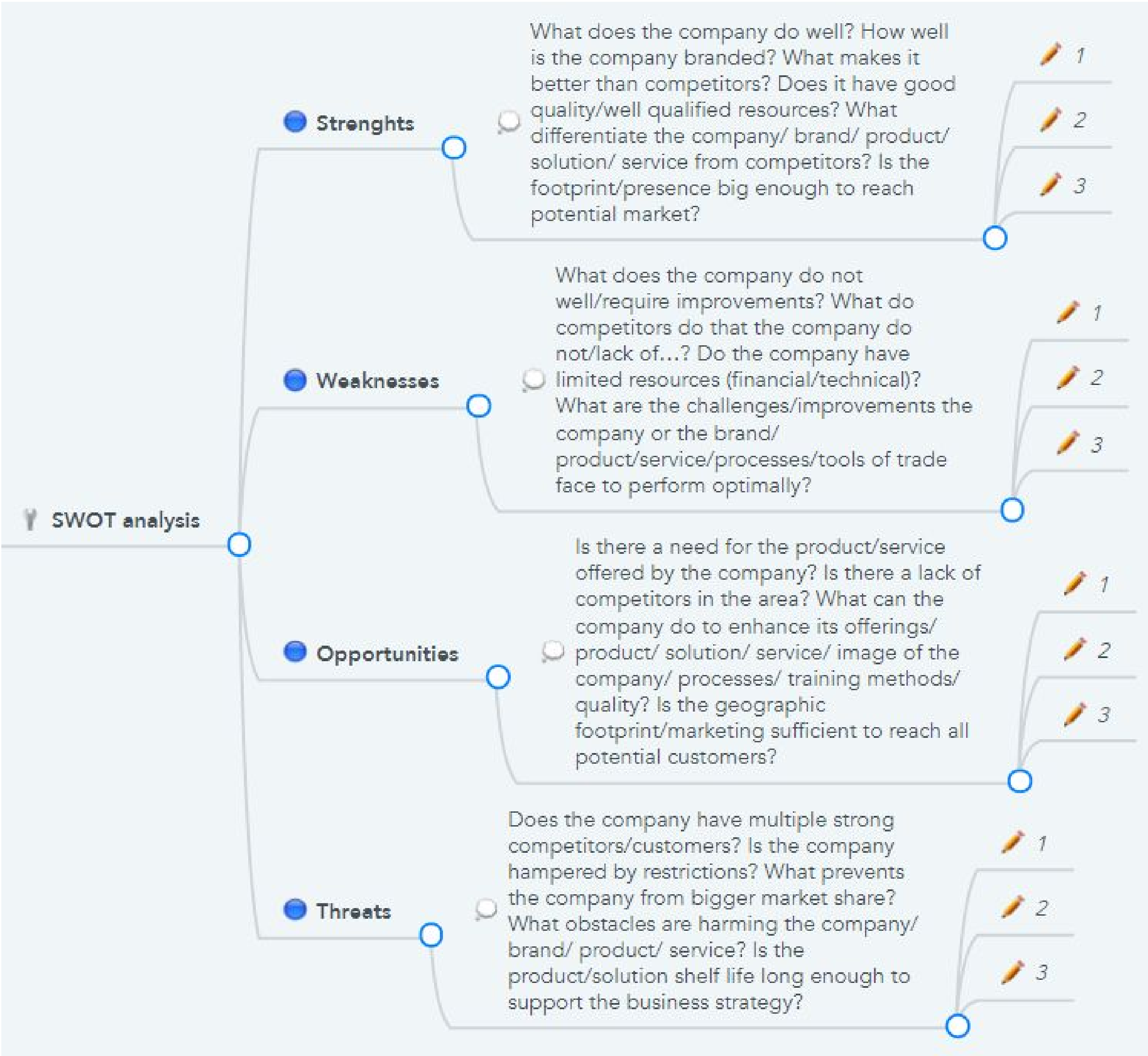
1.1.2 Value network analysis
Analyse and map the current value network.
Actors/ roles
Organisations, companies, customers that currently partake in the value network.
Functions
Processes or groups of activities that are currently performed.
Competencies
(instead of capabilities) Current skills used to fulfil each function.
SBN configuration process
Step 1
Identify and list the required functions. (Table A - columns and Table B - rows)
Step 2
Identify and list all the required competencies. (Table A - rows)
Step 3
Select (x) the competencies required to perform each function. (Table A - xx)
Step 4
Identify possible roles (actors) that have the required competencies. (Table B - columns)
Step 5
Select (x) the roles (actors) that must perform each function. (Table B - xx)
Step 6
Map the roles (actors), functions and competencies using appropriate software (use colours to distinguish between which capabilities are associated with which actor).

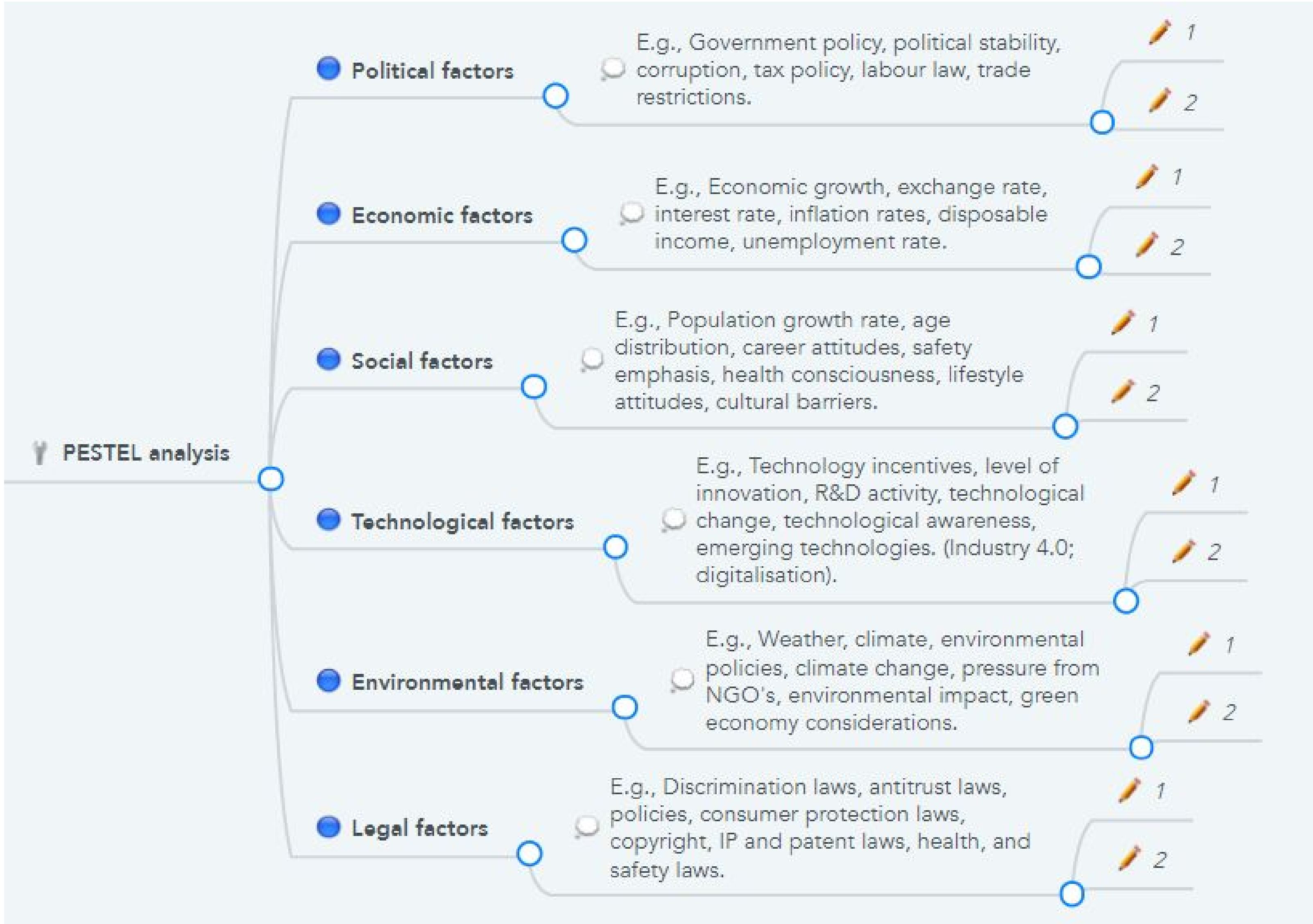


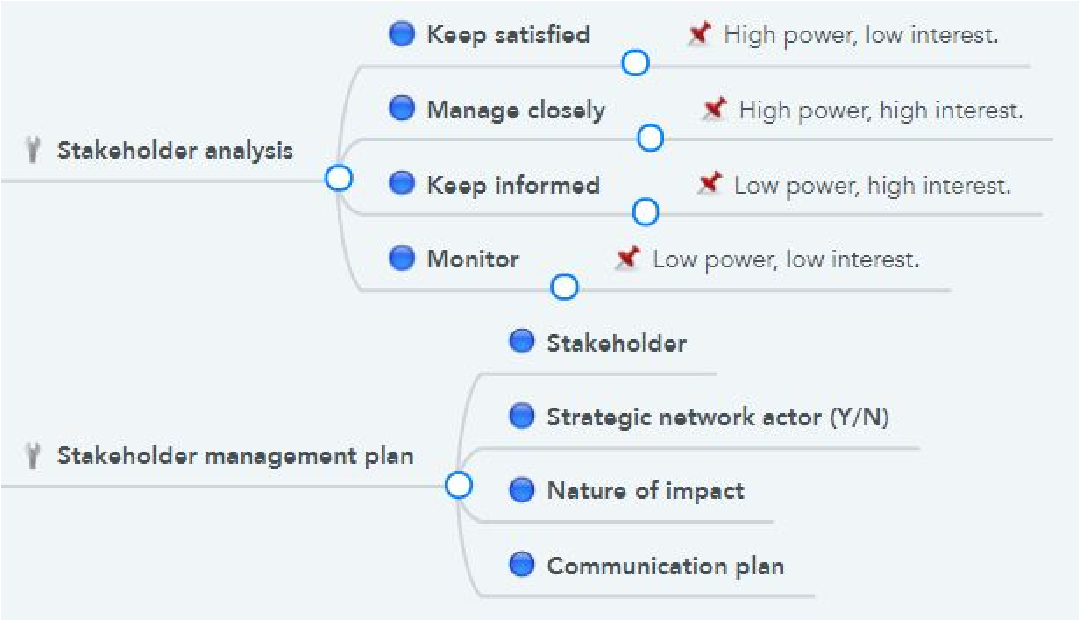
3.4 Networked BM development
3.4.1 Value network elements
Evaluate the feasibility of the elements.
Refer to 1.4.2 and 2.4.1
3.4.2 Value proposition elements
Evaluate the feasibility of the elements.
Refer to 2.4.2
3.4.3 Value architecture elements
Evaluate the feasibility of the elements.
Refer to 2.4.3
3.4.4 Value finance elements
Evaluate the feasibility of the elements.
Refer to 2.4.4



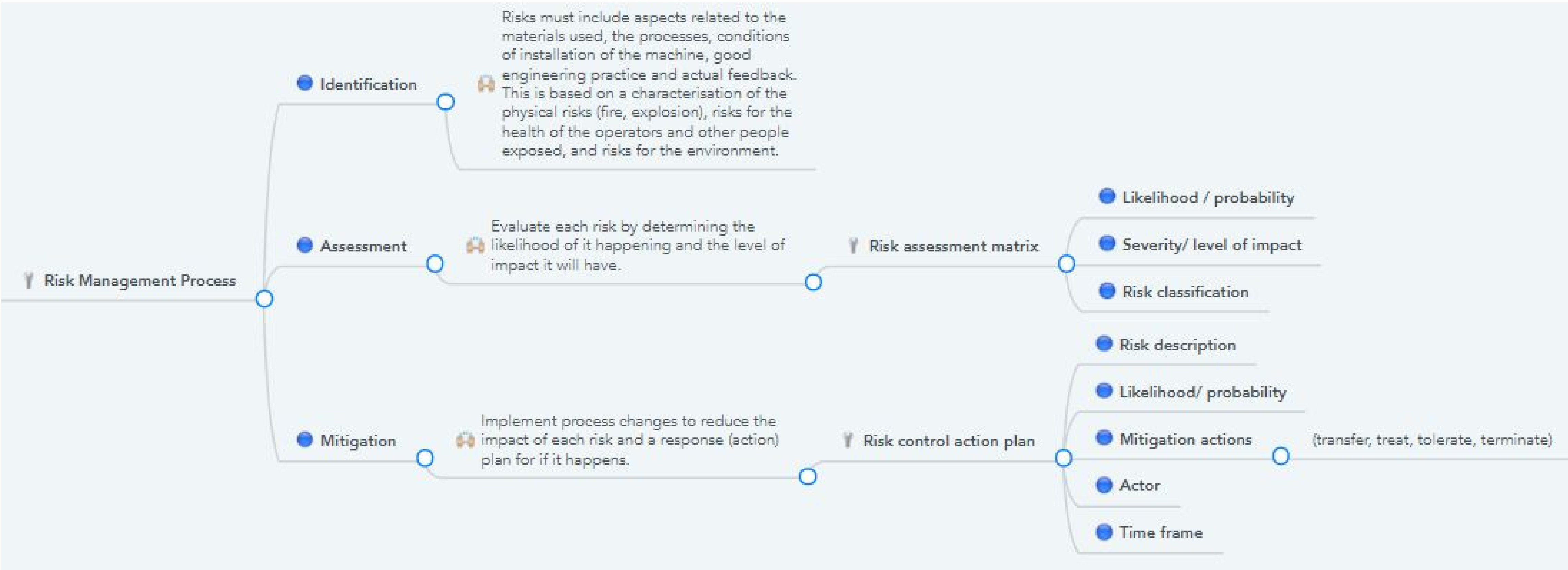
5.1 AM technology decision-making
5.1.1 Strategic integration and alignment (firm-level).
Decide if the selected manufacturing technologies are correct and how it will be integrated into existing strategies and processes.
Do not consider AM in isolation: growing a true AM capability can present opportunities for growth and innovation in other parts of the business.
Consider the following perspectives: Enterprise/company as a whole; Strategy; Value network; Business model; Operations.
5.1.2 Investment and financing (firm-level).
Decide exactly in which technologies to invest in (each partner) and acquire the technology.
Make a final decision on the technology investments (emerging technology and associated ecosystem technologies), ensuring it is the correct technology to address business opportunity.
Determine who in the strategic business net will own which technologies.
Determine what other technology investments each actor will need to make.
Finalise decision on which financing mechanisms will be used.
Acquire/order the technology.


SWOT analysis
Strenghts
What does the company do well? How well is the company branded? What makes it better than competitors? Does it have good quality/well qualified resources? What differentiate the company/ brand/ product/ solution/ service from competitors? Is the footprint/presence big enough to reach potential market?
1
2
3
Weaknesses
What does the company do not well/require improvements? What do competitors do that the company do not/lack of...? Do the company have limited resources (financial/technical)? What are the challenges/improvements the company or the brand/ product/service/processes/tools of trade face to perform optimally?
1
2
3
Opportunities
Is there a need for the product/service offered by the company? Is there a lack of competitors in the area? What can the company do to enhance its offerings/ product/ solution/ service/ image of the company/ processes/ training methods/ quality? Is the geographic footprint/marketing sufficient to reach all potential customers?
1
2
3
Threats
Does the company have multiple strong competitors/customers? Is the company hampered by restrictions? What prevents the company from bigger market share? What obstacles are harming the company/ brand/ product/ service? Is the product/solution shelf life long enough to support the business strategy?
1
2
3


PESTEL analysis
Political factors
E.g., Government policy, political stability, corruption, tax policy, labour law, trade restrictions.
1
2
Economic factors
E.g., Economic growth, exchange rate, interest rate, inflation rates, disposable income, unemployment rate.
1
2
Social factors
E.g., Population growth rate, age distribution, career attitudes, safety emphasis, health consciousness, lifestyle attitudes, cultural barriers.
1
2
Technological factors
E.g., Technology incentives, level of innovation, R&D activity, technological change, technological awareness, emerging technologies. (Industry 4.0; digitalisation).
1
2
Environmental factors
E.g., Weather, climate, environmental policies, climate change, pressure from NGO's, environmental impact, green economy considerations.
1
2
Legal factors
E.g., Discrimination laws, antitrust laws, policies, consumer protection laws, copyright, IP and patent laws, health, and safety laws.
1
2

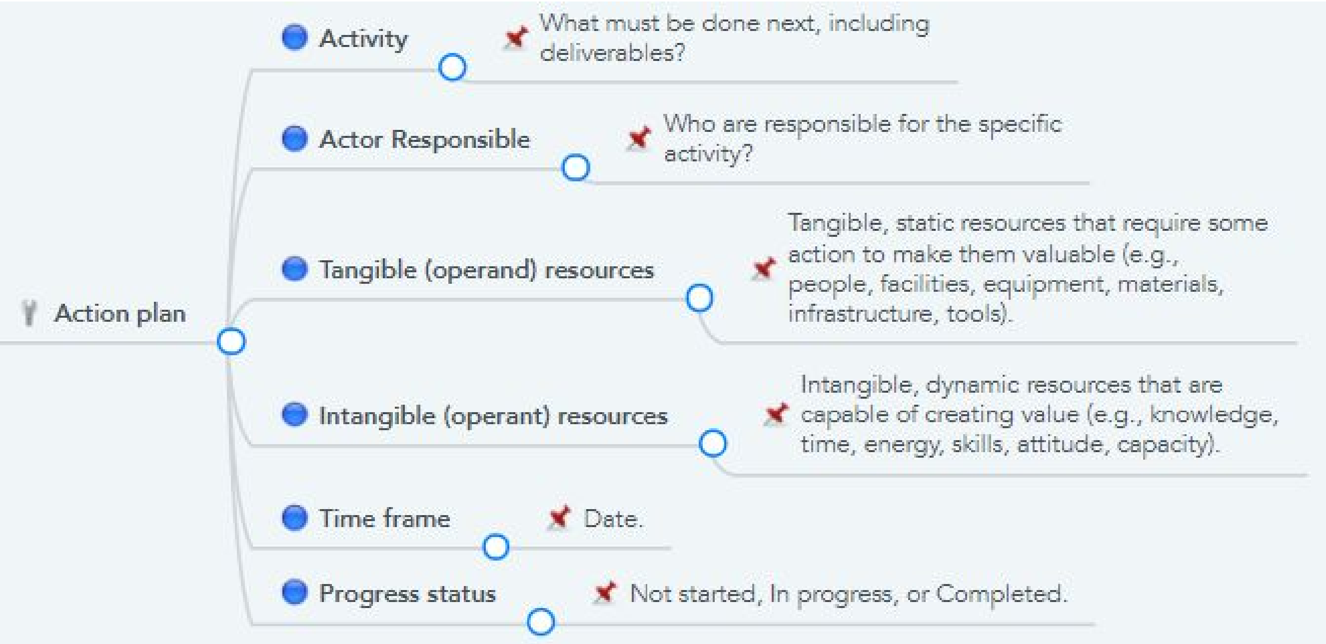

Stakeholder analysis
Keep satisfied
High power, low interest.
Manage closely
High power, high interest.
Keep informed
Low power, high interest.
Monitor
Low power, low interest.
Stakeholder management plan
Stakeholder
Strategic network actor (Y/N)
Nature of impact
Communication plan

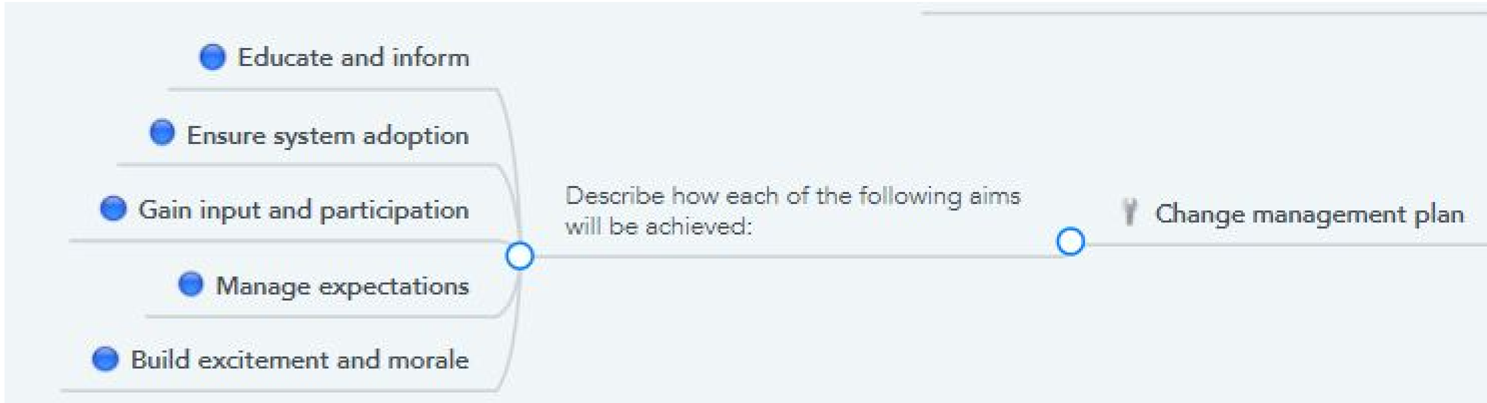

TOWS matrix
Strengths-Opportunities strategies
How can strengths be utilised to exploit opportunities?
1
2
Strengths-Threats strategies
How can strengths be exploited to overcome any potential threats?
1
2
Weaknesses-Opportunities strategies
How can weaknesses be overcome and then opportunities be exploited?
1
2
Weaknesses-Threats strategies
How can weaknesses be minimised to avoid possible threats?
1
2

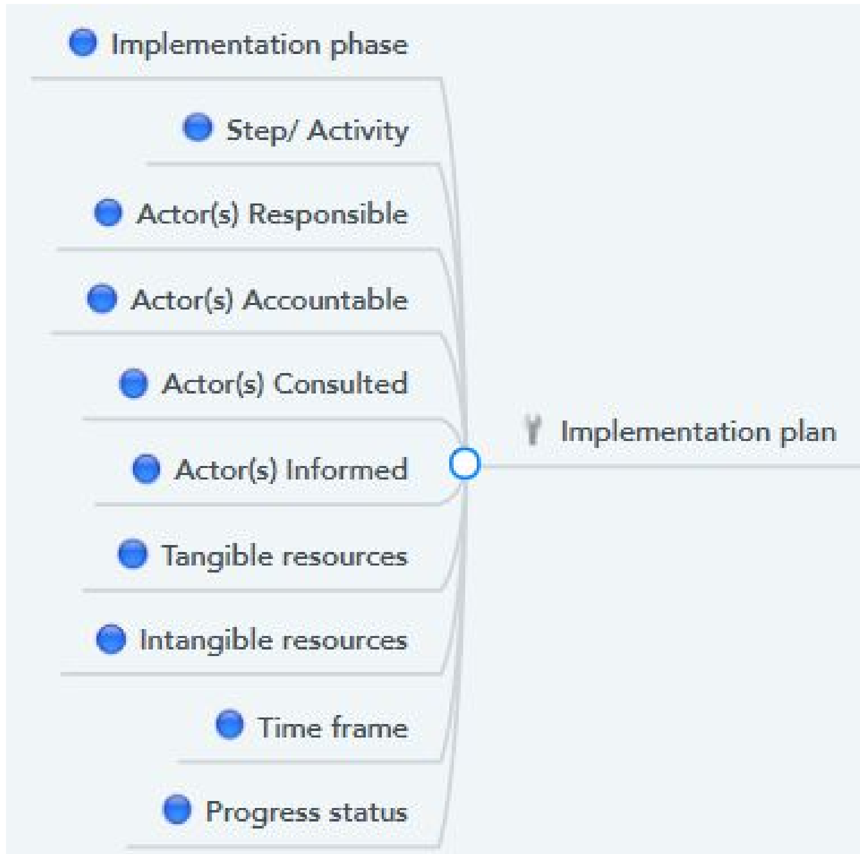

Risk Management Process
Identification
Risks must include aspects related to the materials used, the processes, conditions of installation of the machine, good engineering practice and actual feedback. This is based on a characterisation of the physical risks (fire, explosion), risks for the health of the operators and other people exposed, and risks for the environment.
Assessment
Evaluate each risk by determining the likelihood of it happening and the level of impact it will have.
Risk assessment matrix
Likelihood / probability
Severity/ level of impact
Risk classification
Mitigation
Implement process changes to reduce the impact of each risk and a response (action) plan for if it happens.
Risk control action plan
Risk description
Likelihood/ probability
Mitigation actions
(transfer, treat, tolerate, terminate)
Actor
Time frame


Actor selection template
Perceived advantages
Access to new, complementary resources, reducing costs, reducing time to market, risk reduction and risk sharing, access to new technologies, learning, additional advantages, other identified capabilities (refer to 2.1.3).
Perceived disadvantages
Decreased access to new, complementary resources, increase of costs, no access to new markets, increase risk reduction, increase time to market, no access to new technologies, no opportunities for learning, additional disadvantages.


Balanced scorecard
Customer perspective
How do customers see us? Are we satisfying customer needs?
Internal perspective
What must we excel at? Are we working effectively and efficiently?
Innovation and learning perspective
How can we continue to improve and create value? What are the emerging opportunities and challenges? How can we serve customers better in the future?
Financial perspective
How do we look to shareholders?


Action plan
Activity
What must be done next, including deliverables?
Actor Responsible
Who are responsible for the specific activity?
Tangible (operand) resources
Tangible, static resources that require some action to make them valuable (e.g., people, facilities, equipment, materials, infrastructure, tools).
Intangible (operant) resources
Intangible, dynamic resources that are capable of creating value (e.g., knowledge, time, energy, skills, attitude, capacity).
Time frame
Date.
Progress status
Not started, In progress, or Completed.


Change management plan
Describe how each of the following aims will be achieved:
Educate and inform
Ensure system adoption
Gain input and participation
Manage expectations
Build excitement and morale


Implementation plan
Implementation phase
Step/ Activity
Actor(s) Responsible
Actor(s) Accountable
Actor(s) Consulted
Actor(s) Informed
Tangible resources
Intangible resources
Time frame
Progress status


Responsibility matrix
Change management activity
Main responsibility
Change implementation plan
Intervention/ Change
Description
Actor(s)/ owner(s)
Costs
Time frame

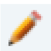
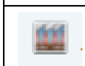

Training plan
Type of training
Trainor (actor)
Trainees (actors)
Resources/ courses
Time frame

8.10 Tool facilitations instructions

The following tool facilitation instructions were formulated and implemented to ensure the ease of understanding and appropriately using the management tool. These facilitation instructions ensure that both technology-oriented and management-oriented audiences will be comfortable using the tool. Figure 8.8 below illustrates the colours used to indicate which activities belong to which development dimension within the management tool. Table 8.5 furthermore presents the keys used within the management tool.

Figure 8.8: Management tool development dimensions colours

Table 8.5: Management tool key instructions

Key	Descriptor	Description
	Note, description or definition	Indicate any notes, descriptions or definitions related to the specific activity or concept used. These definitions or descriptions were formulated throughout this study and/or obtained from the literature body or subject-matter expert interviews. This information and details can also be found in the detailed management framework presented in Appendix F.
	Consideration	Indicate any specific or general considerations that relate to the specific activity or concept, within the context of this study.
	Tool	Indicate a specific tool to be potentially used by the user, together with a few guidelines that may include headings or other considerations related to the tool.
	Action to be done by user	Indicate an action that need to be done by the user, whereafter results or findings need to be documented or an acknowledgement need to be provided that the activity or concept was considered.
	User to complete	Indicate nodes that need to be completed by the user, this may include answers or findings related to a specific activity or configurations of specific concepts.
	Refer to previous activity	Indicate that the user needs to refer to another activity or concept addressed within a previous step that may be in another sub-phase.
	Networked BM element	Indicate the configurations of the networked BM elements which is one of the focus areas of the tool.
	SBN configuration process	Indicate the configuration of the strategic business net through the completion of one or more of the steps associated with the SBN configuration process.
	Additive manufacturing	Indicate specific steps or activities that relate to AM.

Key	Descriptor	Description
	Partner(s) involved	Indicate the potential involvement of partners to complete the activity or to gain insights from partners to complete the activity or step.
	Check	Indicate where users need to investigate and understand specific aspects.
	Tool (template) heading	Indicate proposed headings for a tool or template (as guideline) to be used to conduct the activity.
	Tool template suggestion provided	Indicate where a tool template suggestion is provided, see Appendix F.

It is proposed that one person take responsibility for the completion of the template and facilitation of the process (having *edit* permission) to reduce traceability issues and data security problems. Other employees or role-players can however have access to the mind map, but only have *viewing* permission.

Regarding the use of the specific open-source software application, *MindMeister,* the following instructions may be useful to the potential user or facilitator:

- To expand a node, click on the small white and grey dot.
- To minimise a node, click on the small white dot.
- To edit the text on a node, double click on the node and start typing.
- To add a node or branch on the same level, press enter and start typing.
- To add another node or branch on another sub-level of the current node or branch, press insert and start typing.
- To delete a node, click on the node and press delete.

During the business subject-matter expert interviews (discussed in Section 6.4.4), some of the experts proposed the inclusion of other facilitation instructions regarding feedback (who, when, requirements to proceed etc.), however, these structures are more on the detailed firm-level and therefore excluded from this study's scope. Another concern raised by the business subject-matter experts was to ensure 'buy-in' from employees. Although certain aspects of the framework were re-evaluated to consider the questions *"what is in it for me?"* and *"how will it benefit me?",* 'buy-in' from employees can be achieved if all employees are included in the first two sub-phases of the framework. Consequently, everyone will understand the need to transform as well as the potentials and risks associated with the transformation. This will also help with the change management that needs to be done on the firm-level.

8.11 Conclusion: Chapter 8

This chapter presented all the final research artefacts designed, developed, and evaluated throughout this study. The motivation and purpose of the management tool are discussed. The chapter concluded with the presentation of the final management tool that was built based on the final management framework, answering the last sub-research question. It is furthermore important to note that the management tool contains all the steps of the strategic business net configuration process, divided into the different sub-phases. To improve the user's experience of the tool, a few instructions were presented and described within this chapter to guide the facilitation and implementation of the management tool.

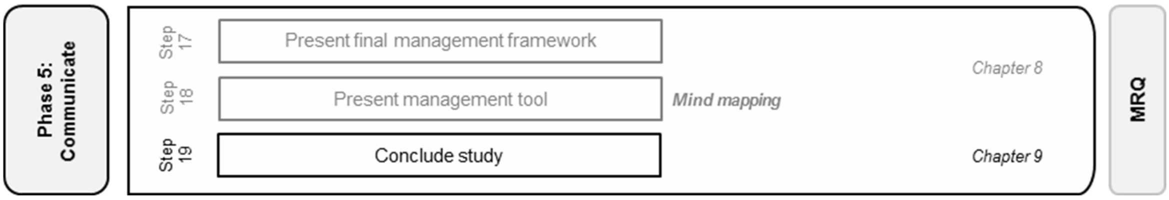
The next chapter concludes this study by providing an overview of the process followed to answer the MRQ, as well as brief reflections on how each of the sub-research questions was answered within this document.

Chapter 9: Conclusion and future work

In this final chapter, an overview of the research process followed throughout this study is provided, the research findings are presented, and the various contributions made in the completion of this study are discussed. The limitations of the study are discussed, and suggestions are made for future research opportunities.

Chapter 9 key objectives:

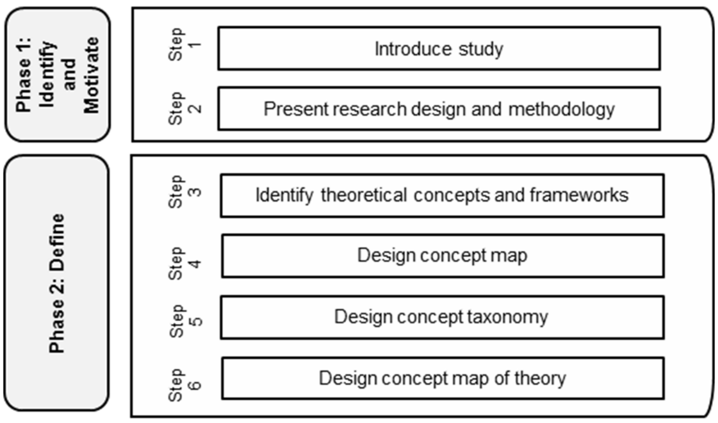
- Present an overview of the research process (Section 9.1).
- Reflect on the research sub-questions and the key research findings (Section 9.2).
- Discuss the contributions and significance of this study (Section 9.3).
- Discuss the limitations of the study (Section 9.4).
- Present suggestions for future work (Section 9.5).



9.1 Overview of the research process

The aim of this study was to systematically develop a business model innovation framework from a VN perspective. The execution of this study was based on the DSR framework and process model and consisted of five major phases, each comprising of individual steps. Within these phases, six design cycle iterations were conducted which were based on the application environment and knowledge base. Furthermore, the execution of these six design cycles enabled the researcher to answer the MRQ, namely: *What main concepts, processes, steps, activities, tools, and considerations need to be included in a networked business model innovation framework and tool to support SMMEs in the development and configuration of their value networks and networked BMs, with application value to the adoption of AM within South African hardmetals sector?*

A summary of the research process followed throughout this study is depicted in Figure 9.1.



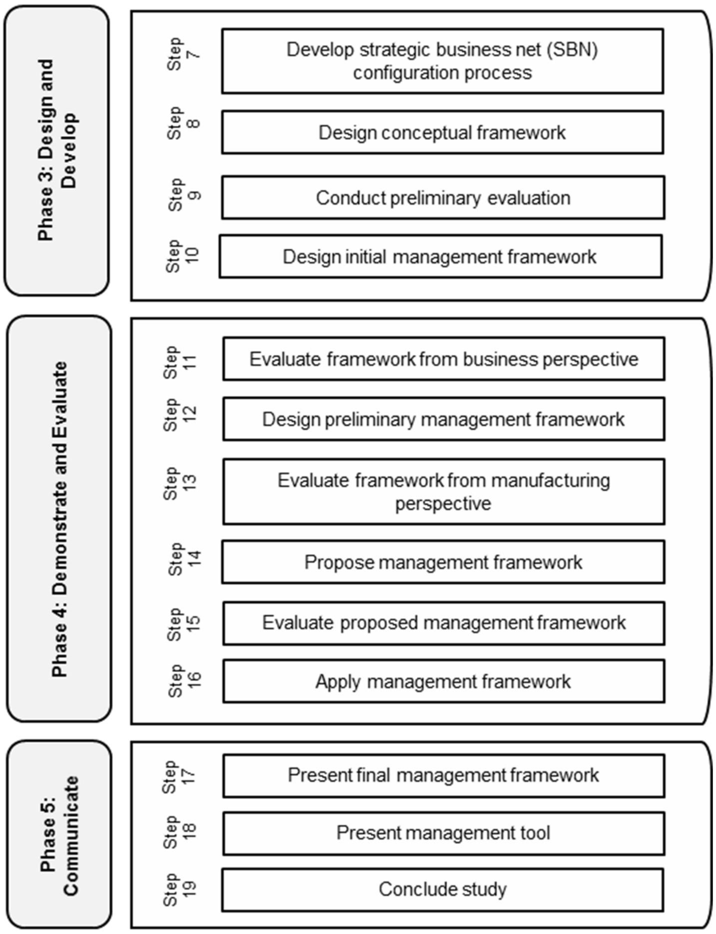


Figure 9.1: Overview of the research design followed in the study

The execution of the five major research phases is briefly discussed and reflected upon in the following section.

9.1.1 Phase 1: Identify and Motivate

Phase 1 aimed to introduce the study and to provide adequate motivation for the study within the application environment. In **step 1**, the study was introduced by giving a brief background on the need for a BMI framework (including steps, activities, and tools) from a VN perspective with application value in the development of the prospective cemented tungsten carbide AM sector in South Africa. The background, together with the identified research gaps, led to the formulation of the research problem, research questions, and objectives (Chapter 1).

In **step 2**, the researcher set out to formulate the research design and process that would effectively and innovatively answer the research questions, and meet the objectives set out in this study. The research process guided the overall research process as well as the development of the management tool. The DSR framework was selected to formulate the research design, consisting of multiple design iterations, and was supplemented with various research methods (Chapter 2).

9.1.2 Phase 2: Define

Phase 2 aimed to answer the first set of sub-research questions of this study, which primarily consisted of the identification, review, analysis, as well as synthesis and integration of the relevant literate bodies. In **step 3**, SRQ1 was answered after a structured literature was conducted that led to the identification of the most relevant definitions, frameworks, elements, and concepts available in each literature body (BM, BMI, and VN). As part of step 3, relevant literature from the contextual domain (AM, SMME, SA) were also reviewed to identify the influence of AM on the other concepts that could potentially be included in the management framework, answering SRQ2.

During steps 4 to 6 the results of the review were presented in a systematic manner, ensuring the management framework and tool were rigorous and grounded using applicable theories and theoretical frameworks. Developing a BMI framework from a VN perspective led to the identification of the need to understand what the concept of *networked BMI* entails and how to approach it, through the integration of the three primary research bodies (BM, BMI, VN).

In **step 4**, the concepts forming part of the concept inventory were structured and presented in a concept map, divided into four value dimensions (value network, value proposition, value finance, and value architecture) with applicable relationships between these concepts. The aim of the concept map was to create a holistic and overall picture of the selected primary dataset, with a focus on the core concepts contained within the BM, BMI, and VN records that can be used as elements to describe the networked BMI concept. These elements were used as a checklist for the conceptual framework, to ensure no key element was overlooked.

To make more sense of the complex concept map containing all the elements, a hierarchical taxonomy was developed in **step 5** to provide a better understanding of what the networked BMI concept entails, answering SRQ3. This hierarchical taxonomy served as a set of theoretical 'requirements' for the conceptual and management frameworks which were used during the internal evaluation process.

In **step 6** a concept map of theory was designed to depict the networked BMI concept, described in the hierarchical taxonomy, answering SRQ4. This concept map aimed to integrate existing theoretical frameworks from each literature body (BM, BMI, and VN) to illustrate the networked BMI concept and to visually present what the proposed management framework aims to achieve. These three research artefacts formed part of the first design cycle, ensuring the rigour of the framework as it demonstrates the fact that it is based on existing knowledge, theories, and frameworks.

9.1.1 Phase 3: Design and Develop

As part of the development of the conceptual framework, it was observed that there was no single practical process to map a strategic business net on the strategic and tactical level. Therefore, in **step 7**, a strategic business net configuration process was developed to be incorporated into the conceptual and management frameworks that will enable users to systematically develop and visually map their strategic business nets. This visualisation tool also aimed to enable users to easily link the concepts of the networked BM and the strategic business net, as the configurations directly influence each other. In **step 8** the initial conceptual framework was designed, consisting of phases, sub-phases, steps, and the concepts addressed in each step, answering SRQ5. The phases, sub-phases and steps were based on theoretical frameworks and findings from the literature review. To identify the concepts that must be addressed in each step, the concept map (based on the concept inventory) was used. The conceptual framework aimed to propose a more high-level practical application of the concept map of theory, through the integration of the framework elements and the core concepts. The conceptual framework provided the theoretical foundation for the management framework and concluded the second design cycle.

In **step 9** the relevance and applicability of the SBN configuration process was evaluated from a business perspective, using a real-life scenario as an example of an SMME within South Africa that want to participate in a VN and want to transform their BM from the firm-level to the network-level. Although the selected SMME was not within the entire contextual landscape of this study (i.e. not considering the adoption of AM), valuable insights were gathered during the application of the process that led to the addition of two steps to the process. The findings and insights obtained regarding the research artefacts as well as the operating environment of SMMEs, guided the completion of the fourth design cycle.

Furthermore, as part of the preliminary evaluation conducted in step 9, the initial conceptual framework was internally evaluated using the hierarchical taxonomy designed in step 5. In step **10** the initial management framework was designed as part of the second design cycle, building on the conceptual framework. Additional steps, sub-steps, tools, considerations, guiding questions, and concept definitions were added to the initial conceptual framework. Since the potential user of the management tool may not necessarily be a business expert, the additions to the framework must be comprehensive to lead the user in the correct direction.

9.1.2 Phase 4: Demonstrate and Evaluate

Four design cycles iterations were completed during Phase 4. In **step 11** the initial management framework and some of the other research artefacts (hierarchical taxonomy, concept map of theory and SBN configuration process) were evaluated through semi-structured interviews with business subject-matter experts from different backgrounds. During **step 12** the preliminary management framework was designed, incorporating contextual considerations and facets identified in step 3 to ensure the framework adequately address AM adoption. In **step 13** the preliminary management framework was evaluated through semi-structured interviews with manufacturing and AM subject-matter experts from diverse backgrounds. After the necessary adjustments and modifications were made, the proposed management framework was presented as part of **step 14**. Conducting multiple interviews with a wide range of subject-matter experts with different backgrounds and different expertise contributed to the overall rigour and relevance of the management framework and other research artefacts. In **step 15**, the activities contained within the proposed management framework were evaluated by business and manufacturing subject-matter experts using a structured questionnaire.

In **step 16** certain steps within the management framework were applied to the contextual application domain of this study (AM, SMME, SA), as part of the final design cycle and answering SRQ7. This application domain initiated the research project, as described in Chapter 1. To make the application domain more practical and applicable, the tooling industry was selected as it has great potential for the adoption of AM technology using cemented tungsten carbide as a manufacturing material. The important role the industry plays in innovation and the introduction of products into the market, stresses the importance to develop this industry specifically. As part of this step, the proposed SBN configuration process was also evaluated from a manufacturing perspective.

Therefore, the contextual application conducted in this study is rather classified as a story instead of a case study. However, based on some of the similarities between the two approaches, it was decided to follow a case study approach which is commonly used in qualitative research design [57] to guide the application process. It is, however, important to note, that because it was a story, created for an emerging technology, some fictionalised elements, not supported by the literature, have been included to demonstrate the framework's functionality and applicability.

9.1.3 Phase 5: Communicate

During the final phase of this study, the framework was finalised and the results, including the management tool, were presented. In **step 17** the management framework was finalised through the integration of all the findings and insights obtained from the different evaluations, completing the final design cycle iteration. During this step, some final versions of other research artefacts designed throughout this study were also presented. In **step 18** the management framework was converted into a management tool using the mind mapping method. The application of the tool was also explained.

The management framework (and tool) was an output from the other research artefacts designed and developed as part of this study. Figure 9.2 below illustrates the proposed relationships between all the artefacts. The concept map designed in Section 4.2 *informed* the concept taxonomy designed in Section 4.3. The concept taxonomy proposed a more structured and hierarchical approach to the networked BMI concept, based on the concepts contained in the concept map. The concept map was also used as a *checklist* during the design of the conceptual framework (Section 4.5), to ensure all fundamental concepts were addressed within the framework.

Furthermore, the concept map of theory, designed in Section 4.4, provided a more holistic approach to the networked BMI concept, and was thus regarded as a set of *requirements for* both the conceptual framework and the management framework. Due to the conceptual nature of the conceptual hierarchy, a concept map of theory was designed to *depict* the information contained in the taxonomy in a more visual way. The concept map of theory, therefore, provided *theoretical guidance for* the design and development of the conceptual framework that aimed to provide more logical steps on how to practically approach the networked BMI concept. As *part of* the development of the conceptual framework, the SBN configuration process was designed to enable visualisation of the strategic business net on a strategic and tactical level. The management tool presented in Chapter 8 is the *practical application of* the management framework, enabling potential users to conduct the activities in the framework in an understandable, interactive, and customisable manner.

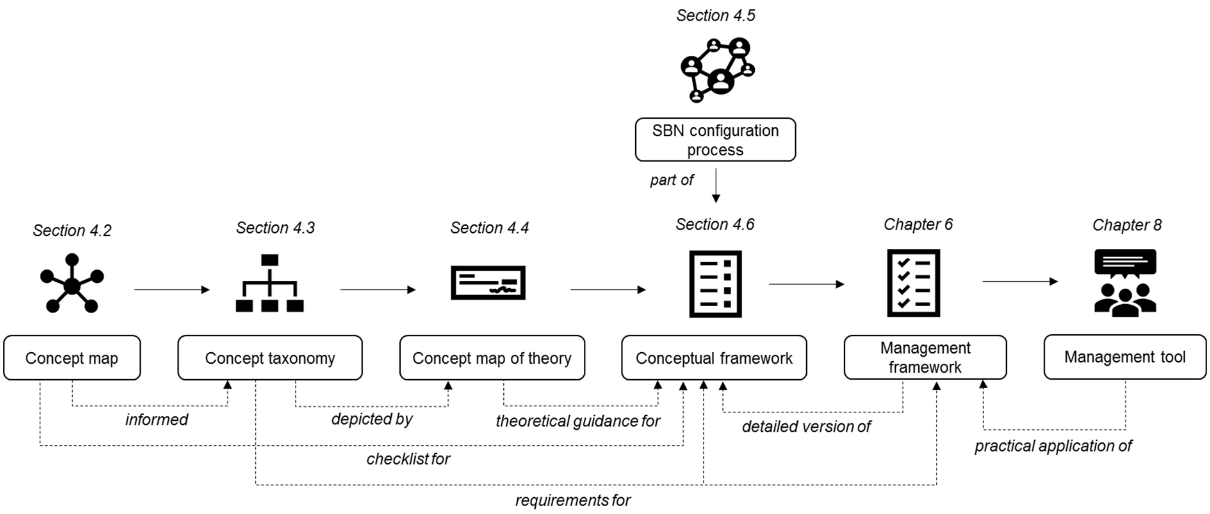


Figure 9.2: Relationships between the research artefacts

In the final step, **step 19**, the study is concluded. The research process is reviewed to show how the research questions were answered. The contributions, limitations and suggestions for future research are discussed.

9.2 Reflection on answering the research questions

The aim of this study was to systematically develop a BMI framework (and converting it into a management tool) from a VN perspective to support SMMEs in the configuration of strategic business nets and the development of appropriate networked BMs, with application value to the prospective cemented tungsten carbide AM industry in South Africa. A main research question was formulated, followed by seven sub-research questions to guide the study in achieving the overall aim. Furthermore, various research objectives were formulated to effectively address the research questions.

The research questions are reflected on, and the fulfilment of their corresponding objectives are presented in the following section.

SRQ1: Which relevant definitions, frameworks, elements, and concepts are available in each literature body (BM, BMI and VN) to support the framework development?

To effectively answer the first sub research-question, the biggest part of research objective 1 was pursued and fulfilled in Chapter 3 and the beginning of Chapter 4. A structured literature review was conducted in Chapter 3 of the BM, BMI and VN literature domains to answer the first two sub-objectives. Since all three literature bodies are vast with various closely associated literature bodies and concepts, it was a challenge to set the scope of this study and to furthermore remain within the study's scope to achieve the overall aim of this study. It is therefore acknowledged that the structured literature review did not consider all search terms or concepts that could possibly be related to the three primary literature bodies. If other search terms or other associated concepts were included in the search string, the selected concept, definitions, frameworks, and study outcomes might have been different. Throughout the selection process of existing theoretical frameworks, the aim was to focus on value, as it is the main theme throughout all the literature bodies (including the AM literature body).

Although it was attempted to keep the scope manageable, the selected primary body still had a big number of concepts. It was noted that some of the key concepts were consistent among the research studies, whereas others were not. Therefore, to enable a holistic view of the primary data set, the researcher selected the most relevant concepts based on extensive reading. No structured, coding process was followed as a structured coding process did not seem like the most relevant approach because of the closely associated concepts and some inconsistencies in the studies regarding the most important concepts.

The most relevant definitions, frameworks and elements are presented in Appendix A. The insights obtained in the fulfilment of objectives 1.a and b were synthesised to enable the researcher to answer objectives 1.c and d in Chapter 4. The fundamental concepts identified in the structured review were catalogued into a concept inventory presented in Appendix B. The fulfilment of these sub-objectives in specific sections within this document is presented in Table 9.1.

Table 9.1: Research objectives addressed in support of answering SRQ1

Research objectives	**Section where reported**
Objective 1.a: To *identify* the relevant definitions, frameworks, elements, and concepts (BM, BMI, VN).	Sections 3.2 - 3.4
Objective 1.b: To *select* the most applicable existing theoretical frameworks as the study's theoretical foundation (BM, BMI, VN).	Sections 3.2 - 3.4
Objective 1.c: To *identify* and *select* the fundamental concepts that form part of the networked BMI concept (BM, BMI, VN).	Section 4.2
Objective 1.d: To *identify* possible relationships between the fundamental concepts (BM, BMI, VN).	Section 4.2

SRQ2: What are the main influences of AM on SMMEs, the BM, BMI and the VN that could support the framework development?

In addition to the first sub research-question, the second question associated with the last part of research objective 1 was also pursued and fulfilled in Chapter 3. As part of the structured literature review, the influence of AM on the other key concepts were investigated and analysed to fulfil objective 1.e, see Table 9.2 for the specific section within this document.

Within the AM literature body, there are numerous articles analysing and describing the effects and impacts of AM on the focus areas and can therefore be regarded as a separate study. Due to the time constraints and the scope of the current study, it was not possible to report on all the influences and impacts, but the researcher rather aimed to provide an overview in highlighting some of the most important influences that relate to aspects of the management framework. Furthermore, the AM literature body is still relatively new and emerging, and because of the IP aspects related to the technologies, various information remains within specific organisations as their competitive advantage. It is therefore acknowledged that some important influences within the industry might have been missed.

Table 9.2: Research objectives addressed in support of answering SRQ2

Research objectives	**Section where reported**
Objective 1.e: To *identify* the main influences of AM on each of the other concepts (BMs, BMI, VNs, SMMEs).	Section 3.5

SRQ3: What is a possible hierarchical taxonomy for the networked BMI concept?

To answer the third sub research-question, the findings and insights obtained from the structured literature review and the concept map were used to fulfil objective 2. The fulfilment of these sub-objectives in specific sections within this document is presented in Table 9.3. The development and design of the hierarchical taxonomy set the basis for the framework and tool as it provided a set of requirements for the networked BMI concept that was under investigation throughout this study. The idea of the concept taxonomy as well as the structure thereof were mainly based on the BM taxonomy proposed by Al-Debei and Avison [6]. The integration and synthesis of the most prominent frameworks and concepts, with appropriate relationships, enabled a structured, rigorous approach to the networked BMI concept which were under investigation.

It is nevertheless acknowledged that the proposed hierarchical taxonomy is only one presentation of a taxonomy for the networked BMI concept on which this study is built upon, based on the researcher's findings, understanding and interpretation. Since the networked

BMI concept is complex with numerous facets and numerous classes, various other configurations are also possible. However, within the identified primary data set, the researcher was not aware of any other existing taxonomies regarding the networked BMI concept.

Table 9.3: Research objectives addressed in support of answering SRQ3

Research objectives	Section where reported
Objective 2.a: To *identify* possible facets and classes towards a taxonomy for the networked BMI concept.	Section 4.3
Objective 2.b: To *identify* possible relationships between the facets of the taxonomy.	Section 4.3

SRQ4: What is a possible concept map of theory to visually illustrate the networked BMI concept?

The findings and understandings obtained from the taxonomy development enabled the researcher to answer the fourth sub research-question, associated with research objective 3, see Tale 9.4 for the specific sections within this document. The identified theoretical frameworks and selected facets and classes of the hierarchical taxonomy were synthesised and integrated into a new visual map, illustrating the concept under investigation. In addition to the elements integrated from existing frameworks, a few other concepts were also added through the various evaluation cycles. However, the underlying logic and reasoning of all elements and aspects presented in the concept map of theory are based on findings from the literature body.

Table 9.4: Research objectives addressed in support of answering SRQ4

Research objectives	Section where reported
Objective 3.a: To *identify* key elements from the existing theoretical frameworks for a concept map of theory.	Section 4.4
Objective 3.b: To *design* a concept map of theory through the integration of the selected elements.	Section 4.4

SRQ5: What are the key conceptual findings that need to be integrated into a conceptual framework?

Since there is a strong relationship between the research artefacts, the previous work enabled the development of the conceptual framework and successful fulfilment of research objective 4, see Table 9.5 for the specific section. The conceptual framework aimed to answer the question regarding how to implement the concept map of theory in a more practical way. During the initial design of the conceptual framework, it was realised that more development dimensions needed to be added to both the hierarchical taxonomy as well as the concept map. The inclusion of the six development dimensions enabled a structured approach to the networked BMI concept, addressing aspects on the strategic, tactical, and operational level of the business net, from a VN perspective. The focus of this study, however, remained on the tactical level, therefore the conceptual framework particularly focused on the inclusion of steps regarding the development and evaluation of the networked BM as well as the SBN configuration process and strategic business net features.

Table 9.5: Research objectives addressed in support of answering SRQ5

Research objectives	**Section where reported**
Objective 4: To *analyse* and *integrate* the research results by *designing* a conceptual framework.	Section 4.6

SRQ6: What aspects must be included in a potential management framework, based on the conceptual framework and external evaluations?

To effectively answer the sixth research question, research objective 5 was pursued and fulfilled, see Table 9.6 for the specific sections. Building and elaborating on the conceptual framework through the addition of more details regarding activities, guidelines, tools and considerations, the management framework aimed to add more detail on the 'how' of the practical implementation of the concept map of theory. The potential audience or users of the framework and tool are not necessarily business experts, and therefore it was of utmost importance to convert the abstract and high-level research artefacts into a more practical framework able to provide guidance and structure to users regarding the networked BMI endeavour.

The iterative development and evaluation of the framework consisted of various steps to ensure the framework is both rigorous and relevant from a business as well as a manufacturing perspective. The framework was developed and grounded in theory and based on the feedback obtained from the subject-matter experts, most of the activities were deemed relevant with adequate perceived importance rankings, therefore, no major changes needed to be made to the framework. Regarding the feedback received during the semi-structured interviews, most experts recognised the framework's potential and value it can add to manufacturing SMMEs or entrepreneurs. However, a few of the experts (the minority) recognised the framework's value but questioned the applicability to SMMEs as they believed the framework might be too comprehensive and too technical for the audience. All the experts did however acknowledge there is not a one-size-fits all approach to BMI and therefore comprehensiveness, but also customisability are important aspects of a management framework.

Table 9.6: Research objectives addressed in support of answering SRQ6

Research objectives	**Section where reported**
Objective 5.a: To *convert* the conceptual framework into a management framework.	Section 6.3
Objective 5.b: To iteratively *develop* and *evaluate* the management framework using appropriate methods.	Sections 6.3 – 6.8

SRQ7: What insights can be obtained through the demonstration of the management framework within the context of this study?

Addressing this sub research-question and fulfilling research objective 6, see Table 9.7 for the specific section, was very important as the context of this study was prescribed and therefore the application value of the research artefacts to the contextual application area needed to be demonstrated. Since a more fundamental gap in the literature was recognised at the beginning of this study, it was assumed that fulfilling the identified gap would have value within the context of this study. Although the framework was only partially applied, the framework (and the SBN configuration process) indeed proved to be valuable and do have the potential to provide guidance for potential users to develop the emerging industry. Based on the feedback received from the various subject-matter experts, it is believed that the other phases that were not demonstrated will be valuable and applicable once they can be executed within the real-life context of this study.

Furthermore, an overview and analysis of the context of this study were also presented in this document that can also be used by future researchers or potential users or investors within the emerging industry as there are not many literature studies that synthesise the different aspects related to the context of the study yet.

Table 9.7: Research objectives addressed in support of answering SRQ7

Research objectives	Section where reported
Objective 6: To *demonstrate* the functionality of the framework to support SMMEs in the introduction and adoption of AM, specifically to produce cemented tungsten carbide products.	Section 7.5

MRQ: What main concepts, processes, steps, activities, tools, and considerations need to be included in a networked business model innovation framework and tool to support SMMEs in the development and configuration of their value networks and networked BMs, with application value to the adoption of AM within South African hardmetals sector?

The fulfilment of the research objectives and the development of the various research artefacts enabled the researcher to answer the main research question of this study successfully. Figure 9.3 below illustrates the systematic approach (Part A-F) followed throughout this study to ultimately create the management tool, answering the MRQ.

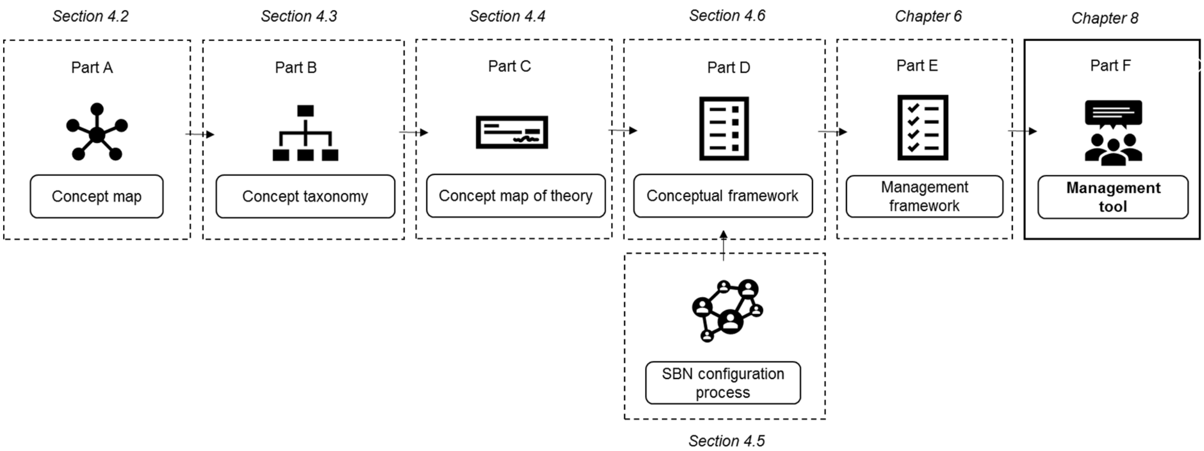


Figure 9.3: Systemic approach followed throughout this study

To effectively fulfil the last two research objectives, see Table 9.8 for the specific sections, the final evaluated management framework was converted into a management tool, and future research areas were proposed. The aim of the management tool was to create a comprehensive understanding of the steps, activities, and concepts needed to consider during the networked BMI process. The tool provides an attempt to structure the networked BMI concept in a logical manner by incorporating and synthesising the most important fundamental concepts, including elements from fundamental theoretical frameworks within each of the three primary literature bodies, considering the context of the study (AM, SMME, SA).

The inclusion of the steps that form part of the SBN configuration process tool, in the management tool, enable and guide the user to visualise the configuration of the VN (strategic business net) on both the strategic and tactical level. This illustrates and emphasises the close interrelationship of the network's configuration with the networked BM and other aspects within the framework. Furthermore, throughout this study, the configuration of the strategic business net proved to be a fundamental part of the networked BMI concept and endeavour.

Table 9.8: Research objectives addressed in support of answering the MRQ

Research objectives	**Section where reported**
Objective 7: To *convert* the management framework into a management tool.	Section 8.9
Objective 8: To *recommend* areas of future research related to this study that may be pursued in the future.	Section 9.5

9.3 Contributions and significance of the study

Several contributions of this study are worth highlighting as this study demonstrated how knowledge and artefacts from the BM, BMI and VN literature bodies, such as theories, frameworks, and methodologies, can be synthesised and presented into a comprehensive management framework to support SMMEs in addressing real-world problems. The contribution of this study is primarily twofold. Firstly, it contributes to the literature body on networked BMs, networked BMI and VNs and secondly, it adds value towards the business-related research regarding the adoption of emerging AM technologies, specifically related to cemented tungsten carbide, by manufacturing SMMEs in South Africa.

The research artefacts developed throughout this study and discussed within this document contribute to the literature and knowledge bodies on networked BMs and networked BMI in various ways:

- Firstly, by analysing and synthesising the literature bodies through a structured literature review and presenting the fundamental concepts, with definitions as a concept inventory), and suggesting relationships as a **concept map** (Section 4.2). The concept inventory provides a tangible set of refined and contextualised concepts that may be considered to inform or understand networked BMI. The relationships depicted between the concepts in the concept map provide a means to consider the interrelated nature of the concepts that help to describe what networked BMI may entail.
- Secondly, by presenting a new **networked BM framework**, consisting of four value dimensions and associated elements (Section 8.4). The networked BM may be used as part of the networked BMI process or on its own to analyse or develop BMs on a network-level, thus having the network as the unit of analysis.
- Thirdly, by proposing a new **hierarchical taxonomy** on the networked BMI concept (Section 8.5). The hierarchical taxonomy depicts the main facets and classes, with associated relationships that provide a more structured and logical approach to what a networked BMI framework should address and how to approach it.
- Fourthly, by proposing a **concept map of theory** to illustrate the networked BMI concept (Section 8.6). The concept map of theory provides a comprehensive, visual understanding of the networked BMI process through the synthesis of existing frameworks and may be used as a basis to further develop theoretical frameworks of the networked BMI concept.
- And finally, by proposing a **management framework** and **management tool** to guide users in the networked BMI endeavour (Section 9.8 – 9.9). The management tool provides systematic guidance for the user to implement networked BMI, although the technology development dimension is focused on AM, it can easily be customised to be applicable to any emerging technology. Furthermore, the management tool

provides a better comprehensive understanding of the networked BMI process on a strategic, tactical, and operational level, utilising the proposed six development dimensions.

The remaining two research artefacts specifically contribute to the VN literature body:

- Firstly, by proposing a set of **strategic business net features** (Section 8.5) that include some of the most important concepts regarding VN development. These features contribute to a better understanding of the VN amidst BMI and provide important contextual considerations for users.
- Secondly, by proposing a **strategic business net configuration process** (Section 8.7) that can be used as a standalone tool or can be implemented as part of the management tool. The process presents an integrated and structured approach to guide the user in a stepwise manner to visually analyse or develop a VN on the strategic and tactical level.

The second part of the research's significance relates to the contributions made towards the understanding of the contextual application domain of this study which relates to the adoption of AM technologies by manufacturing SMMEs in South Africa to manufacture cemented tungsten carbide products.

- Firstly, this study demonstrated the utility of the BM, BMI and VN literature bodies towards the development of the AM industry in South Africa.
- Secondly, this study demonstrated the close relationship between the development of the BM and VN (or strategic business net) in relation to the technology development.
- Thirdly, by proposing a possible configuration of a strategic business net and networked BM for the adoption of AM within the tooling industry to provide a starting point for the emerging industry's development.
- And finally, this study demonstrated that the adoption of AM, including AM technologies associated with cemented tungsten carbide, needs to include important business aspects, approached from a VN perspective, starting within the R&D phase, to ensure successful market introduction.

9.4 Limitations of the study

In critically reflecting on this study, the researcher acknowledges certain limitations to the research approach and findings. In addition to the limitations related to the structured literature review already described in Section 3.7, as well as during the reflection on SRQ1, the following limitations are worth noting.

Firstly, the selection of the primary data set, as well as the identification of the initial set of concepts and theoretical frameworks were all performed by the researcher alone (in contrast to a panel of researchers as with a formal systematic review) and therefore bias may be present in the researcher's interpretation of the content. Additionally, the concepts and theoretical frameworks considered was limited to the primary data set. Therefore, the inclusion of additional search terms and articles may result in the identification and inclusion of additional concepts and frameworks that would have a direct impact on all the research artefacts.

Secondly, the design of the research artefacts, including the relationships suggested between the concepts identified as well as between the selected theoretical frameworks were based on the researcher's interpretation and understanding and may therefore be limited. The relationships between the concepts in the concept map were not evaluated and were only used as a basis to inform the other research artefacts that were evaluated.

Thirdly, the selection of the facets and classes, as well as the relationships contained in the hierarchical taxonomy were grounded in literature, but also the researcher's understanding that may be limited. However, to mitigate the risk of bias, the entire taxonomy was evaluated by some of the business subject-matter experts. The taxonomy was also constantly indirectly evaluated to ensure alignment with the other research artefacts, the researcher however acknowledges that additional facets, classes, and relationships may exist.

Fourthly, the development and design of the conceptual and management frameworks were also done by the researcher alone. The fact that the researcher has no industry knowledge or practical experience may have limited the framework. However, the inclusion of various subject-matter experts to evaluate the activities contained in the management framework aimed to minimise the risk of the framework being not comprehensive, not practical, or not applicable to SMMEs.

The interview findings and subsequent changes to the management framework were also subject to the researcher's interpretation which may result in bias. Another limitation concerns the evaluation of the management framework through the structured questionnaire containing all the activities. It is noted that the questionnaire may have been too long which may have influenced the expert's ratings. Furthermore, due to time limitations, the results of the questionnaires were presented and interpreted in a very simple manner, and no extensive statistical calculations were done as only a small sample was considered. If more in-depth analyses were done, more insights may have been obtained and may have led to other framework modifications.

Furthermore, the contextual application that considered a theoretical story only reflected on a single possible case and application, namely the possible introduction of AM in the tooling industry to produce cemented tungsten carbide products. The relevant resources and studies were identified and interpreted by only one researcher. The completion of the configuration of a possible strategic business net and networked BM required a few assumptions to be made and therefore fictionalised elements were included based on the researcher's understanding (making the contextual application a story rather than a case study). The use of a workshop to gather more accurate insights and information about the industry and application of AM would have been an improved approach, however, due to time constraints and the Covid-19 restrictions it was not a feasible approach for this study.

9.5 Suggested future work

Several opportunities to expand and improve the contributions of this study were identified in the execution of the research and are discussed below.

This study focused on the development of the management tool and did not apply the final tool within the identified application environment. The application of the management tool in the contextual application environment using a workshop with role-players from a specific manufacturing SMME (real-life case study) will provide valuable insights regarding the applicability and relevance of the tool. It will furthermore provide valuable feedback regarding which aspects the management tool best supports within the business development effort as well as to inform further modifications to improve its utility and enable better support for manufacturing SMMEs.

Although the management tool developed in this study aims to support SMMEs in the adoption of AM, it holds the potential to support networked BM endeavours outside the AM environment and may include other emerging technologies. Since one part of the evaluation of the SBN configuration process, as well as the management framework, was done from a business perspective, this is not too much of a stretch. Adapting the framework to be a general framework for emerging technology adoption will not necessarily require a new theoretical foundation since the development of most of the research artefacts were initially done from a business perspective with links to technology development in general. Therefore, future work may include the adoption of the framework to be more generic (specifically adopting the activities associated with the *AM technology* development dimension) and applying the management framework in other contexts concerning emerging technology adoption.

Furthermore, the management tool may be further developed to be more dynamic in nature, maybe using another software or another approach to make the management tool more practical and appropriate for the work environment. Since the framework is a very long and extensive process that may be too much work for a busy person working in an SMME, the entire framework could be simplified.

Regarding the other research artefacts developed throughout this study, future research and work can include some of the adjacent literature bodies (concerning the BM, BMI and VN literature bodies) that may contain additional theoretical concepts and frameworks that may be used to improve the proposed artefacts.

References

1. Abdelkafi, N., Makhotin, S. & Posselt, T. 2013. Business Model Innovations for Electric Mobility — What can be Learned from Existing Business Model Patterns? *International Journal of Innovation Management*. 17(01): p.134.
2. Achrol, R.S. 1997. Changes in the theory of interorganizational relations in marketing: Toward a network paradigm. *Journal of the Academy of Marketing Science*. 25(1): p.56.
3. Adrodegari, F., Saccani, N. & Kowalkowski, C. 2016. A Framework for PSS Business Models: Formalization and Application. *Procedia CIRP*. 47: p.519-524.
4. Ågerfalk, P. & Fitzgerald, B. 2008. Outsourcing to an Unknown Workforce: Exploring Opensourcing as a Global Sourcing Strategy. *MIS Quarterly*.
5. Al-Debei, M.M., Al-Lozi, E.M. & Fitzgerald, G. 2013. Engineering Innovative Mobile Data Services: Developing a Model for Value Network Analysis and Design. *Business Process Management Journal* 19: p.7-20.
6. Al-Debei, M.M. & Avison, D. 2010. Developing a unified framework of the business model concept. *European Journal of Information Systems*. 19(3): p.359-376.
7. Al-Debei, M.M. & Fitzgerald, G. 2010 The design and engineering of mobile data services: Developing an ontology based on business model thinking. in *IFIP Working Conference on Human Benefit through the Diffusion of Information Systems Design Science Research*. Springer.
8. Alcácer, V. & Cruz-Machado, V. 2019. Scanning the Industry 4.0: A Literature Review on Technologies for Manufacturing Systems. *Engineering Science and Technology, an International Journal*. 22(3): p.899-919.
9. Ålgårdh, J., Strondl, A., Karlsson, S. & Farre, S., *Stateof-the-Art for Additive Manufacturing of Metals. Report 2016-03898—State-of-the-art—Version 2.1*. 2017, Swedish Arena for Additive Manufacturing of Metals.
10. Allee, V. 1999. The art and practice of being a revolutionary. *Journal of knowledge management*.
11. Allee, V. 2002. *The Future of Knowledge: Increasing Prosperity through Value Networks*. Boston: Butterworth-Heinemann.
12. Allee, V. 2008. Value network analysis and value conversion of tangible and intangible assets. *Journal of Intellectual Capital*. 9: p.5-24.
13. Amit, R. & Zott, C. 2012. Creating value through business model innovation. *MIT Sloan Management Review*. 53(1): p.40-49.
14. Anon. 2014. *Mind Mapping: Writing Centre Learning Guide*. Available: https://www.adelaide.edu.au/writingcentre/sites/default/files/docs/learningguide-mindmapping.pdf. [2021, March 20]
15. Aspara, J., Hietanen, J. & Tikkanen, H. 2010. Business model innovation vs replication: financial performance implications of strategic emphases. *Journal of Strategic Marketing*. 18(1): p.39-56.
16. Aspara, J., Lamberg, J.-A., Laukia, A. & Tikkanen, H. 2013. Corporate business model transformation and inter- organisational cognition: The case of Nokia. *Long Range Planning*. 46: p.459-474.
17. ASTM. 2012. *Standard terminology for additive manufacturing technologies*. Astm International.
18. Baden-Fuller, C. & Haefliger, S. 2013. Business Models and Technological Innovation. *Long Range Planning*. 46(6): p.419-426.
19. Baden-Fuller, C. & Mangematin, V. 2015. Business models and modelling business models. *Advances in Strategic Management*. 33: p.xi-xxii.
20. Bankvall, L., Dubois, A. & Lind, F. 2017. Conceptualizing business models in industrial networks. *Industrial Marketing Management*. 60: p.196-203.
21. Biem, A. & Caswell, N. 2008 A Value Network Model for Strategic Analysis. IEEE.

22. Biem, A. & Caswell, N. 2008 A value network model for strategic analysis. in *Proceedings of the 41st annual Hawaii international conference on system sciences (HICSS 2008)*. IEEE.
23. Blaikie, N. & Priest, J. 2019. *Designing social research: The logic of anticipation*. John Wiley & Sons.
24. Bobzin, K. 2017. High-performance coatings for cutting tools. *CIRP Journal of Manufacturing Science and Technology*. 18: p.1-9.
25. Bocken, N., Short, S., Padmakshi Rana, P. & Evans, S. 2013. A value mapping tool for sustainable business modelling. *Corporate Governance: The International Journal of Business in Society*. 13(5): p.482-497.
26. Bogers, M., Hadar, R. & Bilberg, A. 2016. Additive manufacturing for consumer-centric business models: Implications for supply chains in consumer goods manufacturing. *Technological forecasting and social change*. 102: p.225-239.
27. Bogers, M., Sund, K.J. & Villarroel, J.A. 2015. *The Organizational Dimension of Business Model Exploration: Evidence from the European Postal Industry*, in N.J. Foss and T. Saebi, Editors. *Business Model Innovation : The Organizational Dimension*. Oxford: Oxford University Press.
28. Boons, F., Montalvo, C., Quist, J. & Wagner, M. 2013. Sustainable innovation, business models and economic performance: an overview. *Journal of Cleaner Production*. 45: p.1-8.
29. Boos, W., Pitsch, M., Kuhlmann, T., Stark, M. & Rittstieg, F., *Tooling in South Africa*. 2014, Fraunhofer.
30. Bouwman, H., de Vos, H. & Haaker, T. 2008. *Mobile service innovation and business models*. Springer Science & Business Media.
31. Bremen, S., Meiners, W. & Diatlov, A. 2012. Selective Laser Melting. *Laser Technik Journal*. 9(2): p.33-38.
32. Breuer, H. & Ludeke-Freund, F. 2017. Values-based network and business model innovation *International Journal of Innovation Management*. 21(03): p.1750028.
33. Brunswicker, S., Wrigley, C. & Bucolo, S. 2013. *Business Model Experimentation: What is the Role of Design-Led Prototyping in Developing Novel Business Models?* p. 139-151.
34. Bryman, A., Bell, E., Hirschsohn, P., Santos, A.d., Toit, J.d.*, et al.* 2014. *Research methodology : business and management contexts*.
35. Bryson, J.M., Crosby, B.C., Stone, M.M. & Saunoi-Sandgren, E.O., *Designing and Managing Cross-Sector Collaboration: A Case Study in Reducing Traffic Congestion*. 2009, IBM Center for The Business of Government: Washington, D.C.
36. Bucherer, E., Eisert, U. & Gassmann, O. 2012. Towards Systematic Business Model Innovation: Lessons from Product Innovation Management. *Creativity and Innovation Management*. 21.
37. Burger, J., A., Grobbelaar, S.S. & Sacks, N. 2022. The development of a decision support tool to assist manufacturing SMEs during adoption and exploitation of novel manufacturing technologies. Master. Stellenbosch: Stellenbosch University.
38. BusinessTech. 2019. *These are the new definitions for micro, small and medium enterprises in South Africa*. Available: https://businesstech.co.za/news/business/305592/these-are-the-new-definitions-for-micro-small-and-medium-enterprises-in-south-africa/. [2021, February 19]
39. BusinessTech. 2021. *South Africa's motoring industry has big plans*. Available: https://businesstech.co.za/news/motoring/476620/south-africas-motoring-industry-has-big-plans/. [2021, August 15]
40. Camarinha-Matos, L.M. & Afsarmanesh, H. 2005. Collaborative networks: a new scientific discipline. *Journal of intelligent manufacturing*. 16(4-5): p.439-452.
41. Cambridge, *Cambridge Dictionary*, in *Cambridge Dictionary*. 2021, Cambridge University: Cambridge.
42. Casadesus-Masanell, R. & Ricart, J.E. 2010. From strategy to business models and onto tactics. *Long Range Planning*. 43: p.195-215.

43. Casadesus-Masanell, R. & Zhu, F. 2013. Business model innovation and competitive imitation: The case of sponsor-based business models. *Strategic Management Journal*. 34(4): p.464-482.
44. Castells, M. 1996. *The Rise of the Network Society*. Blackwell Publishers, Inc.
45. Ceratizit. 2021. Available: https://www.ceratizit.com/int/en.html. [2021, August 16]
46. Chesbrough, H. 2007. Business model innovation: it's not just about technology anymore. *Strategy & Leadership*. 35(6): p.12-17.
47. Chesbrough, H. 2010. Business Model Innovation: Opportunities and Barriers. *Long Range Planning*. 43(2): p.354-363.
48. Chesbrough, H. & Rosenbloom, R.S. 2002. The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. *Industrial and corporate change*. 11(3): p.529-555.
49. Chinchane, A. & Sumant, O. 2021. *Tooling Market by Product Type (Dies & molds, Forging, Jigs & Fixtures, Machine Tools, and Gauges), and End-user Industry (Automotive, Electronics & Electrical Aerospace, Marine & Defense, Plastics Industry, Construction & Mining, and Others): Global Opportunity Analysis and Industry Forecast, 2021–2030*. Available: https://www.alliedmarketresearch.com/tooling-molds-market. [2021, August 10]
50. Chong, L., Ramakrishna, S. & Singh, S. 2018. A review of digital manufacturing-based hybrid additive manufacturing processes. *The International Journal of Advanced Manufacturing Technology*. 95(5-8): p.2281-2300.
51. Christensen, C.M. & Rosenbloom, R.S. 1995. Explaining the attacker's advantage: Technological paradigms, organizational dynamics, and the value network. *Research policy*. 24(2): p.233-257.
52. Clauss, T. 2016. Measuring Business Model Innovation: Conceptualization, Scale Development and Proof of Performance. *R&amp D Management*. 47: p.385-403.
53. Clauß, T., Laudien, S. & Daxböck, B. 2014. Service-dominant logic and the business model concept: Toward a conceptual integration. *International Journal of Entrepreneurship and Innovation Management*. 18: p.266-288.
54. Corallo, A., Errico, F., Latino, M.E. & Menegoli, M. 2019. Dynamic Business Models: a Proposed Framework to Overcome the Death Valley. *Journal of the Knowledge Economy*. 10(3): p.1248-1271.
55. Cotteleer, M., Neier, M. & Crane, J., *3D opportunity in tooling*. 2014, Deloitte.
56. Creswell, J.W. 2009. *Research Design: Qualitative, Quantitative and Mixed Approaches*. 3 ed. California: Sage publications.
57. Creswell, J.W., *Qualitative inquiry: Qualitative inquiry and research design*. 2013, Los Angeles, California: Sage publications.
58. D'Aveni, R. 2015. The 3-D Printing Revolution. *Harvard Business Review*.
59. Dara, M. 2013. Value Networks and Business Models : Formulating and Demonstrating a Methodology for the Development of Value Networks and Alignment of Business Models Based on Design Science Research Methodology. Master. The Netherlands: University of Twente [Online]. Available: https://essay.utwente.nl/63024/.
60. de Beer, D., du Preez, W., Greyling, H. & Prinsloo, F., *A South African Additive Manufacturing Strategy*. 2016, Department: Science and Technology.
61. de Bono, E. 2006. *Perceived Value: When considering value, perception can be as important as reality. From Visual- to Value Perception: The Impact of a New Class of RGBW Display on Mobile Application Statistics Paper*.
62. de Man, A.-P. & Luvison, D. 2019. Collaborative business models: Aligning and operationalizing alliances. *Business Horizons*. 62(4): p.473-482.
63. Despeisse, M., Yang, M., Evans, S., Ford, S. & Minshall, T. 2017. Sustainable Value Roadmapping Framework for Additive Manufacturing. *Procedia CIRP*. 61: p.594-599.
64. Dewa, M., Van der Merwe, A. & Matope, S. 2015. Towards a competitive South African Tooling industry. *International Journal of Social, Behavioral, Educational, Economic and Management Engineering*. 9: p.2463-2468.

65. Dukat, D. 2019. *Additive manufacturing 2016*. Available: https://www.slideshare.net/JacekDukat/additive-manufacturing-2016). [2021, July 22]
66. Eisenhardt, K.M. & Martin, J.A. 2000. Dynamic capabilities: what are they? *Strategic management journal*. 21(10-11): p.1105-1121.
67. FederalCarbideCompany. n.d. *Tungsten Carbide*. Available: https://www.federalcarbide.com/tungsten_carbide.html. [2021, February 19]
68. Fernández, R. & Bonillo, M. 2007. The concept of perceived value: A systematic review of the research. *Marketing Theory* 7: p.427-451.
69. Fielt, E. 2013. Conceptualising business models: Definitions, frameworks and classifications. *Journal of Business Models*. 1(1): p.85-105.
70. Firmansyah, M.R. & Amer, Y. 2013. A review of collaborative manufacturing network models. *International Journal of Materials, Mechanics and Manufacturing*. 1(1): p.6-12.
71. Fjeldstad, Ø. & Haanæs, K. 2001. Strategy tradeoffs in the knowledge and network economy. *Business Strategy Review*. 12(1): p.1-10.
72. Fontana, A. & Frey, J.H. 2005. *The Interview: From Neutral Stance to Political Involvement*. *The Sage handbook of qualitative research*.
73. Fontana, F., Klahn, C. & Meboldt, M. 2019. Value-driven clustering of industrial additive manufacturing applications. *Journal of Manufacturing Technology Management*. 30: p.366-390.
74. Ford, S. & Despeisse, M. 2016. Additive manufacturing and sustainability: an exploratory study of the advantages and challenges. *Journal of Cleaner Production*. 137: p.1573-1587.
75. Foss, N.J. & Saebi, T. 2017. Fifteen Years of Research on Business Model Innovation. *Journal of Management*. 43(1): p.200-227.
76. Franco, D., Miller Devós Ganga, G., de Santa-Eulalia, L.A. & Godinho Filho, M. 2020. Consolidated and inconclusive effects of additive manufacturing adoption: A systematic literature review. *Computers & Industrial Engineering*. 148: p.106713.
77. Frankenberger, K., Weiblen, T., Csik, M. & Gassmann, O. 2013. The 4I-framework of business model innovation: A structured view on process phases and challenges. *International Journal of Product Development*. 18: p.249-273.
78. Fraunhofer. 2019. *Additive manufacturing of carbide machining tools*. Available: https://nachrichten.idw-online.de/2019/10/17/additive-manufacturing-of-carbide-machining-tools/. [2021, July 15]
79. Gambardella, A. & McGahan, A.M. 2010. Business-model innovation: General purpose technologies and their implications for industry structure. *Long Range Planning*. 43: p.262-271.
80. García, J., Collado Ciprés, V., Blomqvist, A. & Kaplan, B. 2019. Cemented carbide microstructures: a review. *International Journal of Refractory Metals and Hard Materials*. 80: p.40-68.
81. Gassmann, O., Frankenberger, K. & Csik, M. 2013. The St. Gallen business model navigator.
82. Gassmann, O., Frankenberger, K. & Sauer, R. 2016. *Exploring the field of business model innovation: New theoretical perspectives*. Springer.
83. Gebler, M., Schoot Uiterkamp, A.J.M. & Visser, C. 2014. A global sustainability perspective on 3D printing technologies. *Energy Policy*. 74(C): p.158-167.
84. Geissdoerfer, M., Savaget, P. & Evans, S. 2017. The Cambridge Business Model Innovation Process. *Procedia Manufacturing*. 8: p.262-269.
85. Geissdoerfer, M. & Weerdmeester, R. 2019. Managing business model innovation for relocalization in the process and manufacturing industry.
86. Geterud, J. & Tegern, S. 2013. Business model innovation an empirically derived framework for early stage business model innovation. Chalmers University of Technology [Online]. Available:
87. Ghezzi, A. 2013. Revisiting Business Strategy Under Discontinuity. *Management Decision*. 51: p.1326-1358.

88. Gibson, I. 2017. The changing face of additive manufacturing. *Journal of Manufacturing Technology Management*.
89. Gliner, J.A., Morgan, G.A. & Leech, N.L. 2011. *Research methods in applied settings: An integrated approach to design and analysis*. Routledge.
90. Golofshani, N. 2003. Understanding Reliability and Validity in Qualitative Research. *The Qualitative Report*. 8(4).
91. Gordijn, J., J.M., A. & J.C., V. 2000. *Business Modeling is not Process Modeling. Conceptual Modeling for E-Business and the Web*. Springer-Verlag.
92. Grant, M.J. & Booth, A. 2009. A typology of reviews: an analysis of 14 review types and associated methodologies. *Health Information & Libraries Journal*. 26(2): p.91-108.
93. Grudinschi, D., Hallikas, J., Kaljunen, L., Puustinen, A. & Sintonen, S. 2015. Creating value in networks: A value network mapping method for assessing the current and potential value networks in cross-sector collaboration. *The Innovation Journal*. 20(2): p.2-27.
94. Håkansson, H. & Johanson, J. 1992. A model of industrial networks. p.28-34.
95. Håkansson, H. & Snehota, I. 1989. No business is an island: The network concept of business strategy. *Scandinavian Journal of Management*. 5(3): p.187-200.
96. Håkansson, H. & Snehota, I., *Developing relationships in business networks*. 1995, London: Routledge.
97. Hämäläinen, M. 2014 Customer centric and value-based business model design : impacts of the additive manufacturing technology on firm's business model.
98. Hannibal, M. 2020. The influence of additive manufacturing on early internationalization: considerations into potential avenues of IE research. *Journal of International Entrepreneurship*.
99. Hedman, J. & Kalling, T. 2003. The business model concept: theoretical underpinnings and empirical illustrations. *European journal of information systems*. 12(1): p.49-59.
100. Heikkilä, M. & Kuivaniemi, L. 2012. Ecosystem Under Construction: An Action Research Study on Entrepreneurship in a Business Ecosystem. *Technology Innovation Management Review*. 2: p.18-24.
101. Hennemann, S. & Liefner, I. 2008. Proposing Bipartite Network Analysis for the Evaluation of Regional Innovation Systems-/-Regions, Actors, and Content.
102. Henning, M. 2019. A conceptual approach to increase competitiveness in a typical South African manufacturing SME. Stellenbosch: University of Stellenbosch [Online]. Available: https://scholar.sun.ac.za/handle/10019.1/105946.
103. Henriques, E. & Peças, P. 2012. *New Business Models for the Tooling Industry*. p. 1-33.
104. Herrala, M. & Pakkala, P., *Value-creating networks – A conceptual model and analysis*. 2009, University of Oulu.
105. Hevner, A. 2007. A Three Cycle View of Design Science Research. *Scandinavian Journal of Information Systems*. 19.
106. Hevner, A.R. & Chatterjee, S. 2004. Design Science Research in Information Systems. *MIS Quarterly*. 28(1): p.1-9.
107. Hevner, A.R., March, S.T. & Park, J. 2004. Design Research in Information Systems Research. *MIS Quaterly*. 28(1): p.65-84.
108. Ibarra Zuluaga, D., Ganzarain Epelde, J. & Igartua López, J.I. 2018. Business model innovation through industry 4.0: a review.
109. IDMentors. 2017. *Case Study, Scenario, Story: What's the Difference?* Available: https://purnima-valiathan.com/case-study-scenario-story-whats-difference/. [20210, November 20]
110. Iivari, M.M., Ahokangas, P., Komi, M., Tihinen, M. & Valtanen, K. 2016. Toward ecosystemic business models in the context of industrial internet. *Journal of Business Models*. 4(2).

111. Jocevski, M., Arvidsson, N. & Ghezzi, A. 2020. Interconnected business models: present debates and future agenda. *Journal of Business & Industrial Marketing*. 35(6): p.1051-1067.
112. Johnson, M.W. 2010. Seizing the white space. Business Model Innovation for Growth and Renewal. *Harvard Business School Press: Boston*.
113. Johnson, M.W., Christensen, C.M. & Kagermann, H. 2008. Reinventing your business model. 86(12): p.57-68.
114. Kage, M., Drewel, M., Gausemeier, J. & Schneider, M. 2016. Value Network Design for Innovations: Developing Alternative Value Network Drafts. *Technology Innovation Management Review*. 6(7).
115. Kajornboon, A.B. 2005. Using interviews as research instruments. *E-journal for Research Teachers*. 2(1): p.1-9.
116. Kalidas, S., Magwentshu, N. & Rajagopaul, A., *How South African SMEs can survive and thrive post COVID-19*. 2020, McKinsey & Company: South Africa.
117. Kaminski, J. 2011. Diffusion of innovation theory. *Canadian Journal of Nursing Informatics*. 6(2): p.1-6.
118. Karevska, S. 2019. *How additive manufacturing is becoming a core process and value driver*. Available: https://www.ey.com/en_gl/consulting/how-additive-manufacturing-is-becoming-a-core-process-and-value-driver. [2021, July 21]
119. Khalifa, A.S. 2004. Customer value: a review of recent literature and an integrative configuration. *Management Decision*. 42: p.645-666.
120. Khallaf, R., Naderpajouh, N. & Hastak, M. 2017 Systematic Literature Review as a Methodology for Identifying Risks. in *The Ninth International Conference on Construction in the 21st Century (CITC-9)*. Dubai.
121. Khanagha, S., Volberda, H. & Oshri, I. 2014. Business model renewal and ambidexterity: structural alteration and strategy formation process during transition to a Cloud business model. *R&D Management*. 44(3): p.322-340.
122. Kitchenham, B. & Charters, S. 2007. *Guidelines for performing Systematic Literature reviews in Software Engineering Version 2.3,"*. EBSE Tech. Rep.
123. Kölsch, P., Herder, C., Zimmermann, V. & Aurich, J. 2017. A novel concept for the development of availability-oriented business models. *Procedia CIRP*. 64: p.340-344.
124. Komulainen, H., Tuija, M., Sinisalo, J., Tahtinen, J. & Ulkuniemi, P. 2006. Business model scenarios in mobile advertising. *International Journal of Internet Marketing and Advertising*. 3(3): p.254-270.
125. Kritzinger, W., Steinwender, A., Lumetzberger, S. & Sihn, W. 2018. Impacts of Additive Manufacturing in Value Creation System. *Procedia CIRP*. 72: p.1518-1523.
126. Kuhn, T.S., *The structure of scientific revolutions*. 1962: Chicago and London.
127. Kühn, W. & Louw, L. 2017. Business Model Innovation For Seizing White Space Opportunities: A Design Framework. Stellenbosch: Stellenbosch University [Online]. Available: https://scholar.sun.ac.za/handle/10019.1/103402.
128. Laya, A., Jocevski, M., Ghezzi, A. & Markendahl, J., *Business model as relational aggregator: Exploring business relationships*, in *INDEK Working Paper Series*. 2016, Royal Institute of Technology.
129. Laya, A., Markendahl, J. & Lundberg, S. 2018. Network-centric business models for health, social care and wellbeing solutions in the internet of things. *Scandinavian Journal of Management*. 34(2): p.103-116.
130. Leal-Ayala, D.R., Allwood, J.M., Petavratzi, E., Brown, T.J. & Gunn, G. 2015. Mapping the global flow of tungsten to identify key material efficiency and supply security opportunities. *Resources, Conservation and Recycling*. 103: p.19-28.
131. Leminen, S., Rajahonka, M., Westerlund, M. & Siuruainen, R. 2015. *Ecosystem business models for the Internet of Things*.
132. Leminen, S., Rajahonka, M., Westerlund, M. & Wendelin, R. 2018. The future of the Internet of Things: toward heterarchical ecosystems and service business models. *Journal of Business & Industrial Marketing*.

133. Leung, W.-C. 2001. *How to design a questionnaire*. Available: https://jan.ucc.nau.edu/~pms/cj355/readings/How%20to%20design%20a%20questionnaire.pdf. [2021, February 20]
134. Leviäkangas, P. & Öörni, R. 2020. From business models to value networks and business ecosystems – What does it mean for the economics and governance of the transport system? *Utilities Policy*. 64: p.101046.
135. Lindgardt, Z. & Reeves, M. 2011. *How to develop and implement a new business model.* Available: http://www.amanet.org/training/media_files/2010/develop-new-business-model/index.htm. [2020, September 16]
136. Lindgren, P., Taran, Y. & Boer, H. 2010. From single firm to network-based business model innovation. *International Journal of Entrepreneurship and Innovation Management*. 12(2): p.122-137.
137. MacGill, M. 2019. *What is a systematic review in research?* Available: https://www.medicalnewstoday.com/articles/281283. 21/04/2020]
138. Malherbe, D. 2007. Benchmarking in the South African tool and die manufacturing industry. Stellenbosch: Stellenbosh University [Online]. Available:
139. Manogharan, G., Wysk, R., Harrysson, O. & Aman, R. 2015. AIMS – A Metal Additive-hybrid Manufacturing System: System Architecture and Attributes. *Procedia Manufacturing*. 1: p.273-286.
140. March, S.T. & Smith, G.F. 1995. Design and natural science research on information technology. *Decision Support Systems*. 15(4): p.251-266.
141. Marchese, K. & Sniderman, B. 2017. *3D opportunity for business capabilities*. Available: https://www2.deloitte.com/za/en/insights/focus/3d-opportunity/additive-manufacturing-business-capabilities.html. [2021, May 24]
142. Markendahl, J., Lundberg, S., Kordas, O. & Movin, S. 2017 On the role and potential of IoT in different industries: Analysis of actor cooperation and challenges for introduction of new technology. in *2017 Internet of Things Business Models, Users, and Networks*. IEEE.
143. Markides, C. 2006. Disruptive Innovation: In Need of Better Theory*. *Journal of Product Innovation Management*. 23(1): p.19-25.
144. Martinsuo, M. & Luomaranta, T. 2018. Adopting additive manufacturing in SMEs: exploring the challenges and solutions. *Journal of Manufacturing Technology Management*. 29(6): p.937-957.
145. Masood, T. & Sonntag, P. 2020. Industry 4.0: Adoption challenges and benefits for SMEs. *Computers in Industry*. 121: p.103261.
146. Maxwell, J.A. 2013. *Qualitative Research Design: An Interactive Approach*. Third edition ed. California: SAGE Publications, Inc.
147. Mellor, S., Hao, L. & Zhang, D. 2014. Additive manufacturing: A framework for implementation. *International Journal of Production Economics*. 149: p.194-201.
148. Mezger, F. 2014. Toward a capability-based conceptualization of business model innovation: insights from an explorative study. *R&D Management*. 44(5): p.429-449.
149. Michalik, A., Besenfelder, C. & Henke, M. 2019. Servitization of small- And medium-sized manufacturing enterprises: Facing barriers through the Dortmund management model. 52(13): p.2326-2331.
150. Miles, M.B., Huberman, A.M. & Saldana, J. 2014. *Qualitative Data Analysis: A Methods Sourcebook.*: SAGE Publications Ltd (CA).
151. Mitchell, D. & Coles, C. 2004. Business Model Innovation Breakthrough Moves. *Journal of Business Strategy*. 25: p.16-26.
152. Mittal, S., Khan, M.A., Romero, D. & Wuest, T. 2018. A critical review of smart manufacturing & Industry 4.0 maturity models: Implications for small and medium-sized enterprises (SMEs). *Journal of manufacturing systems*. 49: p.194-214.
153. Moingeon, B., Yunus, M. & Lehmann-Ortega, L. 2010. Building Social Business Models: Lessons from the Grameen Experience. *Long Range Planning*. 43: p.308-325.
154. Möller, K. & Rajala, A. 2007. Rise of strategic nets—New modes of value creation. *Industrial marketing management*. 36(7): p.895-908.

155. Möller, K., Rajala, A. & Svahn, S. 2005. Strategic business nets - Their type and management. *Journal of Business Research*. 58: p.1274-1284.
156. Morris, M., Schindehutte, M. & Allen, J. 2005. The Entrepreneur's Business Model: Toward a Unified Perspective. *Journal of Business Research*. 58: p.726-735.
157. Müller-Stevens, G. & Lechner, C. 2005. Strategisches Management: Wie strategische Initiativen zum Wandel führen. *Stuttgart: Schäffer-Pöschel Verlag*.
158. Müller, J.M. 2019. Business model innovation in small- and medium-sized enterprises: Strategies for industry 4.0 providers and users. *Journal of Manufacturing Technology Management*.
159. Müller, J.M., Buliga, O. & Voigt, K.-I. 2018. Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. *Technological Forecasting and Social Change*. 132: p.2-17.
160. Nekoo, A.R.H., Ashourizadeh, S. & Zarei, B. 2015. Designing network-based business model ontology. *International Journal of Networking and Virtual Organisations*. 15(4): p.299-318.
161. Nenonen, S. & Storbacka, K. 2010. Business model design: Conceptualizing networked value co-creation. *International Journal of Quality and Service Sciences*. 2: p.43-59.
162. Ngongoni, C.N. 2021. The Role of Innovation Intermediaries in Developing Healthcare Innovation Ecosystems: Value Co-Creation through Platforms. Stellenbosch: Stellenbosh University [Online]. Available: https://scholar.sun.ac.za/handle/10019.1/109814.
163. Niaki, M.K. & Nonino, F. 2016. Additive manufacturing management: a review and future research agenda. *International Journal of Production Research*. 55: p.1-21.
164. Normann, R. & Ramírez, R. 1993. From Value Chain to Value Constellation: Designing Interactive Strategy. *Harvard Business Review*. 71: p.65-77.
165. Öberg, C., Shams, T. & Asnafi, N. 2018. Additive Manufacturing and Business Models: Current Knowledge and Missing Perspectives. *Technology Innovation Management Review*. 8: p.15-33.
166. Oettmeier, K. & Hofmann, E. 2016. *3D-Printing: How Additive Manufacturing Impacts Supply Chain Business Processes and Management Components*.
167. Oksanen, P., Hallikas, J. & Sissonen, H. 2010. The evolution of value networks. . *International Journal of Networking and Virtual Organisations*. 7: p.381-398.
168. Orellano, M., Lambey-Checchin, C., Medini, K. & Neubert, G. 2018 Towards an integration of lifecycle thinking into PSS business models.
169. Ortt, R. 2016. Guest editorial. *Journal of Manufacturing Technology Management*. 27(7): p.890-897.
170. Osterwalder, A. 2004 The business model ontology a proposition in a design science approach.
171. Osterwalder, A. & Pigneur, Y. 2009. *Business Model Generation*. Hoboken, New Jersey: Wiley & Sons.
172. Osterwalder, A. & Pigneur, Y. 2010. *Business model generation: a handbook for visionaries, game changers, and challengers*. John Wiley and Sons.
173. Osterwalder, A., Pigneur, Y. & Tucci, C.L. 2005. Clarifying business models: Origins, present, and future of the concept. *Communications of the association for Information Systems*. 16(1): p.1.
174. Oxford, *Lexicon*, in *Lexicon*. 2021, Oxford University: Oxford.
175. Padmakumar, M. 2020. Additive Manufacturing of Tungsten Carbide Hardmetal Parts by Selective Laser Melting (SLM), Selective Laser Sintering (SLS) and Binder Jet 3D Printing (BJ3DP) Techniques. *Lasers in Manufacturing and Materials Processing*. 7(3): p.338-371.
176. Palo, T. & Tähtinen, J. 2011. A Network Perspective on Business Models for Emerging Technology-Based Services. *Journal of Business & Industrial Marketing*. Vol. 26: p.377–388.

177. Palo, T. & Tähtinen, J. 2013. Networked business model development for emerging technology-based services. *Industrial Marketing Management*. 42(5): p.773-782.
178. Parolini, C. 1999. *The Value Net: A Tool for Competitive Strategy*. England: John Wiley and Sons.
179. Patel, S. 2015. *The research paradigm – methodology, epistemology and ontology – explained in simple language*. Available: https://salmapatel.co.uk/academia/the-research-paradigm-methodology-epistemology-and-ontology-explained-in-simple-language/. [2020, June 25]
180. Peffers, K., Tuunanen, T., Rothenberger, M. & Chatterjee, S. 2007. A design science research methodology for information systems research. *Journal of Management Information Systems*. 24: p.45-77.
181. Peppard, J. & Rylander, A. 2006. From Value Chain to Value Network: Insights for Mobile Operators. *European Management Journal*. 24: p.128-141.
182. Pereira, A.C. & Romero, F. 2017. A review of the meanings and the implications of the Industry 4.0 concept. *Procedia Manufacturing*. 13: p.1206-1214.
183. Petticrew, M. & Roberts, H. 2006. *Systematic Reviews in the Social Sciences: a practical guide*. Malden: MA: Blackwell Publishing.
184. Pieroni, M.P.P., McAloone, T.C. & Pigosso, D.C.A. 2019. Business Model Innovation for Circular Economy and Sustainability: A Review of Approaches. *Journal of Cleaner Production*. 215: p.198-216.
185. Porat, I. & Hovstadius, K. 2018. A business model perspective on additive manufacturing. Stockholm: KTH Royal Institute of Technology [Online]. Available:
186. Porter, M.E. 1980. *Competitive strategy : techniques for analyzing industries and competitors* 1st Free Press ed. ed. New York: Free Press.
187. Porter, M.E. 1985. Technology and competitive advantage. *Journal of business strategy*.
188. Rabionet, S.E. 2011. How I Learned to Design and Conduct Semi-Structured Interviews: An Ongoing and Continuous Journey. *Qualitative Report*. 16(2): p.563-566.
189. Rapid3D. 2020. Available: https://rapid3d.co.za/. [2021, July 3]
190. Rauch, E., Seidenstricker, S., Dallasega, P. & Hämmerl, R. 2016. Collaborative cloud manufacturing: design of business model innovations enabled by cyberphysical systems in distributed manufacturing systems. *Journal of Engineering*. 2016.
191. Rayna, T. & Striukova, L. 2016. 360° Business Model Innovation: Toward an Integrated View of Business Model Innovation. *Research Technology Management*. 59: p.21-28.
192. Rayna, T. & Striukova, L. 2016. From rapid prototyping to home fabrication: How 3D printing is changing business model innovation. *Technological Forecasting and Social Change*. 102: p.214-224.
193. Remane, G., Hanelt, A., Tesch, J.F. & Kolbe, L. 2016. The Business Model Pattern Database - A Tool for Systematic Business Model Innovation. *International Journal of Innovation Management*. 21(1).
194. Ricciotti, F. 2019. From Value Chain to Value Network: A Systematic Literature Review. *Management Review Quarterly*. p.1-22.
195. Riesener, M., Doelle, C., Ebi, M. & Tittel, J. 2019. Implications of Service-related Business Models on Product Development Processes. *Procedia CIRP*. 80: p.756-761.
196. Rizzo, A., Goel, S., M.L., G., Iglesias, R., Jaworska, L.*, et al.* 2020. The Critical Raw Materials in Cutting Tools for Machining Applications: A Review. *Materials -MDPI*. 13: p.1377.
197. Rogers, H., Baricz, N. & Pawar, K. 2016. 3D Printing Services: Classification, Supply Chain Implications and Research Agenda. *International Journal of Physical Distribution & Logistics Management*. 46: p.1-22.
198. Sandberg, C. & Tinglöv, E. 2021. Business Model Innovation for Additive Manufacturing.
199. Santos, J., Spector, B. & Van der Heyden, L. 2009. Toward a Theory of Business Model Innovation within Incumbent Firms. *SSRN Electronic Journal*.

200. Savolainen, J. & Collan, M. 2020. How Additive Manufacturing Technology Changes Business Models?–Review of Literature. *Additive Manufacturing*. 32: p.101070.
201. Schneider, M., Dumitrescu, R., Gausemeier, J. & Reinhold, J. 2017 Design of Future Value Networks. in *ISPIM Conference Proceedings*. The International Society for Professional Innovation Management (ISPIM).
202. Schuh, G., Kuhlmann, K., Pitsch, M. & Komorek, N. 2013 Digitalization as a key enabler for efficient value creation networks in the tool and die making industry. in *2013 Proceedings of PICMET '13: Technology Management in the IT-Driven Services (PICMET)*.
203. Schuh, G., Potente, T., Schittny, B. & Wittek, A. 2011. Industrial product-service-systems for the tooling industry. *2011 17th International Conference on Concurrent Enterprising*. p.1-8.
204. Shafer, S.M., Smith, H.J. & Linder, J.C. 2005. The power of business models. *Business horizons*. 48(3): p.199-207.
205. Shah, S., Mattiuzza, S., Naghi Ganji, E. & Coutroubis, A. 2017 Contribution of Additive Manufacturing Systems to Supply Chain. IEEE.
206. Simon, H.A. 1996. *The sciences of the artificial*. 3rd ed.: MIT press.
207. Smit, Y. & Watkins, J. 2012. A literature review of small and medium enterprises (small and medium enterprises) risk management practices in South Africa. *African Journal of Business Management*. 6(21): p.6324.
208. Smith, L., Maull, R. & Irene, C.L.N. 2014. Servitization and operations management: a service dominant-logic approach. *International Journal of Operations & Production Management*. 34(2): p.242-269.
209. Smith, W., Binns, A. & Tushman, M. 2010. Complex Business Models: Managing Strategic Paradoxes Simultaneously. *Long Range Planning - LONG RANGE PLANN*. 43: p.448-461.
210. Sorescu, A., Frambach, R., Singh, J., Rangaswamy, A. & Bridges, C. 2011. Innovations in Retail Business Models. *Journal of Retailing*. 87: p.3-16.
211. Sosna, M., Trevinyo-Rodríguez, R.N. & Velamuri, S.R. 2010. Business Model Innovation through Trial-and-Error Learning: The Naturhouse Case. *Long Range Planning*. 43(2): p.383-407.
212. Stabell, C.B. & Fjeldstad, Ø.D. 1998. Configuring value for competitive advantage: on chains, shops, and networks. *Strategic management journal*. 19(5): p.413-437.
213. Stacey, R.D. 1996. *Complexity and creativity in organizations*. Berrett-Koehler Publishers.
214. Stahl, R. 2018. *Applications of additive manufacturing in tool and mould making*. Available: https://www.etmm-online.com/applications-of-additive-manufacturing-in-tool-and-mould-making-a-775082/. [2021, July 20]
215. Storbacka, K. & Nenonen, S. 2009. Customer relationships and the heterogeneity of firm performance. *Journal of Business & Industrial Marketing*. 24(5/6).
216. Svejenova, S., Planellas, M. & Vives, L. 2010. An Individual Business Model in the Making: A Chef's Quest for Creative Freedom. *Long Range Planning*. 43: p.408-430.
217. Tao, F., Cheng, Y., Zhang, L. & Nee, A.Y.C. 2017. Advanced manufacturing systems: socialization characteristics and trends. *Journal of Intelligent Manufacturing*. 28(5): p.1079-1094.
218. TechSci. 2019. Global Tungsten Carbide Market By End-User (Automotive Industry, Aerospace & Defense, Mining & Construction Industry, Oil & Gas Industry, Electronic Industry & Others), By Application, By Region, Competition, Forecast & Opportunities (2024).
219. Teece, D.J. 2007. Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. *Strategic management journal*. 28(13): p.1319-1350.
220. Teece, D.J. 2010. Business Models, Business Strategy and Innovation. *Long Range Planning*. 43(2-3): p.172-194.

221. Timmers, P. 1998. Business models for electronic markets. *Electronic markets*. 8(2): p.3-8.
222. Tofail, S.A.M., Koumoulos, E.P., Bandyopadhyay, A., Bose, S., O'Donoghue, L.*, et al.* 2018. Additive manufacturing: scientific and technological challenges, market uptake and opportunities. *Materials Today*. 21(1): p.22-37.
223. Torn, I.A.R. & Vaneker, T.H.J. 2019. Mass Personalization with Industry 4.0 by SMEs: A Concept for Collaborative Networks. *Procedia Manufacturing*. 28: p.135-141.
224. Turati, C. & Ruta, C.D. 2001 Technology in knowledge based value chain. in *PICMET'01. Portland International Conference on Management of Engineering and Technology. Proceedings Vol. 1: Book of Summaries (IEEE Cat. No. 01CH37199)*. IEEE.
225. Tziantopoulos, K., Tsolakis, N., Vlachos, D. & Tsironis, L. 2019. Supply chain reconfiguration opportunities arising from additive manufacturing technologies in the digital era. *Production Planning & Control*. 30(7): p.510-521.
226. Uhlmann, E., Bergmann, A. & Gridin, W. 2015. Investigation on Additive Manufacturing of Tungsten Carbide-cobalt by Selective Laser Melting. *Procedia CIRP*. 35: p.8-15.
227. Uzair Khaleeq, u.Z., Rivette, M., Siadat, A. & Baqai, A.A. 2018. Integrated design-oriented framework for Resource Selection in Additive Manufacturing. *Procedia Cirp*. 70: p.96-101.
228. Vaishnavi, V.K. & Kuechler, W. 2004. *Design Science Research in information systems.* . Available: http://www.desrist.org/design-research-in-information-systems/. [2020, April 4]
229. Vaishnavi, V.K. & Kuechler, W. 2015. *Design Science Research methods and patterns*. *Design Science Research Methods and Patterns*. Taylor & Francis Group.
230. van Heerden, A., Grobbelaar, S.S. & Sacks, N. 2020 The impact of digitalization and additive manufacturing on business models and value chains: A scoping review. in *Towards the Digital World and Industry X.0 - Proceedings of the 29th International Conference of the International Association for Management of Technology, IAMOT 2020*.
231. Van Middendorp, S. 2009. Value Networks in Organization Theory: An Overview.
232. van Staden, A.C., Oosthuizen, F.A. & Sacks, N. 2016. A Fundamental Analysis on Additive Manufacturing of a Cemented Tungsten Carbide. Stellenbosch: Stellenbosch University [Online]. Available:
233. Veit, D., Clemons, E., Benlian, A., Buxmann, P., Hess, T.*, et al.* 2014. Business Models. *Business & Information Systems Engineering*. 6(1): p.45-53.
234. Verboeket, V. & Krikke, H. 2019. Additive Manufacturing: A Game Changer in Supply Chain Design. *Logistics*. 3(2): p.13.
235. Visnjic, I., Wiengarten, F. & Neely, A. 2016. Only the Brave: Product Innovation, Service Business Model Innovation, and Their Impact on Performance. *Journal of Product Innovation Management*. 33(1): p.36-52.
236. Voelpel, S.C., Leibold, M. & Tekie, E.B. 2004. The wheel of business model reinvention: how to reshape your business model to leapfrog competitors. *Journal of Change Management*. 4(3): p.259-276.
237. Vom Brocke, J. & Rosemann, M. 2015. *Handbook on Business Process Management* Berlin, Heidelberg: Springer Berlin Heidelberg.
238. von Leipzig, K. & Dimitrov, D. 2015. Cluster development in the SA tooling industry. *South African Journal of Industrial Engineering*. 26: p.110-124.
239. Weigand, H., Johannesson, P., Andersson, B., Bergholtz, M., Edirisuriya, A.*, et al.* 2007 Strategic Analysis using Value Modelling – a c3 approach. in *Proceedings of the 40th Hawaii International Conference on System Sciences*.
240. Weill, P. & Vitale, M. 2001. *Place to space: Migrating to eBusiness Models*. Harvard Business Press.
241. Weking, J., Hein, A., Böhm, M. & Krcmar, H. 2018. A hierarchical taxonomy of business model patterns. *Electron. Mark.*

242. Weking, J., Stöcker, M., Kowalkiewicz, M., Böhm, M. & Krcmar, H. 2020. Leveraging industry 4.0 – A business model pattern framework. *International Journal of Production Economics*. 225: p.107588.
243. Westerlund, M., Leminen, S. & Rajahonka, M. 2014. Designing Business Models for the Internet of Things. *Technology Innovation Management Review*. 4: p.5-14.
244. Williams, C. 2007. Research methods. *Journal of Business & Economics Research (JBER)*. 5(3).
245. Wirtz, B. & Daiser, P. 2018. Business Model Innovation Processes: A Systematic Literature Review. *Journal of Business Models*. 6(1): p.40-58.
246. Wirtz, B.W., Pistoia, A., Ullrich, S. & Göttel, V. 2016. Business models: Origin, development and future research perspectives. *Long range planning*. 49(1): p.36-54.
247. Woodruff, R.B. 1997. Customer value: The next source for competitive advantage. *Journal of the Academy of Marketing Science*. 25(2): p.139.
248. Wu, J., Guo, B. & Shi, Y. 2013. Customer knowledge management and IT-enabled business model innovation: A conceptual framework and a case study from China. *European Management Journal*. 31(4): p.359-372.
249. Yin, R.K. 2003. *Case study research: Design and methods*. 3rd ed.: Sage Publications.
250. Zanetti, V., Cavalieri, S., Kalchschmidt, M. & Pinto, R. 2015. *The Role of Additive Manufacturing in the B2C Value Chain: Challenges, Opportunities and Models*. Springer International Publishing. p. 137-145.
251. Zanetti, V., Cavalieri, S. & Pezzotta, G. 2016. Additive Manufacturing and PSS: a Solution Life-Cycle Perspective. *IFAC-PapersOnLine*. 49(12): p.1573-1578.
252. Zott, C. & Amit, R. 2007. Business Model Design and the Performance of Entrepreneurial Firms. *Organization Science*. 18(2): p.181-199.
253. Zott, C. & Amit, R. 2008. The fit between product market strategy and business model: Implications for firm performance. *Strategic management journal*. 29(1): p.1-26.
254. Zott, C. & Amit, R. 2010. Business model design: an activity system perspective. *Long range planning*. 43(2-3): p.216-226.
255. Zott, C., Amit, R. & Massa, L. 2011. The Business Model: Recent Developments and Future Research. *Journal of Management*. 37(4): p.1019-1042.

APPENDIX A. Structured literature review

The full set of articles which met the inclusion criteria in the structured literature review (see Chapter 3) is presented in Table A.1.

Table A. 1: Complete set of articles included in the primary data set

Category		Reference	Year	Title
Concepts (Rigour)	BM	Al-Debei and Avison [6]	2010	*“Developing a unified framework of the business model concept”*
		Al-Debei and Fitzgerald [7]	2010	*“The design and engineering of mobile data services: Developing an ontology based on business model thinking”*
		Baden-Fuller and Mangematin [19]	2015	*“Business models and modelling business models”*
		Wirtz *et al.* [246]	2016	*“Business models: Origin, development and future research perspectives”*
		Weking *et al.* [242]	2020	*“Leveraging industry 4.0 – A business model pattern framework”*
	BMI	Teece [220]	2010	*“Business Models, Business Strategy and Innovation”*
		Kühn and Louw [127]	2017	*”Business Model Innovation for Seizing White Space Opportunities: A Design Framework”*
		Foss and Saebi [75]	2017	*“Fifteen Years of Research on Business Model Innovation”*
		Wirtz and Daiser [245]	2018	*“Business Model Innovation Processes: A Systematic Literature Review”*
		Pieroni *et al.* [184]	2019	*“Business Model Innovation for Circular Economy and Sustainability: A Review of Approaches ”*
	VN	Biem and Caswell [22]	2008	*“A Value Network Model for Strategic Analysis”*
		Van Middendorp [231]	2009	*“Value Networks in Organization Theory: An Overview”*
		Dara [59]	2013	*“Value Networks and Business Models : Formulating and Demonstrating a Process for the Development of Value Networks and Alignment of Business Models Based on Design Science Research Process”*
		Ricciotti [194]	2019	*“From Value Chain to Value Network: A Systematic Literature Review”*
Context (Relevance)	SMEs or SMMEs	Mittal *et al.* [152]	2018	*“A critical review of smart manufacturing & Industry 4.0 maturity models: Implications for small and medium-sized enterprises (SMEs)”*
		Torn and Vaneker [223]	2019	*“Mass Personalization with Industry 4.0 by SMEs: A Concept for Collaborative Networks”*
		Masood and Sonntag [145]	2020	*“Industry 4.0: Adoption challenges and benefits for SMEs”*
	AM	Ford and Despeisse [74]	2016	*“Additive manufacturing and sustainability: an exploratory study of the advantages and challenges”*
		Franco *et al.* [76]	2020	*“Consolidated and inconclusive effects of additive manufacturing adoption: A systematic literature review”*

Category		Reference	Year	Title
Integration (Rigour and relevance)	Conceptual integration	Möller and Rajala [154]	2007	*“Rise of strategic nets—New modes of value creation”*
		Nenonen and Storbacka [161]	2010	*“Business model design: Conceptualizing networked value co-creation”*
		Lindgren *et al.* [136]	2010	*“From single firm to network-based business model innovation”*
		Palo and Tähtinen [176]	2011	*“A Network Perspective on Business Models for Emerging Technology-Based Services”*
		Palo and Tähtinen [177]	2013	*“Networked business model development for emerging technology-based services”*
		Nekoo *et al.* [160]	2015	*“Designing network-based business model ontology”*
		Kage *et al.* [114]	2016	*“Value Network Design for Innovations: Developing Alternative Value Network Drafts”*
		Laya *et al.* [128]	2018	*“Network-centric business models for health, social care and wellbeing solutions in the internet of things”*
		Schneider *et al.* [201]	2017	*“Design of Future Value Networks”*
		Jocevski *et al.* [111]	2020	*“Interconnected business models: present debates and future agenda”*
	Contextual integration	Hämäläinen [97]	2014	*“Customer centric and value-based business model design: impacts of the additive manufacturing technology on firm's business model”*
		Zanetti *et al.* [251]	2015	*“The Role of Additive Manufacturing in the B2C Value Chain: Challenges, Opportunities and Models”*
		Rayna and Striukova [192]	2016	*“From rapid prototyping to home fabrication: How 3D printing is changing business model innovation”*
		Bogers *et al.* [26]	2016	*“Additive manufacturing for consumer-centric business models: Implications for supply chains in consumer goods manufacturing”*
		Shah *et al.* [205]	2017	*“Contribution of Additive Manufacturing Systems to Supply Chain”*
		Müller *et al.* [159]	2018	*“Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0”*
		Martinsuo and Luomaranta [144]	2018	*“Adopting additive manufacturing in SMEs: exploring the challenges and solutions”*
		Kritzinger *et al.* [125]	2018	*“Impacts of Additive Manufacturing in Value Creation System”*
		Porat and Hovstadius [185]	2018	*“A business model perspective on additive manufacturing”*
		Tziantopoulos *et al.* [225]	2019	*“Supply chain reconfiguration opportunities arising from additive manufacturing technologies in the digital era”*
		Savolainen and Collan [200]	2020	*“How Additive Manufacturing Technology Changes Business Models?–Review of Literature”*

Table A. 2: A selection of firm-level BM definitions

Author(s)	Definition of a business model	Business model concept elements / core themes	Perspective
Timmers [221]	*"An architecture for products, services and information flows, including a description of various business actors and their roles; a description of the potential benefits for the various business actors; and a description of sources of revenues."*	Architecture, Value Proposition, Business actors and roles, Revenue sources.	Single firm within a network
Weill and Vitale [240]	*"Business model represents the roles and relations among the firm's customers, allies and suppliers identifying the major flows of product, information and money and the major benefits for the actors."*	Actors and roles, value exchanges (flows), relations.	Single firm within a network
Chesbrough and Rosenbloom [48]	*"The business model provides a coherent framework that takes technological characteristics and potentials as inputs and converts them through customers and markets into economic inputs. The business model is thus conceived as a focusing device that mediates between technology development and economic value creation."*	Coherent framework, Mediating construct, Technology, Economic Value.	Single firm
Hedman and Kalling [99]	*"Business model is a term often used to describe the key components of a given business. That is customers, competitors, offering, activities and organisation, resources, supply of factors and production inputs as well as longitudinal process components to cover the dynamics of the business model over time."*	Key business components, Resources, Customers, Value proposition, Network, Architecture, Structure, Dynamic.	Single firm
Voelpel *et al.* [236]	*"The particular business concept (or way of doing business) as reflected by the business's core value proposition(s) for customers; its configurated value network(s) to provide that value, consisting of own strategic capabilities as well as other (e.g. outsourced/alliance) value networks and capabilities; and its leadership and governance enabling capabilities to continually sustain and reinvent itself to satisfy the multiple objectives of its various stakeholders (including shareholders)."*	New customer value proposition (which could also involve new customer base), a value network (re)configuration for that value creation; and . leadership capabilities that ensure the satisfaction of relevant stakeholders.	Single firm within a network
Osterwalder *et al.* [173]	*"A business model is a conceptual tool that contains a set of elements and their relationships and allows expressing the business logic of a specific firm. It is a description of the value a company offers to one or several segments of customers and of the architecture of the firm and its network of partners for creating, marketing, and delivering this value and relationship capital, to generate profitable and sustainable revenue streams"*	Value proposition Target customer Distribution channel Relationship Value configuration Core competency Partner network Cost structure Revenue model	Single firm
Shafer, Smith and Linder [204]	*"Business is fundamentally concerned with creating value and capturing returns from that value, and a model is simply a representation of reality. We define a business model as a representation of a*	Strategic choices (e.g. customer, value proposition, capabilities, pricing, competitors, offering, and strategy)	Single firm within a network.

Author(s)	Definition of a business model	Business model concept elements / core themes	Perspective
	firm's underlying core logic and strategic choices for creating and capturing value within a value network."	Create value (incl. resources/assets, and processes/activities) Capture value (incl. cost, financial aspects, and profit) Value network	
Zott and Amit [252]	*"A business model depicts the content, structure, and governance of transactions designed so as to create value through the exploitation of business opportunities. A business model elucidates how an organisation is linked to external stakeholders, and how it engages in economic exchanges with them to create value for all exchange partners."*	Content of transactions Structure of transactions Governance of transactions Value creation design Links to external stakeholders	Single firm
Zott and Amit [253]	*"The business model can then be defined as the structure, content, and governance of transactions between the focal firm and its exchange partners. It represents a conceptualisation of the pattern of transactional links between the firm and its exchange partners."*	Structure of transactions Content of transactions Governance of transactions Transactional links to exchange partners	Single firm
Bouwman, de Vos and Haaker [30]	*"A blueprint for a service to be delivered, describing the service definition and the intended value for the target group, the sources of revenue, and providing an architecture for the service delivery, including a description of the resources required, and the organisational and financial arrangements between the involved business actors, including a description of their roles and the division of costs and revenues over the business actors."*	Value proposition or service Technological architecture Financial arrangements Organisational arrangements	Single firm
Johnson *et al.* [113]	*"A business model consists of four interlocking elements (customer value proposition, profit formula, key resources, and key processes) that taken together create and deliver value."*	Customer value proposition (including target customer, job to be done, and offering) Profit formula (including revenue model, cost structure, margin model, and resource velocity) Key resources Key processes (including metrics, rules, and norms)	Single firm
Storbacka and Nenonen [215]	*"Business models are defined as configurations of interrelated capabilities, governing the content, process and management of the interaction and exchange in dyadic value co-creation."*	Content of exchange and interaction Process of exchange and interaction Management of exchange and interaction	Single firm within a network
Zott and Amit [254]	*"A system of interconnected and interdependent activities that determines the way the company "does business" with its customers, partners, and vendors."*	Content – activities Structure – how activities are linked Governance – who performs the activities	Single firm

Table A. 3: A selection of firm-level BM frameworks

Author(s)	Business model framework	Elements
Chesbrough and Rosenbloom [48]	Technology-Market Mediation	• "Value proposition • Market segment • Value chain • Cost structure and profit potential • Value network • Competitive strategy"
Osterwalder [170]	Business Model Canvas	• "Customer segments • Customer relationships • Communication, distribution and sale channels • Value propositions • Key resources • Key activities • Key partners • Revenue streams • Cost structure"
Morris *et al.* [156]	Entrepreneur's Business Model	• "How do we create value? (factors related to the offering) • Who do we create value for? (market factors) • What is our source of competence? (internal capability factors) • How do we competitively position ourselves? (strategy factors) • How do we make money? (economic factors) • What is our time, scope, and size ambitions? (personal/investor factors)"
Johnson *et al.* [113]	Four-Box Business Model	• "Customer value proposition (target customer, jobs-to-be-done, offering) • Profit formula (revenue model, cost structure, margin model resource velocity) • Key resources (people, technology, products, equipment, information, channels, partnerships, alliances, brand) • Key processes (processes, rules and metrics, norms)"
Al-Debei and Fitzgerald [7]	The V4 Business Model Structure	• "Value-network (actor, role, relationship, flow-communication, channel, governance, network-mode) • Value-proposition (product-service, intended-value-element, target-segment) • Value-finance (total-cost-of-ownership, pricing-method revenue-structure) • Value-architecture (core resources, value-configuration core-competency)"
Gassmann *et al.* [81]	St Gallen Business Model Navigator	• "Customer (Who is the customer segment?) • Value proposition (What is offered to the customer?) • Value chain (How is the value proposition created and delivered to the customer?) • Revenue model (Why is the business profitable?)"

Rayna and Striukova [191]	360° Business Model Framework	• "Value creation
		    ○ Core competencies
		    ○ Key resources
		    ○ Governance
		    ○ Complementary assets
		    ○ Value networks
		• Value proposition
		    ○ Product offering
		    ○ Service offering
		    ○ Pricing model
		• Value delivery
		    ○ Distribution channels
		    ○ Target market segments

Author(s)	Business model framework	Elements
		• Value capture ○ Revenue model ○ Cost structure ○ Profit allocation • Value communication ○ Communication channels ○ Ethos and story"
Wirtz *et al.* [246]	The Integrated Business Model	• "Strategic components ○ Strategy model ○ Resource model ○ Network model • Customer and market components ○ Customer model ○ Market-offer model ○ Revenue model • Value creation components ○ Manufacturing model ○ Procurement model ○ Financial model"

Table A. 4: A selection of networked-based BM definitions or conceptualisations [109]

Author(s)	Used definition or conceptualisation	Type of conceptualisation	Core themes addressed within publications
Komulainen *et al.* [124]	*"The core elements of network BM include the product/service, the business actors and their roles, and the value-creating exchanges among the actors."*	Used their own definition.	Actor's roles, including end-users Value-creating exchanges
Palo and Tähtinen [176]	*"The concept of a networked BM refers to the strategic net of actors involved in developing, producing, and marketing the technology-based service as well as delivering it to the customers."*	Used their own definition.	Actors' activities and roles Business network
Palo and Tähtinen [177]	*"A networked BM guides how a net of companies will create customer and network value by developing a collective understanding of the business opportunities and shaping the actions to exploit them."*	Used their own definition.	Firm-level and networked BMs Novel technology-based services
Westerlund *et al.* [243]	*"An ecosystem BM is a BM composed of value pillars anchored in ecosystems and focuses on both the firm's method of creating and capturing value as well as any part of the ecosystem's method of creating and capturing value."*	Used their own definition.	BM design tool Ecosystem nature of IoT Value design
Wirtz *et al.* [246]	*"The network BM includes the various, mostly external interactions of a BM. In the network context, the BM represents a management tool to check and control the value distribution with joint value creation."*	The concept is used without a direct definition.	Management tool Value distribution
Bankvall *et al.* [20]	*"A network-embedded BM relies on network-level value creation processes and business exchange patterns that are clearly not aligned."*	Used their own definition.	BM analysis Firm, relationship and network-level Value flow
Markendahl, Lundberg, Kordas and Movin [142]	*"A network model, where BM networks and partners are included, highlights the importance of capturing multi-actor aspects of value creation and how the value network can be composed."*	The concept is used without a direct definition	Move from a single-firm to a networked BM Value co-creation

Author(s)	Used definition or conceptualisation	Type of conceptualisation	Core themes addressed within publications
Laya *et al.* [129]	*"Network-level BM guides how a net of companies will create customer and network value by developing a collective understanding of the business opportunities and shaping the actions to exploit them."*	Used the definition offered by Palo and Tähtinen [177]	Actor's roles and orchestration activity Resource dependency
Leminen, Rajahonka, Westerlund and Wendelin [132]	*"Ecosystem BM i.e. value design expands the BM thinking beyond organisational boundaries and demonstrates how value is created and captured in an ecosystem. It can be conceptualised by four pillars: value drivers, value nodes, value exchanges and value extracts."*	Used definition offered by Westerlund *et al.* [243]	Organisational boundaries Value design tool

Table A. 5: A selection of networked BM frameworks or models

Author(s)	Framework or model	Main elements or themes
Lindgren *et al.* [136]	Building blocks of a network-based BM based on BMC	The key pillars are similar to the BMC (customer segments, value propositions, distribution channels, customer relationships, revenue streams, key resources, key activities, key partnerships, and cost structure [172]), with network-based descriptions of the various elements.
Palo and Tähtinen [176]	A framework of the elements of the networked business model	"The key elements of a business model are presented inside the dash lined rectangle: the service, the customer(s), the actors, and their roles below (ellipses), as well as the value exchanges (arrows) between the actors, the service, and the customer. Hence, the business model describes the value net in producing and delivering the service, and thus the term of a networked business model is used."
Palo and Tähtinen [177]	Networked business model development framework	"The key development phases of a networked business model; service development, pilot, and market phases. The development of the networked business model consists of two dimensions; business net development and the development of business opportunity."
Nekoo *et al.* [160]	Network-based BM ontology	Different entities in the network consist of actors, goals, and resources with trust, shared-mental models, and infrastructure connecting the entities.
Jocevski *et al.* [111]	Network-oriented view of a BM	*Who* refers to the actors that are interconnected through the BM at a network-level, and their orchestration. *What* refers to the joint value proposition that the involved actors are working on. *How* refers to the value flow and needed activities in order to create and deliver jointly proposed value *Why* refers to the reasons and practices behind the utilization of a network-oriented view.

Table A. 6: A selection of BMI definitions [73]

Author(s)	Definition
Mitchell and Coles [151]	*"By business model innovation, we mean business model replacements that provide product or service offerings to customers and end users that were not previously available. We also refer to the process of developing these novel replacements as business model innovation."*
Markides [143]	*"Business model innovation is the discovery of a fundamentally different business model in an existing business."*
Santos, Spector and Van der Heyden [199]	*"Business model innovation is a reconfiguration of activities in the existing business model of a firm that is new to the product service market in which the firm competes."*
Aspara, Hietanen and Tikkanen [15]	*"Initiatives to create novel value by challenging existing industry- specific business models, roles and relations in certain geographical market areas."*
Gambardella and McGahan [79]	*"Business-model innovation occurs when a firm adopts a novel approach to commercialising its underlying assets."*
Moingeon, Yunus and Lehmann-Ortega [153]	*"Business model innovation is about generating new sources of profit by finding novel value proposition/value constellation combinations."*

Author(s)	Definition
Sorescu, Frambach, Singh, Rangaswamy and Bridges [210]	*"As a change beyond current practice in one or more elements of a retailing business model (i.e., retailing format, activities, and governance) and their interdependencies, thereby modifying the retailer's organising logic for value creation and appropriation."*
Amit and Zott [13]	*"Innovate business model by redefining (a) content (adding new activities), (b) structure (linking activities differently), and (c) governance (changing parties that do the activities)."*
Bucherer, Eisert and Gassmann [36]	*"We define business model innovation as a process that deliberately changes the core elements of a firm and its business logic."*
Abdelkafi, Makhotin and Posselt [1]	*"A business model innovation happens when the company modifies or improves at least one of the value dimensions."*
Aspara, Lamberg, Laukia and Tikkanen [16]	*Corporate business model transformation is defined as "a change in the perceived logic of how value is created by the corporation, when it comes to the value-creating links among the corporation's portfolio of businesses, from one point of time to another."*
Casadesus-Masanell and Zhu [43]	*"At root, business model innovation refers to the search for new logics of the firm and new ways to create and capture value for its stakeholders; it focuses primarily on finding new ways to generate revenues and define value propositions for customers, suppliers, and partners."*
Khanagha, Volberda and Oshri [121]	*"Business model innovation activities can range from incremental changes in individual components of business models, extension of the existing business model, introduction of parallel business models, right through to disruption of the business model, which may potentially entail replacing the existing model with a fundamentally different one."*
Foss and Saebi [75]	*"We define business model innovation as designed, novel, nontrivial changes to the key elements of a firm's business model and/or the architecture linking these elements."*

Table A. 7: A selection of BMI process frameworks

Author(s)	Framework	Description
Voelpel *et al.* [236]	Wheel of Business Model Reinvention	Focus on the activities that should be conducted to successfully redesign a business model, consisting of four steps: (1) Sensing potential for change in customer behaviour and new customer value propositions, (2) Sensing the strength, direction and impact of technology, (3) Sensing the potential for value system (re)configuration, including organisational structure(s), and (4) Sensing the economic feasibility and profitability of the proposed business model.
Osterwalder and Pigneur [172]	Five Stage BMI Process	A generic BMI process that consists of five linear stages: mobilise, understand, design, implement and manage. Each of these stages contain a set of practical tools.
Johnson [112]	Repeatable BMI Process	Used to capture a white space through an iterative, systematic and structured process that consist of three phases from which the ideas are tested, and lessons learnt is applied before the next iteration, the three phases are identify and understand the customer's jobs to be done is, construct a blueprint which sets out how the job will be done at a profit, and work out how to bring together the resources and processes needed.
Lindgardt and Reeves [135]	Circular BMI Process	Suggested by the Boston Consulting Group which consisted of a circular procedure with the following steps: uncover opportunities, convert into business models, prepare and test, scale and iterate, and manage business model innovation portfolio.
Teece [219]	Dynamic capabilities-based view	Dynamic capabilities, which are underpinned by organisational routines and managerial skills, are the firm's ability to integrate, build, and reconfigure internal competences to address, or in some cases to bring about, changes in the business environment.
Geterud and Tegern [86]	BMI Tool Framework	Consists of the following four phases: business background, innovating the business model, business model concept assessment, and reinvented business model. Each of these four phases furthermore contain a set of tools as subsections to help with the practical application thereof.

Author(s)	Framework	Description
Frankenberger *et al.* [77]	4I-Framework	A generic framework which consists of two phases and four stages: the Design phase consists of 1) Initiation, 2) Ideation, and 3) Integration, and the Realisation phase consists out of 4) Implementation.
Geissdoerfer *et al.* [84]	Cambridge BMI Process	Consists of three high-level phases (concept design, detail design and implementation) and eight key processes which is cyclical or repetitive in nature. The eight key processes are: Ideation, Concept design, Virtual prototyping, Experimenting, Detail design, Piloting, Launch, and Adjustment and diversification.
Wirtz and Daiser [245]	Generic BMI Process	Identified key BMI process phases with key activities for each phase. The key BMI process phases are Analysis, Ideation, Feasibility, Prototyping, Decision-making, Implementation, and Sustainability.

Table A. 8: A selection of VN conceptualisations

Author (s)	Term	Conceptualisation	Key themes or elements
Normann and Ramírez [164]	Value constellation	They proposed a dynamic fluid system that continuously improves interactions within the model to benefit the entire organisation. New designers should map out the nodes, and relationships between the nodes, to find missing relationships that they could use to create value to benefit the organisation.	Dynamic Nodes Relationships
Christensen and Rosenbloom [51]	Value network	A value network is *"the context within which a firm competes and solves customers' problems"*. According to them the VN is important in understanding disruptive innovation because the VN in which incumbent and new entrants operate in is the factor that determines whether they will succeed or not. Christensen looked beyond the firm's boundaries to the value network comprising the complete, nested set of products and services that define a specific market demand. A VN has boundaries, set by the condition that they embrace all products and services, as well as the companies engaging in the VN to deliver these to a specific customer demand. Therefore, the VN by definition, crosses the individual firm boundary, yet at the same time, it determines a new boundary caused by a specific customer demand.	Disruptive innovation Boundaries Customer demand
Stabell and Fjeldstad [212]	Value network and value shop	After outlining the limitations of the value chain configuration, they introduced the value shop and value network as two additional models for value configuration. A value shop addresses questions and problems in a sequential circular manner, where analysis, action, and evaluation form a recurring cycle of activities, which may be interrupted at any point to deliver value. The value network is a value configuration, apt for firms that add value by connecting customers as part of a service in implicit and explicit ways. The consumers are needed as part of the value creation to create value. The more users in a network, the more valuable the service potential is. The value networks exist independently of customers.	Customers Service provider Contract
Allee [10]	Value network	Allee initially defines a value network as: *"A value network generates economic value through […] complex dynamic value exchanges between one or more enterprises, its customers, suppliers, strategic partners and the community".* Such networks operate on the principle of fair exchange for all types of value. Within a value network there are many non-monetary exchanges of knowledge and benefits as well as revenue exchanges. This means value flows are not simply one directional, but are interwoven, interdependent and multi-directional. The value flows cycle and loop back in a complex series of	Complex, dynamic value exchanges Multi-directional value flow

Author (s)	Term	Conceptualisation	Key themes or elements
		exchanges, encompassing many threads or chains of value.	
Parolini [178]	Value creating system (VCS)	A value-creating system can be defined as a set of activities creating value for customers; they are linked by flows of material, information, financial resources and influence relationships; VCSs also include consumption activities, insofar the value that final consumer enjoy is also a function of the way they use and consume the potential value received; final consumers not only receive and consume the value created, but can also participate in value creating activities; activities may be governed by the market, a hierarchy or intermediate forms of coordination (company networks); various economic players may participate in a VCS (companies, families, public bodies, non-profit organisations) by taking responsibility for one or more activities; an economic player may participate in more than one VCS.	Activities Flow Governance Economic players
Möller *et al.* [155]	Strategic business network	A strategic business net refers to intentionally formed value networks with a finite set of parties that aim to gain or sustain a competitive advantage by focusing on some key activities and outsourcing others. To understand strategic value nets the centrality of the value system and its level of determination is important	Intent Finite set of parties Competitive advantage Level of determination
Allee (2015)	Value network	A value network is *"a web of relationships that generates economic value and other benefits through complex dynamic exchanges between two or more individuals, groups, or organisations"*. It visually describes how value is generated for the consumer. The purpose of a value network is to create value at each node.	Web of relationships Benefits Complex dynamic exchanges

Table A. 9: A selection of VN analysis frameworks or models

Author(s)	Framework or model	Main elements or themes
Håkansson and Johanson [94]	ARA model	Actor, resources, and activities view of the firm. The network evolves through the enactment of activity links (the actors' processes and practices are interlinked), resource ties (the resource configurations of actors are interdependent), and actor bonds (there are different kinds of bonds that influence actors in their actions and decisions).
Gordijn *et al.* [91]	e3-value model	Actor, resources, and activities view of the firm with the following core entities: actor, value object (service, good, money), value port, value exchanged, value interface, market segment. It is divided into three viewpoints: the global actor viewpoint, the detailed actor viewpoint, and the value activity viewpoint.
Weigand *et al.* [239]	c3- value model	Resource-based view of firm, extension of e3-model, sustained competitive advantage is gained by owning strategic resources that are valuable, rare, inimitable, and non-substitutable, suggest analysing strategy along the following three dimensions: customer, capabilities, and competition.
Allee [11]	Value network strategy model	The network is continuously changing itself and is unmanageable. The network consists of the following entities: participants, transactions, deliverables (tangible or intangible), and exchanges which creates value.
Biem and Caswell [22]	Model of economic entity	The VN can be seen as an economic entity which can be analysed from three perspectives: the actor perspective, the capability perspective, or the asset perspective. The network consists of offerings (product, service, knowledge, brand) which refer to any transferable from one economic entity to another through unidirectional links.
Allee [12]	Value network analysis process	Value network analysis draws from a theory based in living systems, knowledge management, complexity theory, system dynamics, and

Author(s)	Framework or model	Main elements or themes
		intangible asset management. The process consists of value network mapping (roles, transactions, and deliverables) with a distinction made between tangible and intangible flows. Value network analysis furthermore include exchange analysis, impact analysis, and value creation analysis.
Hennemann and Liefner [101]	Unipartite and bipartite network analysis of innovation systems	The authors proposed a new form of analysis of innovation systems by bipartite data representation. Their conceptual base comes from innovation systems theory and ideas from knowledge networks theory. This combination offers an explanation for methodological innovation, i.e. it analyses the actors and their territorial origin at the same time as it analyses the interacting processes. This method shed light on the question of how interwoven the innovation process is and which type of potential collaborator is most influential in that process.

Table A. 10: A selection of VN development frameworks or methodologies

Author(s)	Framework or process	Description
Peppard and Rylander [181]	Network Value Analysis process	The aim is to indicate where the value lies in the network and how it is created. Network Value Analysis consists of five steps and is meant to clarify implications for value network development. The steps are as follows: *"1) Defining network objectives, 2) Identifying and defining network participants, 3) Identifying value dimensions of network participants, 4) Defining value linkages, and 5) Analyse and shape."*
Biem and Caswell [22]	Process of strategic analysis	Prescriptive analysis process. The main steps are *"1) Define a strategic value proposition 2) Specify the offerings each partner in the network can provide and evaluate the impact of each on the value proposition, 3) Select the proper partners based on the evaluation and deternine the links that transfer the offerings, 4) Add value and cost to each offering and analyse the VNA model theoretically or by simulation."*
Al-Debei *et al.* [5]	Value network development model	There are seven design constructs that support the development of a value network. The design constructs are *"network-mode, actor, role, relationship, flow communication, channel, and governance."* Value network development and design constructs enable the development of complex, collaborative and inter-connected value networks that foster innovation in changing and competitive environment.
Dara [59]	Value network development approach	Proposed five activities to follow with a corresponding tool to develop a value network. *"Activity 1: Determine the network-mode for the value network (the collaborative framework). Activity 2: Identify value network actors and their roles (the actor selection and roles template). Activity 3: Clarify perceived advantages and disadvantages of value network actors (the BMC). Activity 4: Identify value exchanges between value network actors (a translation from the BMC of actor to value exchanges). Activity 5: Align the business models of value network actors."*
Grudinschi *et al.* [93]	Value network mapping process	The process produce two different maps: the current VN map and the potential value network map. By comparing these two maps, the process of value creation can easily be assessed. The first map (of the current value network) demonstrates the exchange of values among participants in the current state of collaboration (i.e., what kind of value every partner brings to the network). Similarly, the second map (of the potential VN) shows what additional value can be created if the collaboration is properly managed and existing challenges are solved.
Kage *et al.* [114]	Designing value networks for innovation	Process for designing value networks for innovation (innovation pull research stream) to identify necessary competences, find suitable partners, and bundle them to powerful alternative VNs, which consists of the following phases: *"1) determination of co-operation demand, 2) partner preselection, 3) partner evaluation, and 4) implementation planning."*
Schneider *et al.* [201]	Procedure for BM driven design of value networks	Process to design a value network based on a business model (BMC), the phases are: *"1) business model analysis, 2) competence derivation, 3) interaction specification, and 4) operational structure development."*

APPENDIX B. Concept inventory

Table B. 1: Fundamental concepts contained in literature (concept inventory)

	Concept	Brief description	BM	BMI	VN
Value proposition	1) Business opportunity	Potential business opportunities can be identified through analysis of the external and internal environments. The business opportunity can be explained through the value proposition of the solution provided by the value network [177]."New value opportunities help expand the business into new markets and introduce new products and services that offer enhanced benefits to stakeholders"[25].	x	x	x
	2) Business processes	It refers to firm-level processes [172] which consists of steps performed by an actor within the network.	x		
	3) Business value	Individual companies incorporate and design their BMs so that they can maximise their own value, thus building the value for their shareholders. Value networks aid in consideration of the possibilities to collaborate or position the company in a way that improves the prospects of business value. [134]	x		
	4) Collaborative value	To improve business value through VN participation, the implicit assumption is that the value of collaboration has a price that may decrease short-term returns but increase long-term returns through advantageous positioning in the VN. At this point, the strategic management of the firm becomes more of an exogenous rather than endogenous exercise. [134]			x
	5) Contact	It refers to how will the company/VN interact with its customers (hybrid- intermediary and direct/ direct selling) [242].	x		
	6) Complementarity	Complementarities refer to the bundling of products or services to generate more value [254].	x		x
	7) Decision-making	The process followed to select one alternative above the other.	x	x	x
	8) Demand	The market demand for a specific product or service will determine the success rate if the business opportunity is pursued.	x	x	x
	9) Development and design	It refers to who develops and designs the products? (hired or employed experts/ customer or user designed/ development community or crowdsourcing) [242].	x		
	10) Distribution channel	It describes the various means that the network partners can use to reach their target customers [136].	x		x
	11) End customer value	It is strongly related to the value proposition, which in the end should correspond to the end-user needs, be it valued strictly on monetary basis or as a combination of monetary and non-monetary values [134].	x		x
	12) End-to-end solution	The provisioning and delivering of a solution without the involvement of an outside party [185].	x		x

Concept	Brief description	BM	BMI	VN
13) Intended-value-element	It refers to the kinds of value the value network intends to create. Value is basically created when the benefits associated with the solution are equivalent or exceeding the offering's total price. Unless delivered values are different or unique, they should surpass those delivered by competitors to win the market. [6]	x	x	x
14) Intermediary	The BM acts as a link between the strategy and business processes on the firm-level [173], and the networked BM acts as a link between the VN and the firm-level BMs.	x		x
15) Joint offering	It refers to the total offer to your customers created by a group of actors. It is more than the product or service itself and includes elements that represent additional value to your customers, such as availability, convenient delivery, technical support or quality of service. For a joint offering there needs to be a joint value creation and subsequent delivery of the offer, and an adequate distribution of the appropriated value within a network. [111]	x		x
16) Joint value proposition	It comprises everything that wraps around the product and service (solution) to create the total value for the end customer [111].	x		x
17) Knowledge	It refers to the facts, information, and skills acquired through experience or education.	x	x	x
18) Objective	The goal the VN aims to achieve addressing the business opportunity, with the adequate networked BM. The objective of all network actors should be to satisfy, internal or external, customers [104].	x		x
19) Perceived value	*"Customer's perceived preference for an evaluation of those product attributes, attribute performances, and consequences arising from use that facilitate (or block) achieving the customer's goals and purposes in use situations."* [247]	x	x	x
20) Product-service	It describes the potential product(s) and service(s) along with the information provided to target segments [6].	x		x
21) Strategic choices	It refers to the decisions made which determines the future strategy of a firm or value network.	x		x
22) Strategy	A plan of action designed to achieve a long-term or overall aim.	x	x	x
23) Target segment	It refers to the nature of the targeted segment by a particular VN. Segmentation of customers implies clustering them into different groups based on shared common properties and characteristics. Segments might involve customers identified as individuals, groups, or organisations. [7]	x	x	x
24) Value destroyed	Value destroyed can take various forms, but in the sustainability context is mostly concerning damaging environmental and social impacts of business activities (e.g. pollution) [25].	x	x	x
25) Value driver	Within the networks, different value drivers are comprised of individual and shared motivations of actors. That is, on the one hand, there are individual firm ambitions for being a part of the network and the firm's expected value to be captured, and on the other, there are shared objectives that are oriented toward creating the proposed joint value [243].	x		x

	Concept	Brief description	BM	BMI	VN
	26) Value missed	It refers to situations where individual stakeholders fail to capitalise on existing assets, resources, and capabilities, are operating below industry best practice, or fail to receive the benefits they seek from the network. This might be due to poorly designed value creation or capture systems, failure to acknowledge value, or inability to persuade others to pay for the benefit [25].	x	x	x
	27) Value opportunity	New forms of value for existing stakeholders and value for new stakeholders [25].			
	28) Value proposition	It demonstrates the business logic of creating value for customers and/or to each party involved through offering products and services that satisfy the needs of their target segments [7]. It represents the benefits delivered to stakeholders for which payment or another value exchange takes place [25].	x	x	x
Value network	29) Actor	An actor is an economically independent entity (not necessarily a legal entity) representing a company, an organisation, or a customer [22]. Actors partake in the value network by communicating, collaborating, and cooperating in order to launch a particular solution [7]. Actors fulfil certain roles within the network and own resources and capabilities that enable them to carry out value activities in the value network.	x		x
	30) Alliance	A strategic alliance (or strategic partnership) is a type of collaborative relationship which refers to an agreement between two or more parties (actors) to pursue a set of agreed upon objectives, while remaining independent organisations [5]. Within specialisation models, alliances are normally diagonal, involving partners from different businesses [62].	x		x
	31) Benefits	Financial and non-financial benefits (or values) obtained because of the collaboration effort among actors (or partners) in the VN.	x		x
	32) Boundaries	It refers to which actors are included in the value network as well as the stakeholders involved. [254]	x	x	x
	33) Channel	It refers to the communication mediums or ports used to communicate materials among actors (including customers) as a result of their established relationships. Channels could be physical or electronic and can range from manual to fully automated. The number, type, customer reach capabilities, and the quality of communication channels value networks build and maintain with their customers are critical to success. [7]	x		x
	34) Competitors	It refers to other value networks that engage in similar economic activities with similar solutions to address the same customer's needs as the value network under investigation.	x	x	x
	35) Configuration (orchestration)	It refers to the arrangement of parts or elements in a particular form, figure, or combination. Value network configuration or orchestration therefore refers to the arrangement of actors, activities, and resources. [104, 160]	x	x	x

Concept		Brief description	BM	BMI	VN
		Business model configuration refers to the arrangement of the different elements into a cohesive framework [127].			
	36) Collaboration	It refers to the action of working with other actors to enable the co-creation of a solution or joint offering for the customer. Collaboration consist of communication and coordination [85] and requires co-operation and trust between all network actors.			x
	37) Coordination	It refers to the organisation of the different resources, activities, actors, and their roles within the value network to enable them to work together effectively to develop a joint offering. [160, 177]	x	x	x
	38) Co-operation	It refers to the action or process of working together to the same end or goal. [144, 160]	x	x	x
	39) Control	It refers to the power of one or more actors to influence or direct other actor's behaviour or the execution of activities [7].			x
	40) Control point	Control points are areas in the VN where power and control can be applied. They normally result from the various roles played by actors in the value network. Thus, control points are not only functional but are also strategic, and the more control points an actor has the more important they are in the value network. Typically, actors try to achieve more power and control in order to augment the value they can capture [7].			x
	41) Communication	It refers to the exchange of information between actors, activities, or resources through a medium or channel [136].	x	x	x
	42) Culture	Organisational culture refers to the cumulative deposit of knowledge, experience, beliefs, values. The cultures of the respective actors' need to be aligned and adaptable to ensure successful network operation. [152, 205]	x		x
	43) Customer	A person or organisation (actor) who buys products or services from a business or value network.	x	x	x
	44) Customer needs	Customer needs are the named and unnamed needs the customer has when they come in contact with the business or value network, competitors, or when they search for the solutions provided by the business or VN. To identify customer needs, feedback is needed throughout the development process. [220]	x	x	x
	45) Customisation	It refers to how individualised the product is (mass production/ mass customisation/ mass individualisation) [242].	x		
	46) Ecosystem	It refers to *"networks of firms that collectively produce a holistic, integrated technological system that creates value for customers"* [4].	x	x	x
	47) Entrepreneurial actor	Entrepreneurial actors identify and create the business opportunities and can act as facilitators of the business net [177].			
	48) Emerging technology	Technologies that are currently developing, or that are expected to be available within the next five to ten years.	x	x	x

	Concept	Brief description	BM	BMI	VN
	49) External environment	It refers to all the outside factors or influences that impact the operation of the value network.	x	x	x
	50) Flow	It refers to the action or fact of moving from one state to another; thus, from one actor to another. [5]	x		x
	51) Governance	Governance relates to whom within the value network, has control and power over what kind of objects and resources. Value networks can be governed hierarchically or in a flattened mode. [5]			x
	52) Integration	The integration of the activities, capabilities, and resources of different network actors to deliver the joint offering and to reach the objective [76, 152, 223].	x	x	x
	53) Intent	The deliberate action taken to design and develop a strategic VN that aim to achieve a specific goal or objective. [177]			x
	54) Management	The process of dealing with or controlling activities and actors within the VN. A network can however not be managed in a strong sense (full control of another actor's resources and activities) [155].	x	x	x
	55) Market	It refers to the sum total of all the buyers and sellers in an area or region under consideration. The value , cost and price of items trades are as per forces of supply and demand in a market.	x	x	x
	56) Mode	The network-mode refers to understanding the way in which the VN is established and expanded. The network-mode can be open or closed [5].			x
	57) Partner	An external organisation providing the competences that are not available internally [114].	x		x
	58) Partnership	The term can be used to describe all types of collaborative business relationships. To ensure commitment to a common objective, the following conditions must be met: companies must have shared opinions about value creation; be convinced that they need each other; and agree on how the value created is divided between them [178].	x		x
	59) Perceived advantages	It refers to what actors expect to gain from participating in the value network, it also guides their behaviours. Partners should be selected based on evaluation of offerings and the links the partner's offerings have with the strategic value proposition of the network [22]	x		x
	60) Perceived disadvantages	It refers to the opposite of what actors expect to gain from participating in the value network [22].	x		x
	61) Power	Power dependence denotes the influencing forces where one party can partially control and influence another party, as the other party needs those resources or competences held by the first party [250].			x
	62) Push/ pull	It refers to what kind of production paradigm is used (pull, on-demand/ push and pull) [242].	x		
	63) Relationships	It refers to the types of links established between value network actors. Establishing appropriate relationships with value network actors is important given that actors follow different approaches with different types of relationships.	x		x

Concept	Brief description	BM	BMI	VN
	The differences include the level of information exchange, the level of change they would accept to be taking place, and the level of willingness to collaborate and co-operate. The kind of relationships that are established and maintained with various players within the value system is critical to success. The relationships between actors could, for example, take the form of strategic alliances and partnerships, affiliations, joint ventures, mergers, acquisitions, transactional (e.g. cost/ revenue share). [5]			
64) Risks	The unintended outcomes or negative risks introduced by network participation and pursuing a specific business opportunity.	x	x	x
65) Role	Each actor in the VN plays or fulfils a role. Any role controls a set of tangible and intangible assets or resources that support execution of the role [12]. Roles describe how people contribute to a particular activity [12]. A distinction can be made between functional and strategic roles. The functional roles of actors are diverse based on their knowledge domain, experience, and specialty. The strategic roles refer to what key objectives and benefits is obtained by having a particular actor within the VN [5].			x
66) Shared mental model	A strategic vision shared by all the VN actors regarding what the network aims to achieve [160]. To ensure the VN achieve the aim, proper collaboration among the actors is required.			x
67) Shared values	Shared values (tacit or explicit) provide a common ground or understanding among different actors, and is important when selecting roles to be fulfilled within the network [12].			x
68) Strategic business (value) net	A view on a network with deliberately or intentionally formed structures, negotiated roles and goals with a finite set of actors that can be managed in order to be efficient [154].			x
69) Stakeholder	Any organisation or actor with an interest or concern in the operations of the VN and the objectives the VN aim to achieve [25].	x	x	x
70) Trends and drivers	Trends refer to directions of change caused by drivers (the factors that cause the change) [127].	x	x	x
71) Trust	It refers to the firm belief in the reliability, truth, or ability of value network actors to fulfil their roles [160].			x
72) Value driver	An activity or capability possessed by an actor that adds worth to the VN [13].			x
73) Value net integrator	An actor or actors that coordinates activities across the value net by gathering, synthesising, and distributing information. It is often referred to as the hub firm that acts as integrator by controlling the key activities and resources [155].			x
74) Value network	This dimension represents external arrangements that revolve around the communication and collaboration the focal or entrepreneurial actor conduct with others in their value systems including customers, suppliers, allies, business partners, third parties, and intermediaries [7].	x		x

	Concept	Brief description	BM	BMI	VN
Value architecture	75) Activities	Business activities or value activities are actions performed by economic players or actors, using different resources and capabilities or competencies, usually motivated by a potential profit [22]. As value activities are essentially based on knowledge, embedded in capabilities manifested in organisational routines, the level of determination is related to the level of codification of knowledge [154].	x		x
	76) Alignment	It refers to the configurational fit between elements, values, and objectives, internally (on the firm-level [211] and network-level [59]) and externally [216] using dynamic capabilities.	x	x	x
	77) Capabilities	It refers to the ability to do something through the integration of knowledge and skills and adapting and flexing to meet future needs. Furthermore, network actors need to have complementary capabilities that can be combined to deliver an innovative offering or end-to-end solution. Actors possess capabilities to exploit their resources. [22, 136, 191]	x	x	x
	78) Competencies	Core-competencies refer to what can be done more efficiently and effectively than competitors. Core-competencies can also be viewed as repeatable patterns of action in the use of assets and the deployment of acquired resources to create and offer services to target segments [173]. The difference between competencies and capabilities is that competencies refer to the actor's current state or degree of skill to perform a task whereas capability refers to an actor's future state to develop the required competencies to perform a task.	x	x	x
	79) Complementarity	Actor's resources and capabilities need to be complementarity to each other to enable the development of a joint offering.	x	x	x
	80) Data analytics	It refers to where the high-value data comes from (internal data/customer's data) [242].	x		
	81) Dynamic capabilities	Dynamic capabilities are organisational routines – such as strategic decision making, product development, and alliancing – by which firms gain, reconfigure, integrate, and dismiss their resources [219].	x	x	x
	82) Functions	It refers to processes or sets of activities conducted to achieve an overall aim.	x	x	x
	83) Infrastructure	The basic physical and organisational structures and facilities that individual actors own that form part of the value network [177].	x		x
	84) Information flow	It refers to the flow of timely, real-time, and accurate information (including facts, data, knowledge) between network actors to enable close partnerships, the exploitation of network benefits, and overall network performance [22, 104].	x	x	x
	85) Intangible (operant) resources	Operant resources are usually intangible, dynamic resources that are capable of creating value [161].	x	x	x
	86) Inter-organisational	The focus is on the interrelationships with other network actors to collaborate and co-operate together in order to co-create shared value to the targeted customers [91]. The elements and components need to be aligned across	x		x

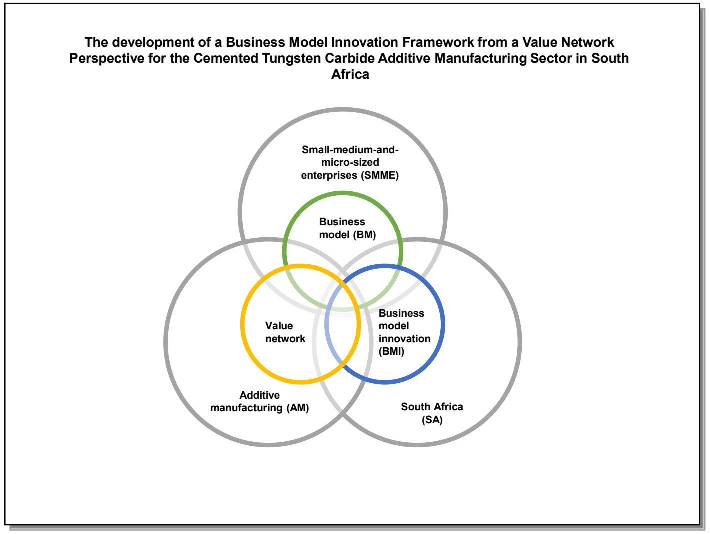
	Concept	Brief description	BM	BMI	VN
		organisational boundaries to ensure value is generated for all partners.			
	87) Joint value creation	It is an exchange of capabilities and assets between two companies where both achieve what neither could do on its own. It focuses on growing or creating new value together, not capturing larger share of fixed value. [111]	x		x
	88) Key success factors	The most important elements required for the VN (enabled or possessed by the actors) to successfully compete in its target markets and reach its goals or objectives.	x	x	x
	89) Offering	An offering refers to any transferable from one economic entity or actor to another. The transferable could be a manufactured product, a service, knowledge, or brand. Offerings are transferred through unidirectional links. Transfer of offerings does not necessarily include a transaction. [22]			x
	90) Link	A link is a connection between places, persons (actors), events, or things, that enable the transfer of a value element or offering. [22]			x
	91) Resources	A stock or supply of assets (tangible and intangible) owned by a network actor. It represent the various assets that are required to deliver the value proposition [113].	x		x
	92) Platform	It refers to what kind of digital platform is an essential part of the BM, if any (IoT/ merchant only/ innovation only/ merchant and innovation) [242].	x		x
	93) Tangible (operand) resources	Operand resources are usually tangible, static resources that require some action to make them valuable [161].	x	x	x
	94) Value architecture	It refers to a broad plan that specifies the network's technological architecture and organisational infrastructure arrangements that allows the provisioning of solutions in addition to information flows [7].	x		x
	95) Value configuration	It refers to the ability of VNs to fruitfully integrate organisational and technological core-resources in a way that allows efficient and effective roll-out of successful solutions [7].	x	x	x
	96) Value co-creation	It refers to the collaborative development of new value (concepts, solutions, products and services) together with experts and/or stakeholders (such as customers, suppliers etc.). Co-creation is a form of collaborative innovation: ideas are shared and improved together, rather than kept to oneself.	x		x
	97) Value creation logic	It refers to the core purpose of the network and describe how the network creates value for their customers. [176]			x
	98) Value creation system	The value creation system is not only production and logistic processes, but it also represents the point of view on how an organisation creates, sells, and delivers products [237]. The value–system construct is based on the notion that each product/service requires a set of value creating activities performed by a number of actors forming a value-creating system [154].	x	x	x

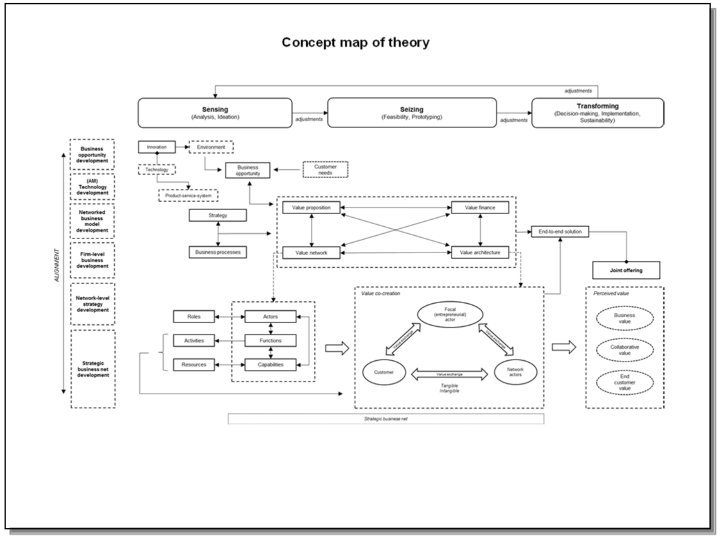
Concept		Brief description	BM	BMI	VN
	99) Value exchange	A transaction refers to the transfer of a deliverable from one participant to another [22]. A transaction is unidirectional and a bi-directional transaction is called an exchange [11]. Exchanges are of primary importance in the model as drivers of value. Deliverables can be tangible such as goods, services, and revenue, or intangible such as knowledge and benefit [22]. Value exchange can furthermore take place between actors, the service, and the customer [176].			x
	100) Value flow	The flow of value (competencies, information, knowledge, hardware, software, material, product, service, or money) within the network between actors, activities, and resources to produce the joint offering. [22, 176]	x		x
	101) Value-in-context	It relates to how value is unique in each context [162]. It is closely associated with unique selling points in the business environment.	x	x	x
	102) Continuity	It refers to how continuous the revenues are (once/ mixed/ continuous) [242].	x		
	103) Cost structure	It refers to the synergistic monetary and non-monetary consequences of the means employed in the network-based BM [136]. It shows the allocation of costs within the value network [113]	x		x
	104) Investment and financing	Investment refers to the action or process of investing money with the aim of making a profit. Financing refers to how the money will be obtained to make the investment. [129]	x	x	x
	105) Metrics	It refers to a standard of measurement used to evaluate or measure the profitability and performance of the value network.	x	x	x
	106) Pricing method	This concept holds information about the prices of different services and products along with the employed pricing mechanisms and billing methods. Pricing methods can be generally classified as fixed, dynamic, or a mixture of both. [6]	x		x
	107) Profit formula	Profit refers to the financial benefit that is realised when the amount of revenue gained from a business activity exceeds expenses, costs, and taxes needed to sustain the activity in question. The profit formula is influences by the revenue and cost structures of the VN. [191]	x		x
	108) Revenue structure	This concept contains information concerning generated revenue. It portrays the profitability of different solutions classes across customer segments. The concept of revenue-structure also shows how the generated revenue is broken down among different economic participating actors. The distributions of costs, risks, and revenues should be made explicit and the way in which revenue is divided among the economic actors should reflect the division of costs and risks [7]. It describes the value to the VNthrough the creation of value for a customer [113].	x		x
	109) Sales model	It refers to what the customer pays for (ownership and service delivery/ use or availability/ result) [242].	x		

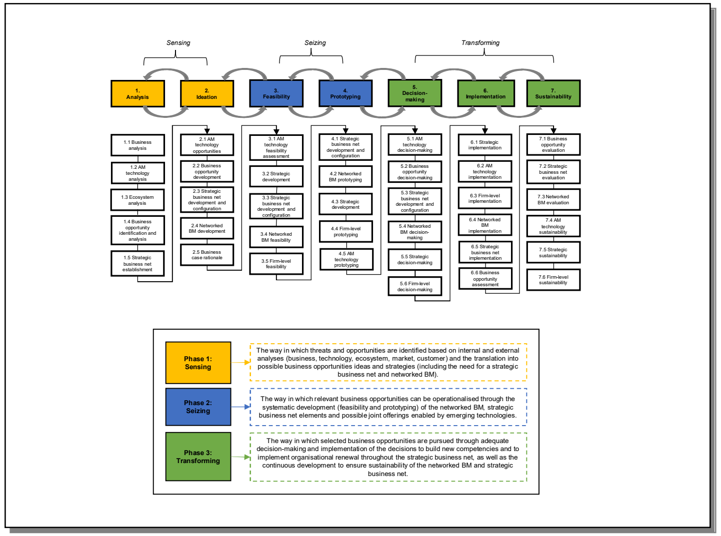
Concept		Brief description	BM	BMI	VN
	110) Total-cost of ownership	This concept deals with financial information about the overall costs with respect to all core arrangements that are needed to create, provide, market, deliver, and maintain solutions throughout their life spans. Total-cost-of-ownership not only includes the cost of tangible materials, but also covers the cost Int development, support, and maintenance, as well as the cost of collaboration between value network actors. [7]	x	x	x
	111) Value finance	It is a description of the core arrangements needed to ensure the economic viability of the offering which includes costing and pricing methods, as well as revenue breakdown, to sustain and improve its creation of revenue [5].	x		

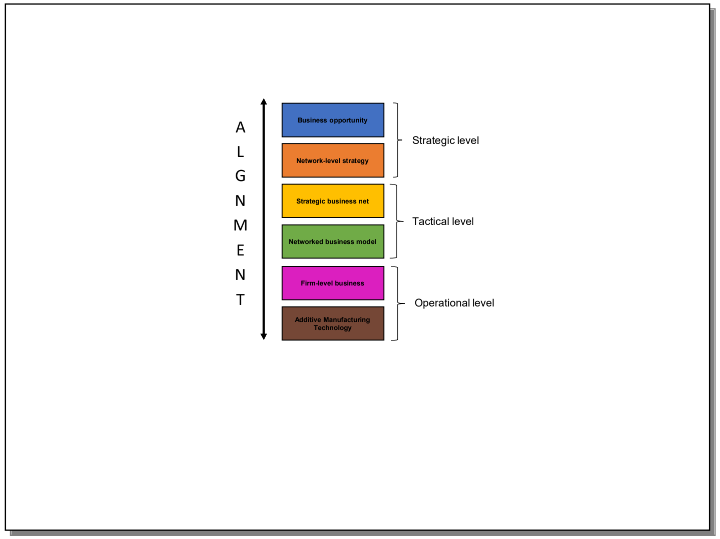
APPENDIX C. Real-life scenario

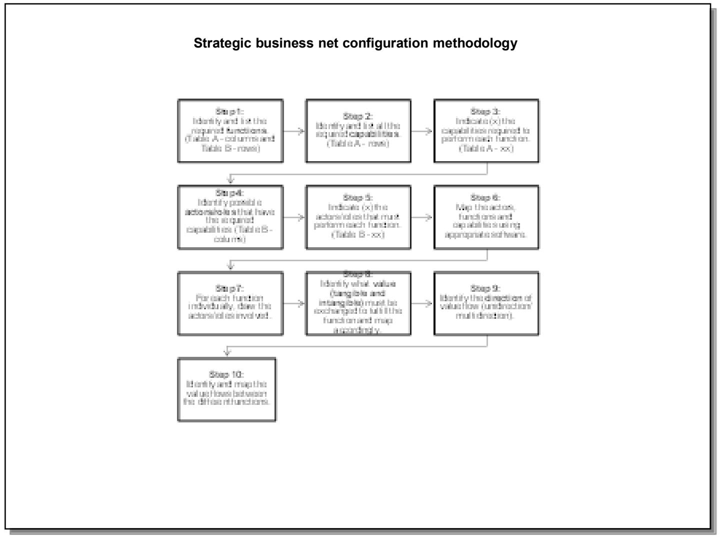
As described in Chapter 5, the following slides were used to provide an overview of the research study to the research participants that formed part of the real-life scenario.






Sensing
Seizing
Transforming
1. Analysis
2. Ideation
3. Feasibility
4. Prototyping
5. Decision-making
6. Implementation
7. Sustainability
Phase 1: Sensing
The way in which threats and opportunities are identified based on internal and external analyses (business, technology, ecosystem, market, customer) and the translation into possible business opportunities ideas and strategies (including the need for a strategic business net and networked BM).
Phase 2: Seizing
The way in which relevant business opportunities can be operationalised through the systematic development (feasibility and prototyping) of the networked BM, strategic business net elements and possible joint offerings enabled by emerging technologies.
Phase 3: Transforming
The way in which selected business opportunities are pursued through adequate decision-making and implementation of the decisions to build new competencies and to implement organisational renewal throughout the strategic business net, as well as the continuous development to ensure sustainability of the networked BM and strategic business net.


A
L
G
N
M
E
N
T
Business opportunity
Network-level strategy
Strategic business net
Networked business model
Firm-level business
Additive Manufacturing Technology
Strategic level
Tactical level
Operational level


Strategic business net configuration methodology
Step 1: Identify and list the required functions. (Table A - columns and Table B - rows)
Step 2: Identify and list all the required capabilities. (Table A - rows)
Step 3: Indicate (x) the capabilities required to perform each function. (Table A - xx)
Step 4: Identify possible actors/roles that have the required capabilities. (Table B - columns)
Step 5: Indicate (x) the actors/roles that must perform each function. (Table B - xx)
Step 6: Map the actors, functions and capabilities using appropriate software.
Step 7: For each function individually, draw the actors/roles involved.
Step 8: Identify what value (tangible and intangible) must be exchanged to fulfil the function and map accordingly.
Step 9: Identify the direction of value flow (unidirection/ multidirection).
Step 10: Identify and map the value flows between the different functions.

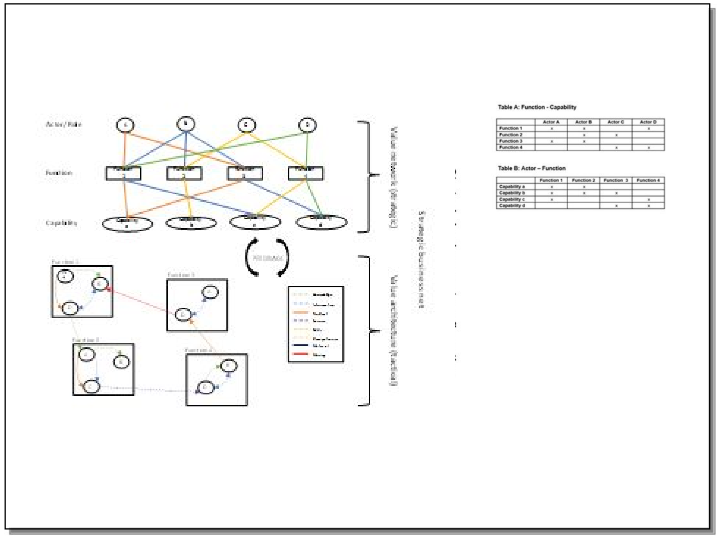

Actor / Role
Function
Capability
Table A: Function - Capability
Table B: Actor – Function

Table C.1 below illustrates *Table A (Function-Capability)*, and Table C.2 illustrates *Table B (Actor-Function)* of the SBN configuration process as applied to the real-life scenario in Chapter 5. The visual maps of the information contained in these two tables are illustrated in Chapter 5

Table C. 1: Real-life scenario: Function-Capability

Main function	**Marketing**		**Implementation**						**End-user support**			**Partner support**			**End-user training**			**Partner training**								**Installation**			**Product development**		
Sub-function	**Pre-marketing**	**Marketing**	**Define requirement**	**Confirm requirement**	**Basic configuration**	**Complex configuration**	**Test Bundle definition**	**Deploy Bundle definition**	**1st level support**	**2nd level support**	**3rd level support**	**1st level support**	**2nd level support**	**3rd level support**	**Overview training**	**Functional training**	**Management training**	**Overview training**	**Functional training**	**Management training**	**Admin training**	**Basic configuration training**	**Scanner installation training**	**Server installation training**	**Complex configuration training**	**Scanner Installation**	**Server Installation**	**Admin**	**Continuous improvement**	**Customisation**	**Legal contracts**
Capability																															
IT skills																					x	x	x	x		x	x	x			
Product knowledge		x							x	x	x	x	x	x	x	x	x	x	x	x	x							x	x	x	
Training																		x	x	x	x	x	x	x	x						
Programming					x	x	x	x																	x				x	x	
Context knowledge		x																													
Linux server knowledge																										x	x				
Marketing	x	x																													
Administration																												x			

Problem solving									x	x	x	x	x	x															x	x	
Analysis			x	x																											
Contract knowledge																															x
Document management knowledge																		x	x	x											

Table C. 2: Real-life scenario: Actor-Function

		Actors							
Main function	**Sub-function**	**FocalActor**	**Emerald**	**Amber**	**Ruby**	**Diamond**	**MarketingCo**	**LegalCo**	**End-user**
Marketing	Pre-marketing	x					x		x
	Marketing	x	x	x	x	x			x
Implementation (once or iterative)	Define requirement	x		x	x	x			x
	Confirm requirement	x		x	x	x			
	Basic configuration	x			x	x			
	Complex configuration	x				x			
	Test Bundle definition	x			x	x			
	Deploy Bundle definition	x				x			
End-user support	1st level support	x	x	x	x	x			x
	2nd level support	x		x	x	x			x
	3rd level support	x				x			x
Partner support	1st level support	x	x	x	x	x			x
	2nd level support	x	x	x	x	x			x
	3rd level support	x	x	x	x	x			x
End-user training	Overview	x							x
	Functional	x							x
	Management	x							x
Partner training	Overview	x	x	x	x	x			
	Functional	x	x	x	x	x			
	Management	x		x	x	x			
	Admin	x		x	x	x			
	Basic configuration	x			x	x			
	Scanner installation	x		x	x	x			
	Server installation	x				x			
	Complex configuration	x				x			
Installation	Scanner Installation	x		x	x	x			
	Server Installation	x				x			
Admin		x		x	x	x			
Product development	Continuous improvement	x							x
	Customisation	x							x
Legal contracts		x						x	

APPENDIX D. Discussion guidelines for subject-matter expert evaluations

Table D.1 contains the overall steps and guidelines used to conduct the semi-structured interviews with the selected subject-matter experts (Chapter 6), which were adjusted based on the interviewee. The overall structure of the interviews was the same, with differences in the discussion based on their respective environments or expertise. After the interviews were conducted, a questionnaire (an example of the layout can be seen in Figure D.1) was sent to the participating the subject-matter experts.

Table D. 1: Overview of semi-structured interviews and structured questionnaire

Step	Overview of how questions were structured	
	Business experts	**Manufacturing experts**
Introduction and background	Introduction to the researcher and the study was provided (see the slides below). Consent was obtained from the participants.	
Discussion questions	• Confirmation of the applicability and relevance of the argument presented in this study. • Confirmation or adaptations to the theoretical frameworks (hierarchical taxonomy, concept map of theory, SBN configuration process). • Confirmation or adaptations to the management framework. • Discussions around challenges regarding application and user requirements to present the framework as a tool to ensure potential use.	• Confirmation of the applicability and relevance of the argument presented in this study. • Confirmation or adaptations to the theoretical framework (SBN configuration process). • Confirmation or adaptations to the management framework. • Discussions around challenges regarding the manufacturing and AM environment and possible implications regarding the framework.
Post review	The complete framework was sent to through with a set of questions forming part of the previous step and the experts provided feedback by email, or by a follow-up meeting.	
Questionnaire	The structured questionnaire containing the framework activities was sent through and the experts provided feedback by email.	

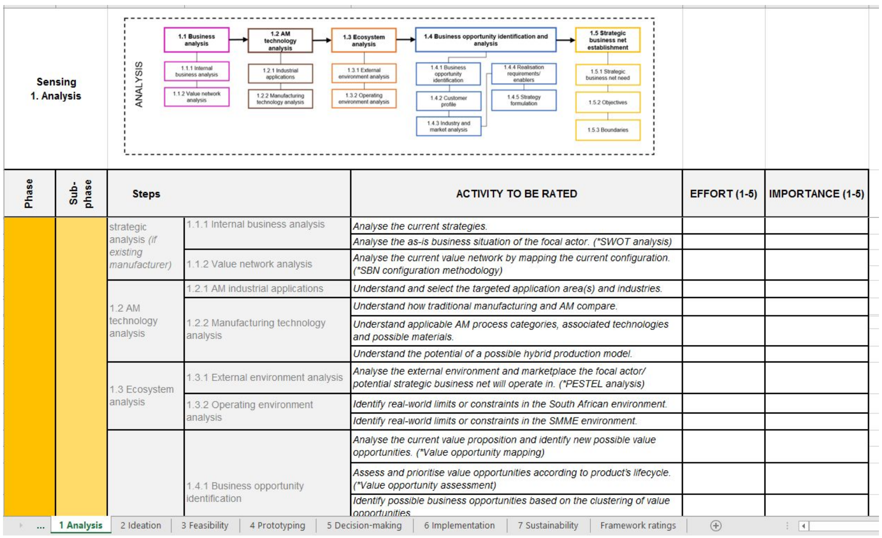
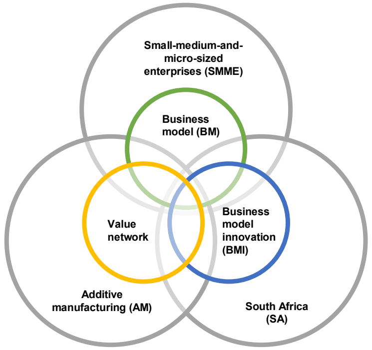
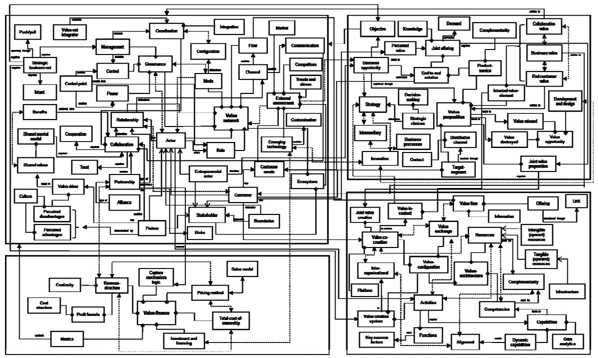


Figure D. 1:Example of the layout of the structured questionnaire

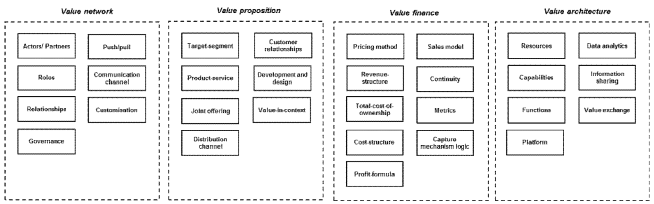
The development of a Business Model Innovation Framework from a Value Network Perspective for the Cemented Tungsten Carbide Additive Manufacturing Sector in South Africa



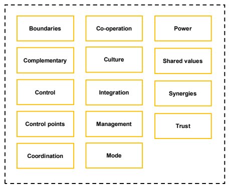
Concept map



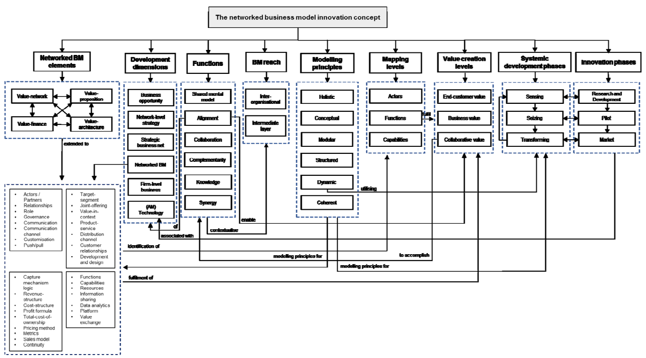
Networked BM elements



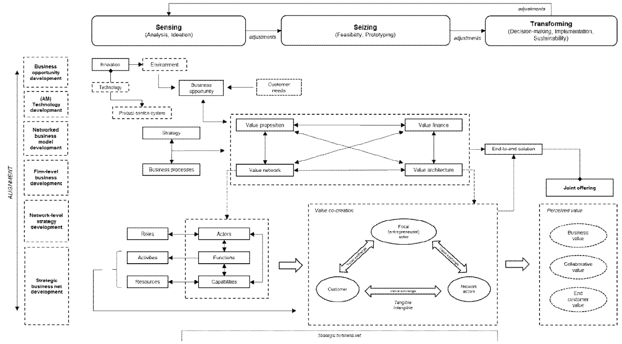
Strategic business net features



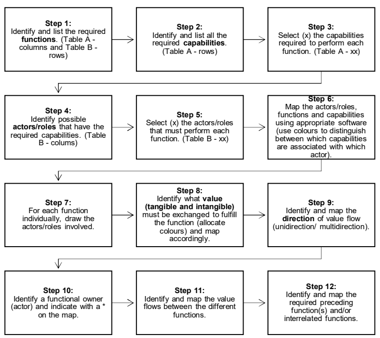
Hierarchical taxonomy

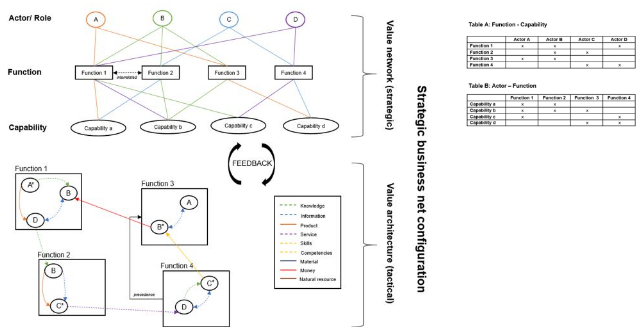


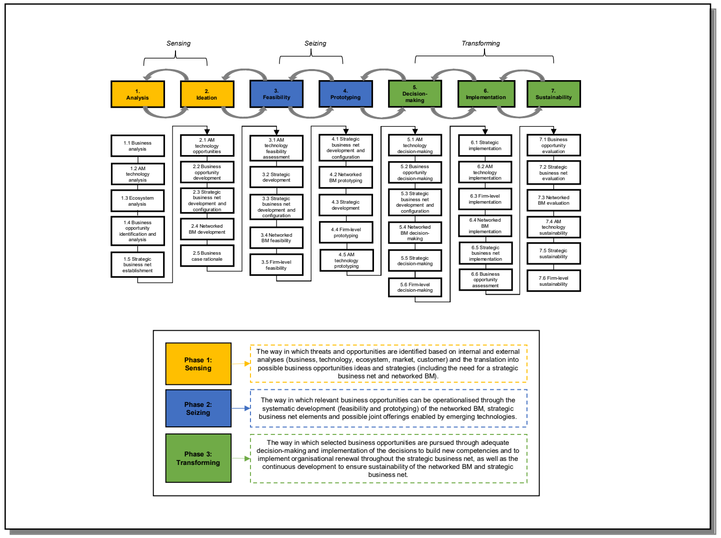
Concept map of theory



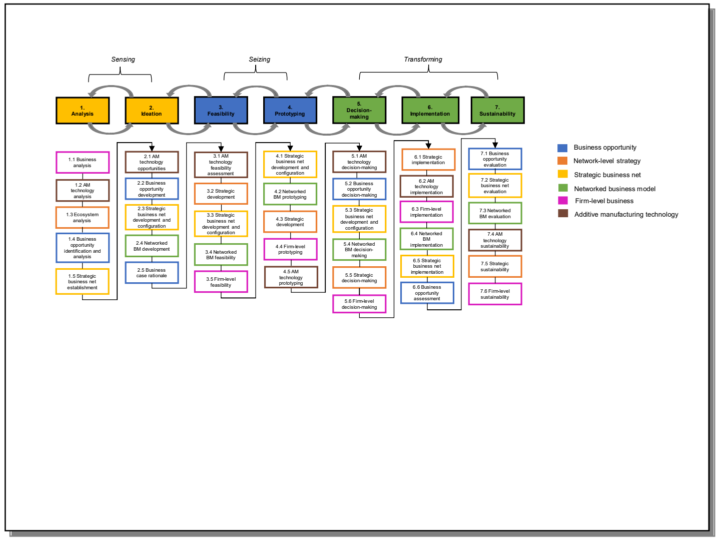
Strategic business net configuration methodology



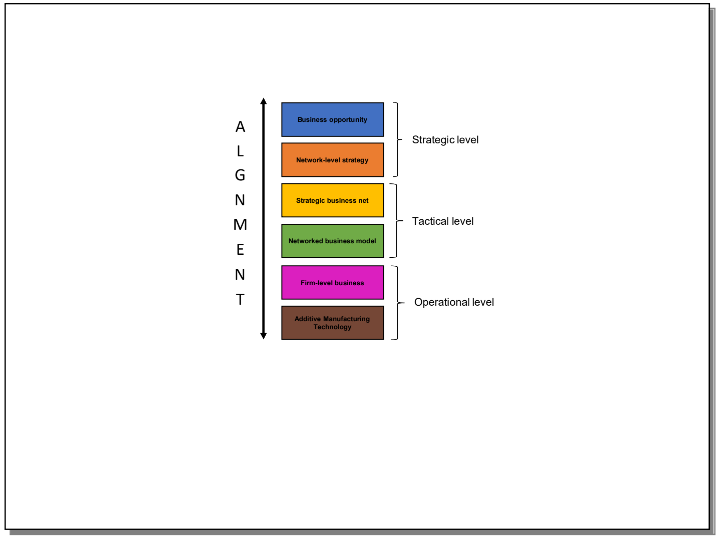




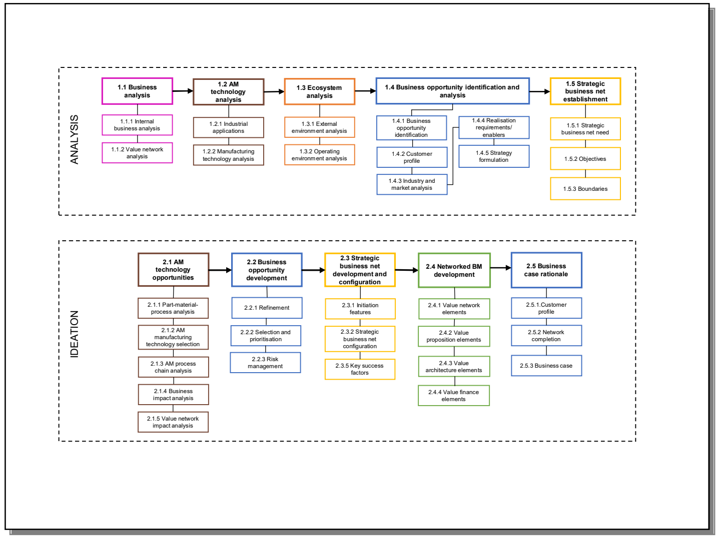
Sensing
Seizing
Transforming
1. Analysis
2. Ideation
3. Feasibility
4. Prototyping
5. Decision-making
6. Implementation
7. Sustainability
Phase 1: Sensing
The way in which threats and opportunities are identified based on internal and external analyses (business, technology, ecosystem, market, customer) and the translation into possible business opportunities ideas and strategies (including the need for a strategic business net and networked BM).
Phase 2: Seizing
The way in which relevant business opportunities can be operationalised through the systematic development (feasibility and prototyping) of the networked BM, strategic business net elements and possible joint offerings enabled by emerging technologies.
Phase 3: Transforming
The way in which selected business opportunities are pursued through adequate decision-making and implementation of the decisions to build new competencies and to implement organisational renewal throughout the strategic business net, as well as the continuous development to ensure sustainability of the networked BM and strategic business net.



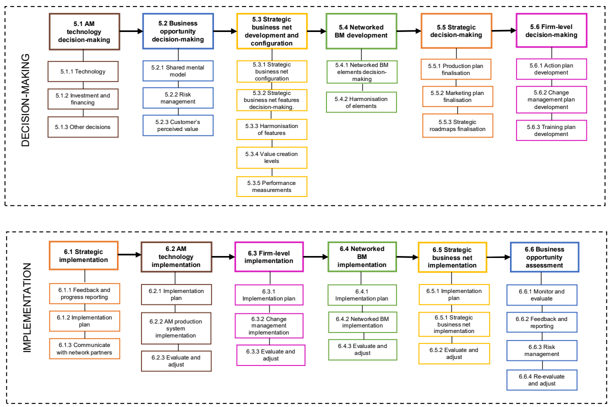
Sensing
Seizing
Transforming
1. Analysis
2. Ideation
3. Feasibility
4. Prototyping
5. Decision-making
6. Implementation
7. Sustainability
Business opportunity
Network-level strategy
Strategic business net
Networked business model
Firm-level business
Additive manufacturing technology

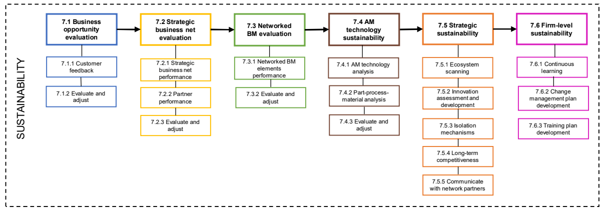


ALGNMENT
Business opportunity
Network-level strategy
Strategic business net
Networked business model
Firm-level business
Additive Manufacturing Technology
Strategic level
Tactical level
Operational level

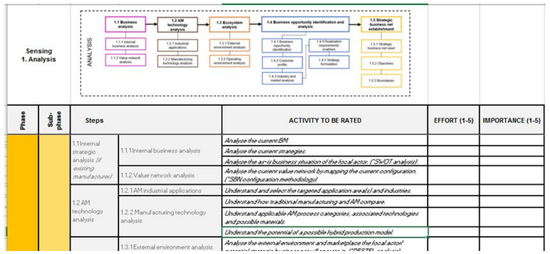


ANALYSIS
1.1 Business analysis
1.2 AM technology analysis
1.3 Ecosystem analysis
1.4 Business opportunity identification and analysis
1.5 Strategic business net establishment
IDEATION
2.1 AM technology opportunities
2.2 Business opportunity development
2.3 Strategic business net development and configuration
2.4 Networked BM development
2.5 Business case rationale





Questionnaire format



Evaluation process

APPENDIX E. Contextual application

Table E. 1: Additional literature studies included for the contextual application

	Reference	Year	Title	Type	SA	SMME	Tooling industry	AM	BM	Cemented tungsten carbide	PSS (servitization)
1	Malherbe [138]	2007	*"Benchmarking the South African Tool and Die Industry"*	Thesis	x	x	x				
2	Schuh *et al.* [203]	2011	*"Industrial product-service-systems for the tooling industry"*	Article		x	x				x
3	Henriques and Peças [103]	2012	*"New Business Models for the Tooling Industry"*	Article			x		x		
4	Schuh *et al.* [202]	2013	*"Digitalization as a Key Enabler for Efficient Value Creation Networks in the Tool and Die Making Industry"*	Article			x				
5	Cotteleer *et al.* [55]	2014	*"3D opportunity in tooling: Additive Manufacturing shapes the future"*	Report			x	x			
6	Boos *et al.* [29]	2014	*"Tooling in South Africa"*	Report	x		x				
7	Uhlmann, Bergmann and Gridin [226]	2015	*"Investigation on Additive Manufacturing of Tungsten Carbide-cobalt by Selective Laser Melting"*	Article				x		x	
8	Dewa *et al.* [64]	2015	*"Towards a competitive South African tooling industry"*	Article	x		x				
9	von Leipzig and Dimitrov [238]	2015	*"Cluster development in the SA tooling industry"*	Article	x		x				
10	Adrodegari *et al.* [3]	2016	*"A framework for PSS business models: formalization and application"*	Article							x
11	Ålgårdh *et al.* [9]	2017	*"State-of-the-art for Additive Manufacturing of Metals"*	Report				x			
12	Bogers *et al.* [26]	2017	*"Additive manufacturing for consumer-centric business models: Implications for supply*	Article					x		

	Reference	Year	Title	Type	SA	SMME	Tooling industry	AM	BM	Cemented tungsten carbide	PSS (servitization)
			chains in consumer goods manufacturing"								
13	Dewa *et al.* [64]	2018	*"Digitalisation of shop-floor operations in the South African Tool, Die, and Mould making industry"*	Article	x		x				
14	Riesener, Doelle, Ebi and Tittel [195]	2019	*"Implications of service-related business models on product development processes"*	Article							x
15	Kalidas *et al.* [116]	2020	*"South African SMEs post Covid-19"*	Report	x	x					
16	Padmakumar [175]	2020	*"Additive Manufacturing of Tungsten Carbide Hardmetal Parts by Selective Laser Melting (SLM), Selective Laser Sintering (SLS) and Binder Jet 3D Printing (BJ3DP) Techniques"*	Article						x	
17	Sandberg and Tinglöv [198]	2021	*"Business model innovation for Additive Manufacturing"*	Thesis				x	x		

Table E. 2:Contextual application: As-is value network Function-Capability

Main functions	Product development		Quotation					Design						Manufacturing									Try-out				Approval	Product production			
Sub-functions	**Product design**	**Prototypes**	**Product specification**	**Product model**	**Production requirements**	**Quotation**	**Quotation approval**	**Product design for manufacturing**	**Tool initial design**	**Process and structural analysis**	**Tool design approval**	**Materials order**	**Tool design detail**	**Process planning**	**Powder processing**	**Powder mixing**	**Powder milling**	**Powder pressing**	**Dewaxing**	**(Liquid phase) Sintering**	**Post-sintering**	**Inspection**	**Tool try-out (tool shop)**	**Product inspection (tool shop)**	**Tool try- out (client shop)**	**Product inspection (client shop)**	**Tool approval**	**Product production**	**Tool maintenance**	**Tool recycling**	**Tool end-of-life**
Capabilities																															
Product design knowledge	x	x	x	x				x	x		x																				
Manufacturing capabilities		x																					X								
Product functional knowledge	x	x	x	x							x													X		x	x				
Tool production process knowledge					x	x			x	x			x	x																	
Technical capabilities					x																										
Resource estimation capabilities						X																									
Cost estimation capabilities						X																									
Financial capabilities							x																								
Digital (CAD) design capabilities								x	x				x																		
Simulation capabilities										x																					
Ordering capabilities												x																			

Raw material supply capabilities												x																			
Planning capabilities														x																	
Scheduling capabilities														x																	
Project management capabilities														x																	
Machining capabilities															x		x	x	x												
Inspection capabilities																x		X	x			x		X		x					
Powder manufacturing knowledge															x	x	x	x													
Maintenance and service capabilities															x		x	x		x	x								x		
Sintering capabilities																				x											
Post-processing capabilities																					x										
Dimensional testing capabilities																						x									
Surface testing capabilities																						x									
Assembling capabilities																															
Try-out/testing capabilities																							X	X	x	x					
Tool usage capabilities																												x			
Product (series) production capabilities																												x			
Recycling capabilities																														x	
Waste management capabilities																															x

Table E. 3:Contextual application: As-is value network Role (actor)-Function

		Roles									
Main-functions	**Functions**	**Tool shop (manufacturer)**	**Customer**	**External service provider A**	**External service provider B**	**External service provider C**	**External service provider D**	**Materials supplier A (powders)**	**Materials supplier B (wax)**	**Equipment supplier C (machines, components, etc.)**	**Equipment supplier D (machines, components, etc.)**
Product development	Product design		x								
	Prototypes		x								
Quotation	Product specifications	x	x								
	Product model	x	x								
	Production requirements	x	x								
	Quotation	x	x								
	Quotation approval	x	x								
Design	Product design for manufacturing	x									
	Tool initial design	x	x								
	Process and structural analysis	x		x							
	Tool design approval		x								
	Materials order	x						x	x		
	Tool design detail	x	x								
Manufacturing	Process planning	x									
	Powder processing	x			x						
	Powder mixing	x									
	Powder milling	x			x						
	Powder pressing	x									
	Dewaxing	x									
	(Liquid phase) Sintering	x			x						x
	Post-sintering	x			x						x
	Inspection	x									
Try-out	Tool try-out (tool shop)	x									
	Product inspection (tool shop)	x									
	Tool try-out (client shop)		x								
	Product inspection (client shop)		x								
Approval	Tool approval		x								
Product production	Product production		x								
	Tool maintenance		x			x					
	Tool recycling						x				
	Tool end-of-life						x				

Table E. 4:Contextual application: Future strategic business net Function-Capability

Main functions	Product design		Quotation								Design for AM						Build preparation		Manufacturing (build process)				Post-processing					Testing and inspection				Try-out					Product production				
Sub-functions	**Product design**	**Prototypes**	**Product specifications**	**Product model**	**Production requirements**	**Part (tool) screening**	**Feasibility evaluation**	**Quotation**	**Quotation approval**	**Production process planning**	**3D CAD volume model**	**Finite element simulation**	**Final design/ slicing**	**Tool design approval**	**Materials order**	**Final design / slicing**	**Machine preparation**	**Process preparation**	**(LBPF) Build process**	**Build plate removal**	**Quality assurance**	**Maintenance**	**Stress relieving**	**Part and support structure removal**	**Heat treatment**	**Finishing**	**Surface treatment**	**Dimension analyses**	**Surface analyses**	**Non-destructive testing**	**Destructive testing**	**Tool try out (tool shop)**	**Product inspection (tool shop)**	**Tool try-out (client shop)**	**Product inspection (client shop)**	**Tool approval**	**Product production**	**Tool maintenance**	**Tool refurbishment**	**Tool recycling**	**Tool end-of-life**
Capabilities																																									
Product design knowledge	x	x	x	x										x																											
Manufacturing) capabilities		x																														x									
Product functional knowledge	x	x	x	x										x																			x	x	x	x					
Tool production process knowledge					x						x																														
Technical capabilities					x																																				

AM process knowledge						x	x			x					x		x	x																							
AM material knowledge						x	x																																		
Metallurgical knowledge						x	x																																		
AM part selection knowledge							x																																		
Resource estimation capabilities								x																																	
Cost estimation capabilities								x																																	
Financial capabilities									x																																
Communication capabilities										x																															
Project management capabilities										x																															
Planning capabilities										x																															
Scheduling capabilities										x																															
Health and safety capabilities										x																															
Design for AM capabilities											x		x	x																								x	x		
Digital (CAD) design capabilities										x		x	x																									x	x		
Simulation capabilities												x																													
Ordering capabilities														x																											

Powder manufacturing capabilities														x																											
Powder distribution capabilities														x																											
Gas supply capabilities														x																											
Gas distribution capabilities														x																											
AM machine knowledge															x		x	x	x	x																					
AM process knowledge																					x																				
3D printing capabilities																				x																					
Scanning capabilities																			x																						
Accreditation (standardisation) capabilities																					x							x	x												
Quality assurance capabilities																			x		x																				
Service and maintenance capabilities																						x																			
Transportation capabilities																							x			x		x													
Stress relieving capabilities																							x																		
Material removal capabilities																								x																	

Heat treatment capabilities																									x																
Machining capabilities																										x															
Surface treatment capabilities																											x														
Dimensional testing capabilities																												x													
Surface testing capabilities																													x												
AM part testing capabilities																														x	x										
R&D capabilities																															x										
Inspection capabilities																																x									
Try-out/testing capabilities																															x	x		x							
Part (series) production capabilities																																					x				
Tool usage capabilities																																					x				
Service capabilities																																					x				
Maintenance capabilities																																						x			
Refurbishment capabilities																																							x		
Recycling capabilities																																								x	
Waste management capabilities																																									x

Table E. 5:Contextual application: Future strategic business net Role (actor)-Function

		Role/Actor															
Main function	**Sub-functions**	**Tool shop (manufacturer)**	**Customer**	**AM consultant / expert**	**Software supplier**	**Tool designer**	**Process simulator**	**Materials supplier A (powder)**	**Materials supplier B (gas)**	**AM machine supplier**	**Competitor**	**Post-processing supplier C**	**Post-processing supplier D**	**Transporter/Distributor**	**Tester and quality assurer**	**Research and development partner**	**Recycler**
Product development	**Product design**	x	x	x													
	Prototypes		x	x													
Quotation	**Product specifications**		x	x													
	Product model		x														
	Production requirements	x		x													
	Part (tool) screening			x													
	Feasibility evaluation			x													
	Quotation	x	x	x													
	Quotation approval		x														
	Production process planning	x		x													
Design for AM	**3D CAD volume model**				x	x											
	Finite element simulation				x	x	x										
	Final design/ slicing				x	x											
	Tool design approval		x														
	Materials order	x						x	x								
	Final design / slicing																
Build preparation	**Machine preparation**	x								x	x						
	Process preparation	x									x						
Manufacturing (build process)	**(LBPF) Build process**	x									x						
	Build plate removal	x									x						
	Quality assurance	x									x						
	Maintenance	x								x	x						
Post-processing	**Stress relieving**											x		x			
	Part and support structure removal											x					
	Heat treatment											x					
	Finishing												x	x			

	Surface treatment												x				
Testing and inspection	**Dimension analyses**	x												x	x		
	Surface analyses	x													x		
	Non-destructive testing	x													x		
	Destructive testing	x													x	x	
Try-out	**Tool try out (tool shop)**	x															
	Product inspection (tool shop)	x															
	Tool try-out (client shop)		x											x			
	Product inspection (client shop)		x														
	Tool approval		x														
Product production	**Product production**	x	x														
	Tool maintenance	x				x											
	Tool refurbishment	x															
	Tool recycling	x				x											x
	Tool end-of-life	x															x

APPENDIX F. Management framework

Phase	Sub-phase	Steps			Possible tools, guiding questions, and considerations
Sensing	1. Analysis	1.1 Business analysis *(if existing manufacturer)*	1.1.1 Internal business analysis	*Analyse the current BM.*	Consider the following elements: **Value network:** **Relationships:** The current links established with the actors/ partners. **Value proposition:** **Product-service:** The current product(s) and service(s) provided to customers. **Target-segment:** The current customer groups (clustered according to shared properties or characteristics). **Distribution channel:** The way customers are currently reached. **Offering:** Including unique features such as cost, expertise, flexibility, innovative leadership, training, speed, convenience, reliability, software, security, environmental friendliness, variety, customer productivity, quality, customer service. **Value architecture:** **Resources:** The current tangible resources and intangible resources the firm owns. **Value finance:** **Pricing method:** The current way in which different products and services are priced. **Revenue structure:** The type of revenue sources currently utilised. **Cost structure:** The current allocation of costs within the firm. **Profit-formula:** The current financial benefit that is currently realised. (Actors/partners, function, competencies addressed with value network analysis)
				Analyse the current strategies.	These strategies include the business, brand, market, manufacturing, processes, marketing, footprint, and R&D strategies.
				Analyse the as-is business situation of the focal actor.	***SWOT analysis:** **Strengths:** What does the company do well? How well is the company branded? What makes it better than competitors? Does it have good quality/well qualified resources? What differentiate the company/ brand/ product/ solution/ service from competitors? Is the footprint/presence big enough to reach potential market? **Weaknesses:** What does the company do not well/require improvements? What do competitors do that the company do not/lack of…? Do the company have limited resources (financial/technical)? What are the challenges/improvements the company or the brand/ product/service/processes/tools of trade face to perform optimally? **Opportunities:** Is there a need for the product/service offered by the company? Is there a lack of competitors in the area? What can the company do to enhance its offerings/ product/

				solution/ service/ image of the company/ processes/ training methods/ quality? Is the geographic footprint/marketing sufficient to reach all potential customers? **Threats:** Does the company have multiple strong competitors/customers? Is the company hampered by restrictions? What prevents the company from bigger market share? What obstacles are harming the company/ brand/ product/ service? Is the product/solution shelf life long enough to support the business strategy?
	1.1.2 Value network analysis	*Analyse the current value network.*		***SBN configuration process** **Actors/roles:** Organisations, companies, customers that currently partake in the value network. **Functions:** Processes or groups of activities that are currently performed. **Competencies** (instead of capabilities): Current skills used to fulfil each function. **STEP 1:** Identify and list the required functions. (Table A - columns and Table B - rows) **STEP 2:** Identify and list all the required competencies. (Table A - rows) **STEP 3:** Select (x) the competencies required to perform each function. (Table A - xx) **STEP 4:** Identify possible roles (actors) that have the required competencies. (Table B - columns) **STEP 5:** Select (x) the roles (actors) that must perform each function. (Table B - xx) **STEP 6:** Map the roles (actors), functions and competencies using appropriate software (use colours to distinguish between which capabilities are associated with which actor).
1.2 AM technology analysis	1.2.1 Industrial applications	*Understand and select the targeted application area(s).*		Consider the range of application areas of AM in different industries such as: **Health; Aerospace; Automotive; Consumer goods and electronics; Industrial equipment and tooling; Construction; Energy.**
	1.2.2 Manufacturing technology analysis	*Understand how traditional manufacturing and AM compare.*		**Traditional manufacturing vs Additive manufacturing:** E.g., Available materials; Processing speed; Energy consumption; Industry-level standards; Equipment costs; Training; Facility requirements; Ancillary equipment; Component specific comparisons; Health and Safety.
		Understand applicable AM process categories, associated technologies and possible materials.		**Binder Jetting:** 3D Printing, Ink-jetting, S-Print, M-print (metal, polymer, ceramic) **Direct Energy Deposition:** Direct Metal Deposition, Laser Deposition, Laser Consolidation, Electron Beam Direct Melting (metal: powder and wire) **Material Extrusion:** Fused Deposition, Modeling (polymer) **Material Jetting:** Polyject, Ink-jetting, Thermojet (photopolymer, wax) **Powder Bed Fusion:** Selective Laser Sintering, Selective Laser Melting, Electron Beam melting (metal, polymer, ceramic) **Sheet Lamination:** Ultrasonic Consolidation, Laminated Object Manufacture (hybrids, metallic, ceramic) **Vat photopolymerisation:** Stereolithography, Digital Light Processing (photopolymer, ceramic)
		Understand the potential of a possible hybrid production model.		Traditional manufacturing and AM are not mutually exclusive but are rather complements that can be used together in a hybrid approach (producing hybrid products) – it may be the most suitable production model. *Consider possible attributes and configurations of a hybrid production model.*
1.3 Ecosystem analysis	1.3.1 External environment analysis	*Analyse the external environment and marketplace.*	External factors	***PESTEL analysis:** **Political factors:** E.g., Government policy, political stability, corruption, tax policy, labour law, trade restrictions.

						Economic factors: E.g., Economic growth, exchange rate, interest rate, inflation rates, disposable income, unemployment rate. **Social factors:** E.g., Population growth rate, age distribution, career attitudes, safety emphasis, health consciousness, lifestyle attitudes, cultural barriers. **Technological factors:** E.g., Technology incentives, level of innovation, R&D activity, technological change, technological awareness, emerging technologies. (Industry 4.0; digitalisation). **Environmental factors:** E.g., Weather, climate, environmental policies, climate change, pressure from NGO's, environmental impact, green economy considerations. **Legal factors:** E.g., Discrimination laws, antitrust laws, policies, consumer protection laws, copyright, IP and patent laws, health, and safety laws.
					Trends, drivers, and game changers	Trends refer to directions of change caused by drivers (the factors that cause the change). General driver dimensions to consider: E.g., Political and economic context, social and environmental aspects, industrial ecosystem and competitors, market and customer, company milestones. Drivers of change to consider: Market failure, disruptive business and technical concepts, industry/market/ economic needs, the need for customised and sustainable production. Value network trends include the following: Decentralisation, personalisation, sustainability, globalisation, collaboration, intangible assets, flexibility, agility, with digitalisation and dematerialisation being the foundation of these transitions.
			1.3.2 Operating environment analysis	*Identify real-world limits or constraints in the South African environment.*		**Political**: Political instability, political influences have an impact on finance and access to finance; BEE have a huge impact on funding and allocation of contracts; impact of state capture. **Finance:** Lack of finance, lack of access to finance, high cost of capital. **Technological:** Due to the lack of finance, SMMEs cannot invest in the necessary technology. **Capacity:** SMMEs lack of access to global markets due to their limited resource capacity base; if a company's capacity is small a large project will absorb all the capacity for several months, rendering it incapable to bid for more work; SMMEs may not necessarily have innovation capacity in-house. **Human resources:** Due to the lack of finance (funds and working capital) SMMEs cannot afford the necessary expertise required to manage big projects, resulting in a massive skill shortage problem; there is an urgent need to strengthen the educational system for training as it restrains industrial companies. **Global trade and pricing:** Volatile exchange rate, without purchasing power SMMEs may pay double the international prices for materials and components; shipping cost may also be a barrier for SMMEs. **Unions**: Possess high power; must be monitored as industrial actions may compromise work (especially when new technologies are adopted as it may have an impact on their work and work security). **Energy supply**: Availability and reliability are compromised (continuous load shedding), consider own energy supply through renewable sources. **Employment:** South Africa has an extremely high unemployment rate; adoption of AM may cause job losses that will cause resistance from the workforce.
				Identify real-world limits or constraints in the SMME environment.		**Finance:** Financial resources, or the lack of resources. **Technical resource availability:** Use of advanced technologies, software umbrella, R&D, less specific divisions of labour, resource management. **Product specialisation:** Nature of product specialisation. **Organisational culture:** Organisational culture/ leadership flexibility, company strategy, decision making, organisational structure, less bureaucracy, lack of systematic development procedures.

					Standards: Standards consideration. **Employee participation:** Human resource engagement, exposure to human resource development, knowledge, and experience industry, greater capacity to absorb new knowledge and technologies (SMMEs). **Alliances:** Alliances with universities or research institutions. **Collaboration:** Important activities, dependence on collaborative network, customer/supplier relations, manage and control customer co-creation. **Other:** Implementation; Strategy; Security and IP protection; Big data.
		1.4 Business opportunity identification and analysis	1.4.1 Business opportunity identification	*Identify possible business opportunities.*	***Brainstorming** Opportunities that can expand the business into new markets and introduce new products and services that offer enhanced benefits to stakeholders. Consider upstream and downstream in own market. Consider sideways into related markets and new markets.
				Assess and prioritise business opportunities according to product's lifecycle.	***Value opportunity assessment** (refer to template suggestion)**:** *Divide opportunities according to:* **Beginning of Life** (BoL): a) design of products and processes, b) manufacturing system configuration, c) business model; **Middle of Life** (MoL): d) efficiency in use phase, e) product life extension; **End of Life** (EoL): f) closing the loop. ***Value opportunity prioritisation** (refer to template suggestion)**:** *Prioritise/ assess the opportunities according to the feasibility vs impact/ importance.*
				Identify possible joint offerings.	***Networked BM:** **Joint offering:** It refers to the total offering provided to the customers, which are created by the group of actors that form part of the strategic business net, including factors such as availability, technical support, quality of service.
				Identify value-in-context elements.	***Networked BM:** **Value-in-context:** It refers to how the value associated with the joint offering is unique in the specific context (closely associated with unique selling points and value-added benefits or value offer to the customers). Note: It can either be based on added value for customer or reduced effort for value creation.
			1.4.2 Customer profile	*Identify the customer target-segment(s).*	***Networked BM:** **Target-segment:** It refers to the clustering of the strategic business net's customers into different groups based on shared common properties and characteristics.
				Identify the customer needs.	A customer need is a motive that prompts a customer to buy a product or service. Note: To accurately identify customer needs, feedback is required throughout the process.
				Refine the identified joint offerings.	Refer to 1.4.1
				Determine customer involvement and interaction (where, how).	Consider: Customer engagement; Exploration of value-adding elements with customers; Close customer relationships; Customer co-creation; Customer feedback.

1.4.3 Industry and market analysis	*Identify the key competitive industry drivers.*			E.g., Brand presentation, Due date conformance, Export price, Product cost, Product quality, Speed to market, Volume flexibility.
	Analyse the competitors.			***Porter's five forces:** **Supplier power:** The ease of suppliers to increase their prices. How many potential suppliers do you have, how unique is product or service they provide, and how expensive would it be to switch from one supplier to another? **Buyer power:** The ease of buyers to drive prices down. How many buyers are there and how big are their orders, how much would it cost them to switch to those of rival, are buyers strong enough to dictate terms to you? **Threat of substitutes:** The likelihood of customers finding a different way of doing what they do. **Threat of new entry:** The ability for other role-players to enter the market. How easy is it to get it, how much will it cost, how tightly is sector regulated? **Competitive rivalry:** The number and strength of competitors. Who are they and how does the quality of their products and services compare with yours?
	Analyse the target market.			**Market size:** The number of individuals in a certain market segment who are potential buyers. **Market share:** The portion of a market controlled by the company. **Market segments:** A market segment is a group of people who share one or more common characteristics, lumped together for marketing purposes. **Demand:** The quantity of consumers who are willing and able to buy products at various prices during a given period of time.
	Identify influential government structures.	Policies		E.g., National/regional policy and programs, Science/innovation policy, Regional policy, Industry/ SME/ entrepreneurship policy, Cluster policy and programs.
		Programmes		E.g., Government programmes (e.g., National Tooling Initiative Programme)
		Legislation		E.g., Policies, programmes, legislation introduced by Department of Trade and Industry (e.g., the Industrial Financing and Loan facilities, company incentives, policies, international relationships).
	Benchmark the local industry with international industries.			Benchmark in terms of market, product, process, and resources.
	Identify specific best practices within the industry.			World-class business and manufacturing practices are needed to ensure success.
1.4.4 Realisation requirements/ enablers	*Identify the requirements/ enablers to realise the identified business opportunities.*			E.g., Technology, product, process, demand, functional, standards, quality, IP protection. These requirements may be linked to the maturity of the elements.
1.4.5 Strategy formulation	*Formulate appropriate strategies.*			***TOWS matrix:** (based on SWOT analysis) **Strengths-Opportunities** strategies: How can strengths be utilised to exploit opportunities? **Strengths-Threats** strategies: How can strengths be exploited to overcome any potential threats? **Weaknesses-Opportunities** strategies: How can weaknesses be overcome and then opportunities be exploited?

					Weaknesses-Threats strategies: How can weaknesses be minimised to avoid possible threats?
				Ensure alignment and coherence among formulated strategies.	Ensure alignment and coherence among all the types of strategies formulated, e.g., business, brand, market, manufacturing, processes, marketing, footprint, and R&D.
		1.5 Strategic business net establishment	1.5.1 Strategic business net need	*Define the need for the establishment of a strategic business net.*	Consider the competencies and capacity of the company. Consider the geographical location of the strategic business net (e.g., the formation of clusters).
			1.5.2 Objectives	*Define the objective(s) of the strategic business net.*	The objective of all network actors should be to satisfy internal or external customers (right time, right place, right price).
			1.5.3 Boundaries	*Identify and classify all stakeholders.*	Stakeholders are all organisations with an interest or concern in the operation of the strategic business net and the objectives the strategic business net aim to achieve. ***Stakeholder analysis:** **Keep satisfied:** High power, low interest. **Manage closely:** High power, high interest. **Keep informed:** Low power, high interest. **Monitor:** Low power, low interest. Note: Some of these stakeholders may form part of the broader ecosystem and may be excluded from the mapping. ***Stakeholder management plan:** Stakeholder, Strategic network actor (Y/N), Nature of impact, Communication plan
				Determine which stakeholders are included in the strategic business net.	Typical actors for strategic business nets include the focal firm, customers, distributors, suppliers, research institutions (including universities) and partners. Note: Ecosystems are broader extensions of business nets and usually include competitors, suppliers, potential collaborators, public institutions, governments, and investing firms.
	FEEDBACK				

Phase	Sub-phase	Steps			Possible tools, guiding questions, and considerations
Sensing	2. Ideation	2.1 AM technology opportunities	2.1.1 Part-material-process analysis	*Identify possible parts to be manufactured using AM.*	For each potential part to be manufactured (within each application area and industry), understand the implications and requirements regarding **part-material-process** (as there is a direct link between the concepts): **Part:** Possible part, also consider the design (conceptual design) – minor changes or major changes (in most cases the part should be redesigned in order to add value from the benefits offered by AM). **Material:** Possible raw material and powder to produce part (consider if it exists, maturity, how it can be obtained). **Process:** Possible process to produce part, using the required material (consider process maturity).

					The following factors may influence the above: Dimension; Production volume; Time; Value; Cost; Complexity. Note: Due to the complexity of the part selection process, consider the use of an experienced AM consultant or AM expert to aid with this process. Note: Do not only consider existing components but exploit AM potential on a larger scale.
			2.1.2 AM manufacturing process and technology selection	*Select the required AM manufacturing technologies.*	Select the correct process and AM machine to fulfil the part-material-process requirements. Refer to 1.2 and 2.1.1
			2.1.3 AM process chain analysis	*Identify typical functions within the selected AM process chain.*	Generic process chain to guide specific process chain analysis: **Part design; Data preparation; Build preparation; Build process; Part extraction; Post processing; Part inspection; Waste management.** (include powder, gas, software, machines, equipment suppliers, PPE and other consumables) ***SBN configuration process:** **STEP 1:** Identify and list the required functions. (Table A - columns and Table B - rows)
				Identify process chain requirements.	**Pre-processing requirements** (including part design, data preparation) **Processing requirements** (including build preparation, build process) **Post-processing requirements** (including part extraction, post processing, part inspection) Note: During the part design phase, consider part optimisation (Design for AM) including topology optimisation or generative design.
				Identify the required capabilities within the process chain.	***SBN configuration process:** **STEP 2:** Identify and list all the required capabilities. (Table A - rows) **STEP 3:** Select (x) the capabilities required to perform each function. (Table A - xx)
				Identify the required roles within the process chain.	***SBN configuration process:** **STEP 4:** Identify possible roles (actors) that have the required capabilities. (Table B - columns) **STEP 5:** Select (x) the roles (actors) that must perform each function. (Table B - xx)
			2.1.4 Business impact analysis	*Identify possible applicable AM benefits.*	**Strategic:** E.g., Improving business risk, customisation capability, product diversity, sales and servitization possibility. **Operational:** E.g., Improving internal operational performance measures (such as department integration, production flexibility, AM equipment reliability/availability, production complexity, and support for a lean manufacturing approach) and external supply chain performance measures (such as collaboration with the supplier, customer/client interaction, logistics efficiency, supply chain decentralisation, outsourcing). **Environmental:** E.g., Increased sustainability, improved resource efficiency, extended product life; configuration of value chains.
				Identify possible applicable AM challenges.	**Technology-related** (AM technology and material uncertainties). **Strategy-related** (strategy and economic situation). **Supply chain-related** (digital data transfer, software). **Operational** (design, R&D, innovation). **Organisational** (current skills and practices, lack of knowledge). **External** (customer and subcontractor relationships and marketing). Note: people and adoption challenges are critical within practice.
			2.1.5 Value network impact analysis	*Determine the impact on the value network (strategic business net).*	**Configuration:** Centralised or decentralised.

					Location: Where will the AM facility be located? Consider the impact on transportation of materials and to customer. **Agility:** More agile supply chain to cater to faster innovation cycles. Consider the impact on inventory management, forecasting, production patterns.
		2.2 Business opportunity development	2.2.1 Refinement	*Refine the identified business opportunities (and joint offerings) based on the AM technology analysis.*	Refer to 1.4.1
			2.2.2 Selection and prioritisation	*Select the best business opportunities and prioritise them according to short, medium, and long-term.*	Consider all analyses conducted, assumptions made, and value-in-context elements to select the best opportunities.
			2.2.3 Risk management	*Identify the main risks associated with the selected AM process.*	***Risk Management Process:** **Identification:** Risks must include aspects related to the materials used, the processes, conditions of installation of the machine, good engineering practice and actual feedback. This is based on a characterisation of the physical risks (fire, explosion), risks for the health of the operators and other people exposed, and risks for the environment. **Assessment:** Evaluate each risk by determining the likelihood of it happening and the level of impact it will have. ***Risk assessment matrix:** **Likelihood / probability:** Rare, unlikely, possible, likely, almost certain. **Severity/ level of impact:** Catastrophic, major, moderate, minor, insignificant. **Risk classification:** Low, moderate, high, extreme **Mitigation:** Implement process changes to reduce the impact of each risk and a response (action) plan for if it happens. ***Risk control action plan:** Risk description, Likelihood/ probability, Mitigation actions (transfer, treat, tolerate, terminate), Actor, Time frame
				Identify company risks and develop a risk management plan.	***Risk Management Process:** **Identification:** Risks related to business, finance, and personnel. ***Risk assessment matrix.** **Mitigation.** ***Risk control action plan.**
				Identify joint risks and develop a risk management plan.	***Risk Management Process:** **Identification:** Risks related to the strategic business net and realisation of the business opportunity. ***Risk assessment matrix.** **Mitigation.** ***Risk control action plan.**
		2.3 Strategic business net development and configuration	2.3.1 Initiation features	*Determine the scope of the networked BMI initiative.*	**Scope:** Business and network aspects that need innovation.
				Identify the vision and mission of the networked BMI initiative.	**Vision:** The vision sets the way for innovative ideas and how to achieve it. It acts as the starting point for objectives, metrics, and strategic plans. **Mission:** A powerful, simple, and effective sense of purpose that will yield meaningful outcomes. It will keep stakeholders focused on what is important when it comes to the innovation process.

				Determine how the process will be integrated with existing systems and/or processes.	**Integration:** Consider possible touching points, additions, changes needed, change management implementation.
			2.3.2 Strategic business net configuration	*Configure the future strategic business net and map.*	***SBN configuration process** Use the functions, capabilities and roles identified in 2.1.3 (associated with the AM process), refine, and complete the tables. **STEP 1:** Identify and list the required functions. (Table A - columns and Table B - rows) **STEP 2:** Identify and list all the required capabilities. (Table A - rows) **STEP 3:** Select (x) the capabilities required to perform each function. (Table A - xx) **STEP 4:** Identify possible roles (actors) that have the required capabilities. (Table B - columns) **STEP 5:** Select (x) the roles (actors) that must perform each function. (Table B - xx)
			2.3.3. Strategic business net features	*Consider the impact of the SBN features on the network.*	***Strategic business net features:** **Co-operation:** It refers to the process of working with other actors towards the same goal. **Coordination:** It refers to the organisation of the different actors and their roles, functions, capabilities, and resources within the strategic business net to enable collaboration and value co-creation. **Trust:** It refers to the firm belief in the reliability, truth, or ability of strategic business net actors to fulfil their roles and to successfully perform their functions and activities. **Integration**: It refers to the integration of the functions, capabilities, and resources of different network actors to deliver the joint offering and to reach the network's goal or objective. It also includes the integration of findings/ outcomes on the network-level into existing firm-level processes and structures. **Power**: Power dependence denotes the influencing forces where one actor can (partly) control and influence another actor, as the other actor needs those resources or competences held by the first actor. **Control:** It refers to the power of one or more actors to influence or direct other actor's behaviour or the execution of functions or activities within the strategic business net. **Control points**: It refers to areas in the strategic business net where power and control can be applied - functional and strategic (the more control points an actor have, the more important are they in the network). **Management:** It refers to the process of dealing with or controlling functions, activities, and actors within the strategic business net.
			2.3.4 Key success factors	*Identify key success factors for the strategic business net.*	Essential ingredients/ factors that will allow the strategic business net to sustain a long-term competitive advantage. E.g., Operational factors, competitive standing, organisational/ strategic business net structure, technical factors.
		2.4 Networked BM development	2.4.1 Value network elements	*Provide possible configurations/ ideas for the value network BM elements.*	***Networked BM:** **Governance:** It refers to who within the strategic business net has control and power over what kind of objects and resources e.g., data, relationships, channels, functions, patents, brands, and transactions. It can either be hierarchical where one or few actors dominate the power or flat where all actors share costs, risks, knowledge, and capabilities more equally. **Relationships:** It describes the type of links established between actors within the strategic business net. E.g., strategic alliances and partnerships, affiliations, joint venture, mergers, acquisitions, transactional etc. **Communication:** It refers to the exchange of information between actors, functions, or resources through a medium or channel. It also includes determining what must be communicated to whom and when.

					Communication channel: It refers to the communication mediums or ports used to communicate materials and information among actors (including customers) as a result of their established relationships. Channels could be physical or electronic and can range from manual to fully automated. E.g., blog/ social media/ advertisements/ press releases/ trade shows/ launches/ webinars/ exhibitions. **Customisation:** It refers to how individualised the product-service is (mass production/ mass customisation/ mass individualisation). **Push/pull:** It describes the kind of production paradigm used (pull, on-demand/ push and pull).
			2.4.2 Value proposition elements	*Provide possible configurations/ ideas for the value proposition BM elements.*	***Networked BM:** **Distribution channel:** It refers to how the joint offerings are going to reach the customers. **Customer relationships:** It describes the type of relationship established with customers. **Development and design:** It refers to who develops and designs the products (hired or employed experts/ customer or user designed/ development community or crowdsourcing). It includes who owns the CAD design files and products.
			2.4.3 Value architecture elements	*Provide possible configurations/ ideas for the value architecture BM elements.*	***Networked BM:** **Information flow:** It refers to the flow of timely, real-time, and accurate information (including facts, data, knowledge) between network actors to enable close partnerships, the exploitation of network benefits, and overall network performance. **Data analytics:** It refers to the source of high-value data (internal data/ customer's data). **Platform:** It refers to the kind of digital platform, if any, that forms an essential part of the BM (IoT/ merchant only/ innovation only/ merchant and innovation).
			2.4.4 Value finance elements	*Provide possible configurations/ ideas for the value architecture BM elements.*	***Networked BM:** **Cost structure:** It refers to the allocation of costs within the strategic business net. **Revenue structure:** It refers to the type of revenue sources utilised, e.g., reselling consumables/ sale/ leasing/ rental partner. It also includes how the profitability of different joint offerings are split among customer segments. **Profit formula:** It refers to the financial benefit which is realised when revenues gained exceeds that of expenses, costs, and taxes needed to sustain the activities conducted as part of the strategic business net. **Pricing method:** It refers to how different services and products delivered by the strategic business net are priced (e.g., fixed, dynamic, or a mixture). **Total-cost of ownership:** It refers to the overall costs with respect to all core arrangements that are needed to create, provide, market, deliver, and maintain the joint offering throughout its lifespan (including development, support, maintenance, collaboration costs). **Sales model:** It refers to what the customer is paying for (ownership/ service delivery or use/ availability or result). **Continuity:** It refers to how continuous the revenues are (once/ mixed/ continuous).
		2.5 Business case rationale	2.5.1 Customer profile	*Refine the customer profile.*	Refer to 1.4.2
				Identify potential anchor/ lead customers.	An anchor/lead customer act as a brand ambassador which is a customer who will promote the joint offering among other potential customers. Consider building close relationships with these customers.
			2.5.2 Network completion	*Ensure the network is complete.*	Apply network thinking and make use of prototyping customer scenarios to test the delivering of end-to-end solutions. Obtain customer feedback where possible.

			2.5.3 Business case	*Ensure a comprehensive business case is created.*	Creating a sound business rationale for the preferred business opportunity (and joint offerings) based on all analyses, risks, costs, benefits evaluations conducted.
FEEDBACK					

Phase	**Sub-phase**	**Steps**			**Possible tools, guiding questions, and considerations**
Seizing	**3. Feasibility**	3.1 AM technology feasibility assessment	3.1.1 Technical feasibility assessment	*Conduct technical feasibility studies (proof of concept).*	A technical feasibility study is an assessment of the practicality from a technical and technological perspective of the proposed plan of introducing AM manufacturing technologies to make sure the business opportunities can be achieved before investment take place. Include detailed designs of the identified parts. Include technology readiness/maturity levels. Consider using outside organisations that already have the technology such as universities or consulting companies.
			3.1.2 Financial feasibility assessment	*Identify the investment requirements.*	**Investment:** What must be invested in? (think about entire process chain/value network, not just the focal actor) **Machines:** AM machines, supporting equipment and infrastructure. **Materials:** Adequate materials (e.g., powders, gas, handling and storage protocols) to manufacture potential products. **Digital/ software:** Tailored workflow software is essential. **People (knowledge)**: People are a key resource in AM. **Energy:** South Africa has a potential risk of intermittent electricity supply, consider investing in own energy sources.
				Identify and understand costs associated with AM.	**Costs:** What will the required investments cost? What will be the recurring costs? Fixed cost/ nonrecurring manufacturing costs. Cost of process qualification and component certification. Logistical costs. Running costs. What will be a potential favourable return on investment (ROI)?
				Determine the required revenues to obtain a favourable ROI.	What will be the required revenues needed to obtain the identified favourable ROI?
				Develop a financing plan.	A financing plan describes the current financial status, financial goals, when you want to achieve them, and strategies to meet those goals. It also includes how and where the money will be obtained to cover the investment costs (bank/ investors etc).
			3.1.3 Business feasibility assessment	*Conduct business feasibility studies (including sustainability).*	A business feasibility study is an overall assessment of identifying problems and opportunities, determining objectives, describing situations, defining successful outcomes and assessing the range of costs (including investment and other costs) and benefits associated with the introduction of AM manufacturing technologies.

					Include enterprise, supply chain, and capability readiness/maturity levels.
				Determine alignment with firm-level business strategies, processes, and BM.	The introduction of AM manufacturing technologies into the business must be aligned with other strategies and firm-level BM processes.
		3.2 Strategic development	3.2.1 Business environment assumptions	*State the assumptions made about the business environment.*	Note: Emerging technologies and BMs are associated with great uncertainty and therefore some assumptions must be made based on known data and facts. Furthermore, innovation value creation potential is unpredictable, uncertain, and continuously changing as innovation progress, therefore business decisions are often based on assumptions. These assumptions must be listed and reviewed and revised as new insights about the business environment and technology are obtained.
			3.2.2 Production plan development	*Develop a proposed production plan (high-level).*	A production plan is a document containing the results of production planning which is the administrative process of ensuring sufficient raw materials, staff, equipment, and other necessary items are procured and ready to create products according to the schedule specified. Note: This production plan refers to the strategic business net and must be compiled accordingly.
			3.2.3 Strategic roadmaps development	*Develop a strategic roadmap for the strategic business net (short, medium, and long-term).*	A strategic roadmap is a time-based plan that defines where the strategic business net is, where it wants to go, and how it will get there. It is a visual representation that organises and presents important information related to future plans. This enables SMMEs to better time, visualise, and understand each move and decisions that they need to make during the transformation process. ***Strategic roadmap planning:** Phase, Strategy category, Objective, Deliverable, Activity, Actor(s) Responsible, Actor(s) Accountable, Actor(s) Consulted, Actor(s) Informed, Time frame ***Strategic roadmap visualisation** (refer to template suggestion)**:** Strategy category, Activities, Time frame
				Develop a technology roadmap for the strategic business net (short, medium, and long-term).	A high-level, visual plan that communicates the strategic business net's strategy (vision and plans) for a complex technology undertaking. It is a powerful technique for supporting R&D and implementation of future technologies. It will guide internal (including R&D) teams to make strategic decisions around their technical infrastructure. ***Technology roadmap planning:** Phase, Technology category, Objective, Deliverable, Activity, Actor(s) Responsible, Actor(s) Accountable, Actor(s) Consulted, Actor(s) Informed, Time frame ***Technology roadmap visualisation** (refer to template suggestion)**:** Technology category, Activities, Time frame
		3.3 Strategic business net development and configuration	3.3.1 Partner evaluation and selection	*Evaluate the possible actors based on rankings obtained using an adequate criterion (including identified capabilities).*	***Actor selection template** (refer to template suggestion)**:** **Perceived advantages:** Access to new, complementary resources, reducing costs, reducing time to market, risk reduction and risk sharing, access to new technologies, learning, additional advantages, other identified capabilities (refer to 2.1.3). **Perceived disadvantages:** Decreased access to new, complementary resources, increase of costs, no access to new markets, increase risk reduction, increase time to market, no access to new technologies, no opportunities for learning, additional disadvantages.
				Select the highest scoring actors to form part of the strategic business net as partners.	In addition to the perceived advantages and disadvantages, consider the following: ***Strategic business net features:** **Shared values:** Shared values (tacit or explicit) provide a common ground or understanding among different actors. **Culture**: Organisational culture refers to the cumulative deposit of knowledge, experience, beliefs, values. The cultures of the respective actors' need to be aligned and adaptable to ensure successful network operation.

				Complementary: Strategic business net partner's capabilities and resources should be complementary to each other to enable the creation and delivery of innovative joint offerings.
	3.3.2 Partner involvement	*Identify what information to disclose to which partner.*		Identify what information about the business opportunity and strategic business net to disclose to potential core partners. Ensure a non-disclosure agreement is in place before partners are approached and information is disclosed.
		Inform partners about business opportunities, obtain ideas, and integrate.	Inform	Inform potential core partners about opportunities.
			Ideation	Obtain additional value ideas from partners.
			Integrate	Integrate their ideas with the current business opportunities.
	3.3.3 Strategic business net features	*Consider the impact of selected strategic business net features on the feasibility of the network and business opportunity.*		Refer to 2.3.3
	3.3.4 Strategic business net configuration	*Refine the configuration of the future strategic business net and add the actors/partners.*		***SBN configuration process:** **STEP 5:** Select (x) the roles (actors) that must perform each function. (Table B - xx) Revise based on partner selections (refer to 3.3.1) **STEP 6:** Map the roles (actors), functions and capabilities using appropriate software (use colours to distinguish between which capabilities are associated with which actor).
	3.3.5 Performance measurements	*Identify performance measurements for the strategic business net.*		***Networked BM:** **Metrics:** It refers to the standard measurements to evaluate or measure the profitability and performance of the strategic business net and individual partners. ***Balanced scorecard:** **Customer perspective:** How do customers see us? Are we satisfying customer needs? **Internal perspective:** What must we excel at? Are we working effectively and efficiently? **Innovation and learning perspective:** How can we continue to improve and create value? What are the emerging opportunities and challenges? How can we serve customers better in the future? **Financial perspective:** How do we look to shareholders? (Internal efficiency + customer satisfaction = financial success) Note: Depending on the maturity (use of sensors) for major tasks, real time data can be available (moving performance management process to an operational process).
		Identify performance measurements for each network partner.		***Networked BM:** **Metrics:** It refers to the standard measurements to evaluate or measure the profitability and performance of the strategic business net and individual partners. ***Balanced scorecard.**
3.4 Networked BM feasibility	3.4.1 Value network elements	*Evaluate the feasibility of the value network elements.*		Refer to 1.4.2 and 2.4.1
	3.4.2 Value proposition elements	*Evaluate the feasibility of the value proposition elements.*		Refer to 2.4.2
	3.4.3 Value architecture elements	*Evaluate the feasibility of the value architecture elements.*		Refer to 2.4.3

			3.4.4 Value finance elements	*Evaluate the feasibility of the value finance elements.*	Refer to 2.4.4
		3.5 Firm-level feasibility	3.5.1 Feasibility and profitability assessment	*Assess the feasibility and profitability of the strategic business net on a firm-level.*	Consider firm-level strategies and processes in relation to the strategic business net and determine feasibility and profitability for the firm.
			3.5.2 Customer feedback	*Test some of the ideas with anchor/ lead customers and obtain customer feedback.*	Test some of the ideas formed as part of the strategic business net with trusted customers or brand ambassadors, obtain feedback, and implement changes accordingly.
	FEEDBACK				

Phase	Sub-phase	Steps			Possible tools, guiding questions, and considerations
Seizing	4. Prototyping	4.1 Strategic business net development and configuration	4.1.1 Strategic business net configuration	*Configure and map the value exchange and flow for each function within the strategic business net.*	***SBN configuration process:** **STEP 7:** For each function individually, draw the roles (actors) involved. **STEP 8:** Identify what value (tangible and intangible) must be exchanged to fulfil the function (allocate colours) and map accordingly**.** Tangible value flow: E.g., money, product, material. Intangible value flow: E.g., knowledge, information, skills, service, software. **STEP 9:** Identify and map the direction of value flow (unidirectional/ multi-directional). **STEP 10:** Identify a functional owner (actor) and indicate with a * on the map. **STEP 11:** Identify and map the value flows between the different functions.
			4.1.2 Functional interdependence assessment	*Assess the interdependence between functions within the strategic business net.*	***SBN configuration process:** **STEP 12:** Identify and map the required preceding function(s) and/or interrelated functions. Note: Interdependence and interrelationships must be assessed to understand precedencies and dependencies which can have an influence on how the business opportunity must be implemented.
		4.2 Networked BM prototyping	4.2.1 Value network elements	*Create prototypes of the elements.*	Refer to 1.4.2, 2.4.1 and 3.4.1
			4.2.2 Value proposition elements	*Create prototypes of the elements.*	Refer to 2.4.2 and 3.4.2
			4.2.3 Value architecture elements	*Create prototypes of the elements.*	Refer to 2.4.3 and 3.4.3
			4.2.4 Value finance elements	*Create prototypes of the elements.*	Refer to 2.4.4 and 3.4.4

	4.2.5 Alignment	*Ensure internal and external alignment of the networked BM.*	Internal	**Internal firm-level alignment:** Ensure alignment with firm-level strategies and business processes. **Internal network-level alignment (configurational fit):** Ensure alignment between the network-level BM and firm-level BMs, as well as between all the firm-level BMs. Note: Network-level BMs are often seen as a set of interrelated BMs.
			External	**External alignment:** Ensure alignment with the external environment (including changes in venture needs, customer needs, and stakeholder priorities).
4.3 Strategic development	4.3.1 Production plan prototyping	*Create a prototype of the production plan (high-level).*		Refer to 3.2.2
	4.3.2 Strategic roadmaps development	*Create a prototype of the strategic roadmap.*		Refer to 3.2.3
		Create a prototype of the technology roadmap.		Refer to 3.2.3
	4.3.3 Marketing plan development	*Create a prototype marketing plan.*		The marketing plan outlines the marketing strategy and tactics focused on a specific period of time. The aim is to create a demand for the product-service among potential customers. The following must be included: product, price, promotion, packaging, positioning, and people. Consider the following: How will awareness be created among potential customers? How will the market be approached by the network? Who will perform the marketing activities? What material is needed?
	4.3.4 Action plan development	*Compile an action plan to realise the value co-creation on a network-level.*		An action plan is a proposed strategy or course of action. ***Action plan:** **Activity:** What must be done next, including deliverables? **Actor Responsible**: Who are responsible for the specific activity? **Tangible (operand) resources):** Tangible, static resources that require some action to make them valuable (e.g., people, facilities, equipment, materials, infrastructure, tools). **Intangible (operant) resources):** Intangible, dynamic resources that are capable of creating value (e.g., knowledge, time, energy, skills, attitude, capacity). **Time frame:** Date. **Progress status:** Not started, In progress, or Completed.
4.4 Firm-level prototyping	4.4.1 Action plan development	*Compile an action plan to realise the value co-creation on a firm-level.*		***Action plan.**
	4.4.2 Firm-level prototyping	*Create prototypes of applicable elements on the firm-level.*		These elements can include BM elements or configurations, or strategic business net features, or any business or technology structure or aspect.
4.5 AM technology prototyping	4.5.1 Joint offering prototyping	*Create physical prototypes of joint offering(s) (may use service bureau).*		Develop prototypes of the joint offering (or possible joint offerings) that will enable addressing the business opportunity. Consider R&D partners, or other companies that maybe already have/own the specific technology.

			4.5.2 Customer feedback	*Test the prototypes with anchor/ lead customers and obtain customer feedback.*	Obtain feedback from customers from the use of the prototype, provide the required feedback and implement the required adjustments.
FEEDBACK					

Phase	Sub-phase	Steps			Possible tools, guiding questions, and considerations
Transforming	5. Decision-making	5.1 AM technology decision-making	5.1.1 Strategic integration and alignment (firm-level).	*Decide if it is the selected manufacturing technologies are correct and how it will be integrated into existing strategies and processes.*	Do not consider AM in isolation: growing a true AM capability can present opportunities for growth and innovation in other parts of the business. Consider the following perspectives: Enterprise/company as a whole; Strategy; Value network; Business model; Operations.
			5.1.2 Investment and financing (firm-level).	*Decide exactly in which technologies to invest in (each partner) and acquire the technology.*	Make a final decision on the technology investments (emerging technology and associated ecosystem technologies), ensuring it is the correct technology to address business opportunity. Determine who in the strategic business net will own which technologies. Determine what other technology investments each actor will need to make. Finalise decision on which financing mechanisms will be used. Acquire/order the technology.
			5.1.3 Other decisions	*Determine how other general considerations regarding AM will be addressed.*	**Regulation:** Public sector officials who specify regulations for a geographic area, for example, pertaining to liability. **Compatibility:** It refers to whether two interrelated entities are compatible, whether older generations of a product are compatible with newer ones. **IP protection:** When designers send files for printing, the file can be intercepted, copied, and altered which can compromise mission-critical parts. **Repeatability:** Achieving repeatable quality isn't easily achieved in AM. Establishing a closed-loop control system is considered the most efficient way to increase repeatability in AM. **Information systems**: Inadequate inter-organisational information systems hinder the adoption of digital supply chain innovations. **Data**: Obtained from supply chain/ network; AM software solutions need to include data preparation, monitoring, quality assurance, and data connectivity. **Stock holding:** Including the impact on inventory (and inventory holding policy) and the budget. **Data security:** Cybersecurity is becoming a critical element of AM; compliance with international data protection standards. **Standards:** Consider standards applicable to AM (or the lack thereof), it is believed that as AM's maturity increase, more standards will be developed. (consider standards applicable to the network e.g., communication, terminology etc. standards).

		5.2 Business opportunity decision-making	5.2.1 Shared mental model	*Establish a collective understanding among network partners.*	A shared mental model refers to a strategic vision shared by all the strategic business net actors regarding what the network aims to achieve. Ensure all legal documents such as service-level-agreements and restraint of trades are in place.
			5.2.2 Risk management	*Re-assess and monitor the identified technology, company, and joint risks.*	***Risk Management Process:** **Monitoring**: On a continuous basis, review the progress of the plan and check if a risk has occurred but was missed. **Reporting**: Communicate the effectiveness of the risk plan to stakeholders to keep engagement up.
			5.2.3 Customer's perceived value	*Evaluate the customer's perceived value and alignment with customer needs.*	Without perceived value of the offering, no business opportunity will be successfully implemented. Evaluate the joint offering's attributes, attribute performances and the consequences from use. Evaluate how the joint offering's value-added benefits are aligned with the identified customer needs.
		5.3 Strategic business net development and configuration	5.3.1 Strategic business net configuration	*Finalise the decisions regarding the strategic business net configuration.*	***SBN configuration process** *Revise, refine and finalise the SBN configuration mapping* (value network and value architecture mapping).
			5.3.2 Harmonisation of features	*Ensure harmonisation and coherence among all strategic business net features.*	Refer to 3.3.3 and 4.1.3
			5.3.3 Value creation levels	*Evaluate the value creation levels per function. If value is not generated on any level, revise function.*	***Value meta-model:** **Business value:** Value (stakeholder value) for an individual company. **Collaborative value**: Improvement of business value through collaboration (value network value) which may decrease short-term returns but increase long-term results for an individual actor. **End-customer value:** Strongly related to the value proposition which correspond to end-user needs. A value is not a value unless it is perceived to be one.
				For each function, determine how value will be measured on the applicable value creation level.	Use appropriate measurement techniques and metrics.
			5.3.4 Performance measurements	*Refine and confirm the performance measurements for the strategic business net.*	Refer to 3.3.5
				Refine and confirm the performance measurements for each partner.	Refer to 3.3.5
		5.4 Networked BM decision-making	5.4.1 Value network elements	*Decide on the best configuration for each networked BM element.*	Refer to 1.4.2, 2.4.1, 3.4.1 and 4.2.1
			5.4.2 Value proposition elements	*Decide on the best configuration for each networked BM element.*	Refer to 2.4.2, 3.4.2 and 4.2.2
			5.4.3 Value architecture elements	*Decide on the best configuration for each networked BM element.*	Refer to 2.4.3, 3.4.3 and 4.2.3

	5.4.4 Value finance elements	*Decide on the best configuration for each networked BM element.*	Refer to 2.4.4, 3.4.4 and 4.2.4
	5.4.5 Harmonisation of elements	*Ensure harmonisation and coherence among all networked BM elements.*	Refer to 5.4.1- 5.4.4
5.5 Strategic decision-making	5.5.1 Production plan finalisation	*Finalise decisions regarding the production plan.*	Refer to 3.2.2
	5.5.2 Marketing plan finalisation	*Finalise decisions regarding the marketing plan.*	Refer to 4.3.3
	5.5.3 Strategic roadmaps finalisation	*Finalise decisions regarding the strategic and technology roadmaps.*	Refer to 3.2.3
5.6 Firm-level decision-making	5.6.1 Action-plan development	*Refine the action plan and add detailed tasks.*	Refer to 4.4.1
	5.6.2 Change management plan development	*Determine what changes must be made and how it will be implemented.*	Individual actors must determine what changes (strategic and operational) must be made on a firm-level. Implementing these changes are challenging, therefore an organisational change management plan must be compiled. Include change management strategies. This plan must address human challenges (strategic and technical), the development of know-how within manufacturing engineering teams, how to overcome resistance to innovative technology, etc. ***Change management plan:** Describe how each of the following aims will be achieved: Educate and inform, Ensure system adoption, Gain input and participation, Manage expectations, Build excitement and morale. ***Responsibility matrix:** Change management activity, Main responsibility. ***Change implementation plan:** Intervention/ Change, Description, Actor(s) / owner(s), Costs, Time frame
	5.6.3 Training plan development	*Compile a training plan in line with the change management plan.*	Each actor within the strategic business net need to compile a training plan on how people will be upskilled and trained to implement the needed changes to address the business opportunity and producing the joint offering. This training plan should be based on the overarching roadmap and the organisational change management plan. Include technical education. Training plans can furthermore also be used to develop personal development plans for individuals within the company. ***Training plan:** Type of training, Trainer (actor), Trainees (actors), Resources/ courses, Time frame
FEEDBACK			

Phase	Sub-phase	Steps			Possible tools, guiding questions, and considerations
Transforming	6. Implementation	6.1 Strategic implementation	6.1.1. Feedback and progress reporting	*Obtain feedback from all partners and brand ambassadors.*	Feedback and progress reports are needed from all network partners, based on their capability developments, change implementation and overall progress based on the different roadmaps.
			6.1.2 Implementation plan	*Compile a network-level implementation plan through integration of action plans, roadmaps, and progress reports.*	***Implementation plan:** Implementation phase, Step/ Activity, Actor(s) Responsible, Actor(s) Accountable, Actor(s) Consulted, Actor(s) Informed, Tangible resources, Intangible resources, Time frame, Progress status.
			6.1.3 Communicate with network partners	*Communicate the implementation plan with all network partners.*	Inform all actors of the implementation plan, obtain feedback, and make the necessary adjustments to ensure everyone is on the same page.
		6.2 AM technology implementation	6.2.1 Implementation plan	*Compile a phased AM technology implementation plan based on the production plan and technology roadmap.*	Integration of the technology roadmap, feasibility assessments, and investment decisions (for each network partner). ***Implementation plan.**
			6.2.2 AM production system implementation	*Step-by-step implementation of the AM production system.*	Step-by-step implementation.
			6.2.3 Evaluate and adjust	*Evaluate implementation and make the necessary adjustments.*	Adjustments include changes to the implementation plan, or decisions regarding the AM manufacturing technologies.
		6.3 Firm-level implementation	6.3.1 Implementation plan	*Compile a phased firm-level implementation plan based on the action plan, change management plan, and training plan.*	***Implementation plan.**
			6.3.2 Firm-level implementation	*Step-by-step implementation of the firm-level implementation plan.*	Step-by-step implementation.
			6.3.3 Evaluate and adjust	*Evaluate change implementation and make the necessary adjustments.*	Adjustments include changes to the implementation plan, change management plan, training plan or firm-level configurations of elements.
		6.4 Networked BM implementation	6.4.1 Implementation plan	*Compile a phased networked BM implementation plan based on the networked BM.*	***Implementation plan.**
			6.4.2 Networked BM implementation	*Step-by-step implementation of the networked BM elements.*	Step-by-step implementation.
			6.4.3 Evaluate and adjust	*Evaluate networked BM elements and make the necessary adjustments.*	Adjustments include changes to the implementation plan, or networked BM elements configurations.

		6.5 Strategic business net implementation	6.5.1 Implementation plan	*Compile a phased strategic business net implementation plan based on the strategic business net configuration, strategic roadmap, and action plan.*	***Implementation plan.**
			6.5.2 Strategic business net implementation	*Step-by-step implementation of the strategic business net.*	Step-by-step implementation.
			6.5.3 Evaluate and adjust	*Evaluate strategic business net and make the necessary adjustments.*	Adjustments include changes to the implementation plan, strategic business net features configuration, or the configuration of the strategic business net.
		6.6 Business opportunity assessment	6.6.1 Monitor and evaluate	*Monitor and evaluate network and partner performance.*	Use the appropriate roadmaps and action plans, to monitor and evaluate the overall network performance, as well as each partner or actor's performance during each implementation phase. Use the defined metrics to measure specific performance (refer to 5.3.5).
			6.6.2 Partner feedback and reporting	*Obtain feedback and reports on progress from all partners.*	Partners need to provide feedback to everyone in the strategic business net regarding their role in the strategic business net and any challenges, opportunities, benefits, or barriers experienced or identified during implementation.
			6.6.3 Risk management	*Re-assess and monitor the identified technology, company and joint risks.*	**Risk Management Process:** **Monitoring**: Review the progress of the plan and check if a risk has occurred but was missed on a continuous basis. **Reporting**: Communicate the effectiveness of the risk plan to stakeholders to keep engagement up.
			6.6.4 Re-evaluate and adjust	*Re-evaluate performance and make the necessary adjustments.*	Re-evaluate the performance metrics defines (refer to 5.3.5) and make adjustments accordingly. Include changes to roadmaps etc. if required.
	FEEDBACK				

Phase	Sub-phase	Steps			Possible tools, guiding questions, and considerations
Transforming	7. Sustaina	7.1 Business opportunity evaluation	7.1.1 Customer feedback	*Obtain feedback from customers of the joint offering.*	Obtain feedback (e.g., client satisfaction survey) from customers of the joint offering and other elements implemented. Evaluate warranty replacement, re-evaluate, and adapt manufacturing processes if needed.

			7.1.2 Re-evaluate and adjust	*Re-evaluate business opportunities based on customer feedback and make the necessary adjustments.*	Refer to 2.2
		7.2 Strategic business net evaluation	7.2.1 Strategic business net performance	*Constantly monitor the overall strategic business net performance.*	Innovation success is hard to predict, therefore continuous performance measurements and tracking is required. Refer to 5.3.5
			7.2.2 Partner performance	*Constantly monitor each partner's performance.*	Refer to 5.3.5
			7.2.3 Evaluate and adjust	*Re-evaluate and adjust the strategic business net based on performance measurements.*	Use the performance measurements to make the necessary adjustments to the network configuration, networked BM components, business opportunity, joint offering, or the joint value proposition.
		7.3 Networked BM evaluation	7.3.1 Networked BM elements performance	*Constantly measure the performance of each networked BM element.*	Refer to 5.4.1
			7.3.2 Evaluate and adjust	*Evaluate the networked BM elements and make the necessary adjustments.*	Refer to 5.4.1
		7.4 AM technology sustainability	7.4.1 AM technology analysis	*Analyse the developments (maturity) of the AM technologies.*	Refer to 1.2
			7.4.2 Part-process-material analysis	*Analyse the part-process-material maturity to identify improvements and additions to the joint offering.*	Refer to 2.1
			7.4.3 Evaluate and adjust	*Evaluate the findings and make the required adjustments (business opportunity, joint offering or strategic business net-related) due to technology advancements.*	Refer to 2.2
		7.5 Strategic sustainability	7.5.1 Ecosystem scanning	*Constantly scan the ecosystem for any changes that may influence the strategic business net.*	Refer to 1.3
			7.5.2 Innovation assessment and development	*Remain innovative through continuous innovation assessments and promote the development and improvement of joint offerings.*	Ensure that the strategic business net remains innovative through continuous innovation assessments (business model, technologies, offerings) and constantly promote the development of new components, features or improvements.
			7.5.3 Long-term competitiveness	*Determine how long-term competitiveness can be secured.*	Long-term competitiveness is extremely important for the network, because of the high investments required. If long-term competitiveness is not created, the technology investments will not be able to create a return on investment.
			7.5.4 Communicate with network partners	*Communicate ideas with network partners and obtain feedback.*	Communicate innovation ideas with network actors, obtain feedback and adjust as needed.
		7.6 Firm-level sustainability	7.6.1 Continuous learning	*Promote and enable continuous learning.*	Value creation potential from innovation is unpredictable, therefore continuous learning needs to take place. Promote and enable continuous learning within the organisation and across the network to prevent stagnation and the creation of a 'comfort zone'; make use of training/learning environments either virtually or physically.
			7.6.2 Change management plan development	*Develop a change management plan based on lessons learnt and changes required on firm-level.*	***Change management plan.**

			7.6.3 Training plan development	*Compile a training plan (firm-level) to successfully implement the change management plan.*	***Training plan.**
FEEDBACK					

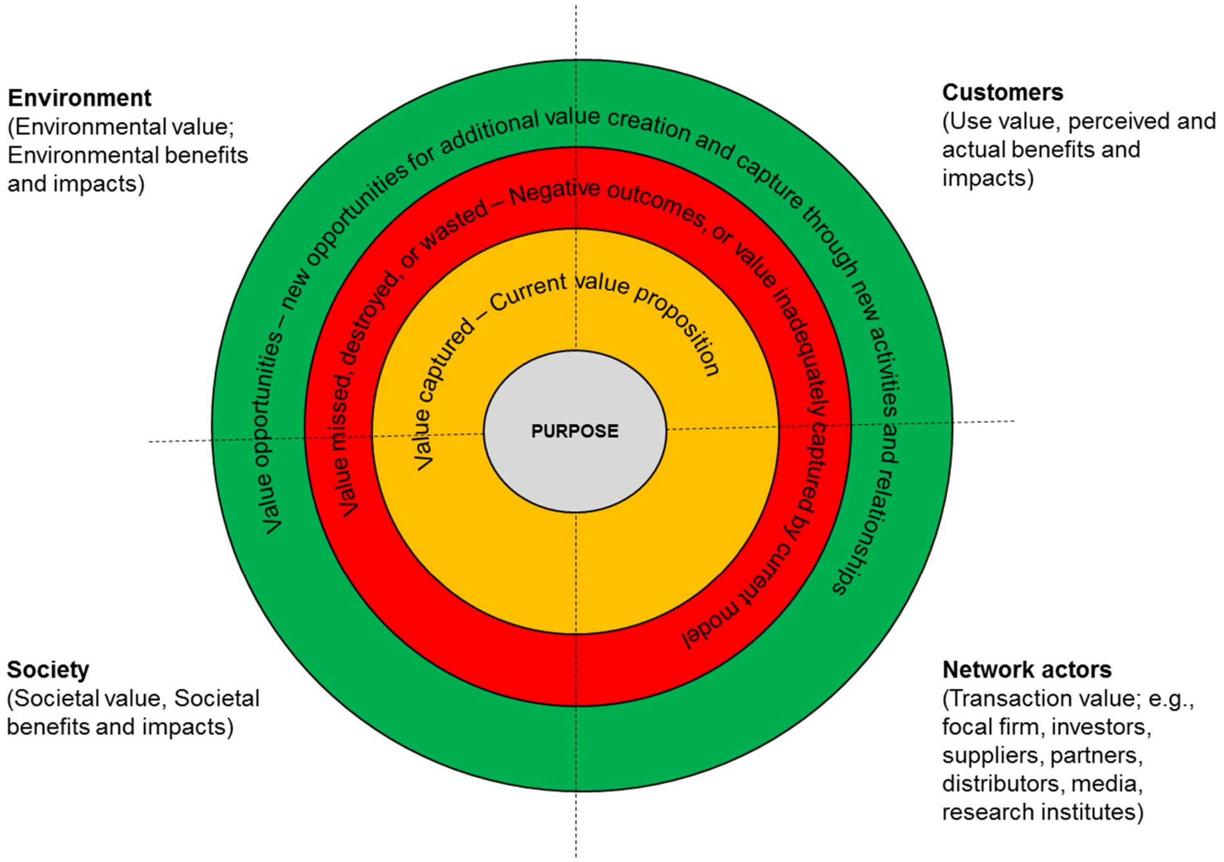


Figure F. 1: Value opportunity mapping template suggestion (adapted from [25])

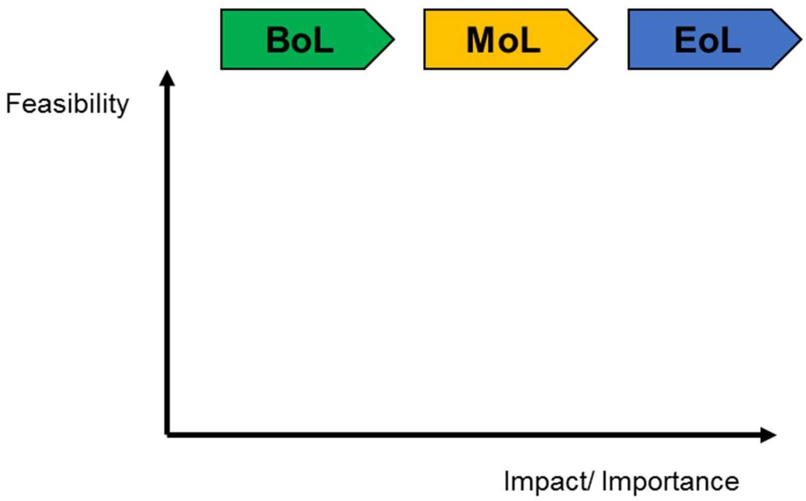


Figure F. 2: Value opportunity assessment template suggestion (adapted from [63])

		Actor A	Actor B	Actor C	Total occurrences of actor perceptions
Perceived advantages	Access to new, complementary resources				
	Reducing costs				
	Reducing time to markets				
	Risk reduction and risk sharing				
	Access to new technologies				
	Additional advantage/ key success factor 1				
	Additional advantage/ key success factor 2				
	Additional advantage/ key success factor 3				
Total occurrences of advantages per actor					
Perceived disadvantages	Decreased access to new, complementary resources				
	Increase of costs				
	Increase of time to market				
	No access to new markets				
	Increase of risk reduction				
	No access to new technologies				
	No opportunities for learning				
	Additional disadvantage 1				
	Additional disadvantage 2				
Total occurrences of disadvantages per actor					

Figure F. 3: Actor selection template suggestion (adapted from [59])

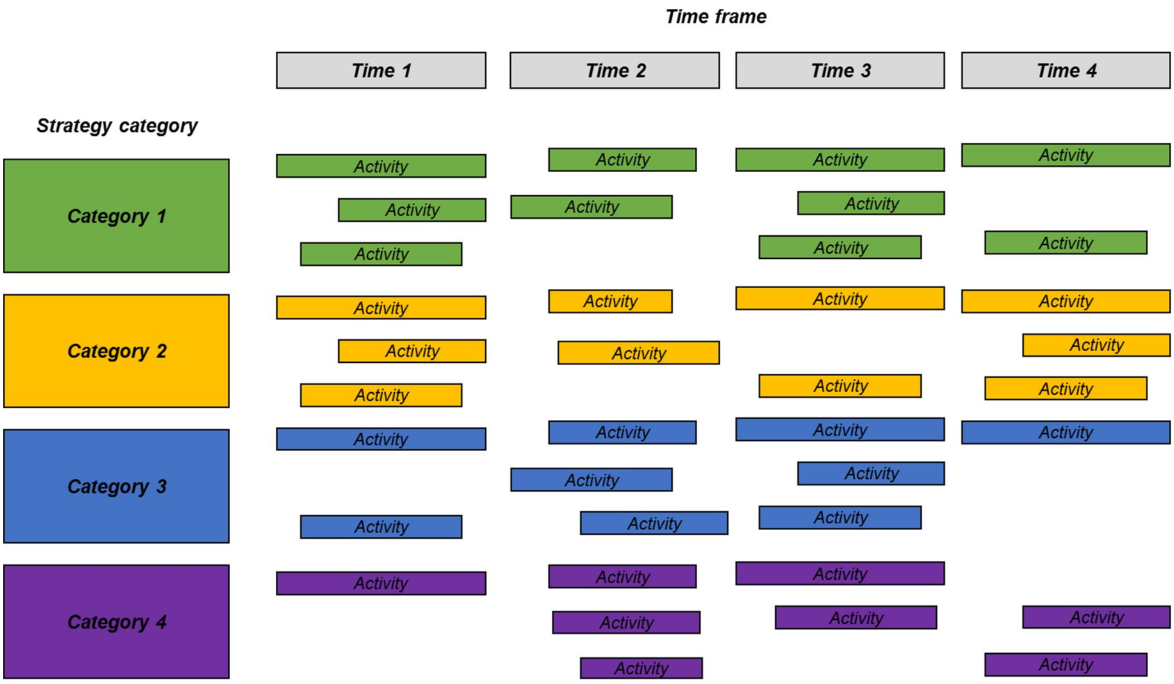


Figure F.4: Strategy roadmap template suggestion

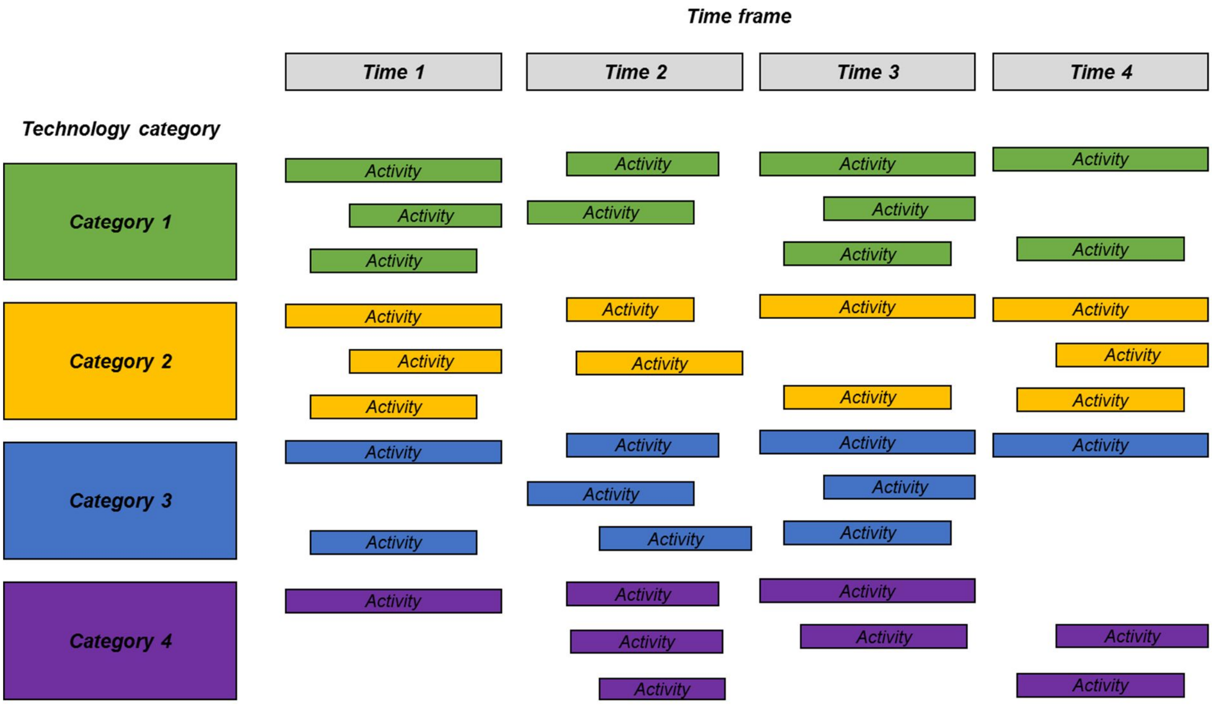


Figure F.5: Technology roadmap template suggestion