THE CREATION OF A FRAMEWORK FOR ASSESSING INNOVATION CAPABILITY MATURITY OF SUPPLY CHAINS

Analysing the status quo and developing an improvement strategy for the Scottish aerospace industry during the Covid-19 pandemic

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“The best way to predict the future is to create it.“

Alan Kay

ABSTRACT

In days of more interconnectivity of supply chains, competition is considered happening more between different supply chains than only between different single organisations. To be competitive and to remain competitive, organisations and supply chains need to change, need to develop new products and processes; in short, they need to innovate.

Innovation, just like competition, already takes place along supply chains. This way single organisations can leverage their own resources. Consequently, the question arises what makes a supply chain innovative or more precisely how to measure innovation capability of a supply chain. Whereas innovation capability of single organisations has gained considerable attention in academia, little investigation has been carried out into innovation capability of supply chains. There are few spill overs from innovation capability research of single organisations into supply chains and spill overs from supply chain management namely supply chain integration literature focussing on innovation capability.

What is missing is a framework that allows to measure the innovation capability in terms of its maturity for the whole end-to-end supply chain. As a result, the manufacturing supply chain innovation capability maturity assessment framework (MaSCICMAF) is created using a systems approach to supply chains with an understanding of supply chains based on the SCOR model and its supply chain planning level. MaSCICMAF, based on academic literature, is a framework that is built on the idea that innovation capability of a supply chain consists out of individual innovation capability of single organisations and their interactions. Hence, MaSCICMAF offers are company scoring model and a supply chain scoring model.

For validation of MaSCICMAF, the Covid-19 pandemic offered an unexpected opportunity as surviving through Covid-19 and rebuilding afterwards was a dominant topic. In this context, innovation capability of supply chains is extremely relevant. For maximum practical impact of the research, more investigation into which Scottish manufacturing sector needed the most innovation capability building support was carried out. This resulted in the aerospace sector, precisely one Scottish aerospace supply chain, being the subject of application of MaSCICMAF and its field validation. This supply chain's innovation capability was analysed in a total of six workshops with two companies of the four TIER supply chain and a supply chain delegation

group. In a next step, improvement strategies are developed for each company and the supply chain setup. These are based on the future scenario approach to strategizing. For further practical relevance of the research, these strategies are turned into direct policy making advice. Four main areas for changes in policies are identified. These are open innovation support, building more supply chain resilience, changing funding practices, and advice on skills shortages and education.

It must be clarified that there are certain limitations to the present research. MaSCICMAF must be used more in different industries to enable comparison between supply chains as MaSCICMAF only allows relative assessments at present. Derived policy advice should be confirmed further as it is only built on two of four companies of one supply chain. Nevertheless, MaSCICMAF evidently and verifiably offers to analyse innovation capability of supply chains and effectively create improvement strategies. Hence, MaSCICMAF contributes to academia in a way that it clearly defines which factors contribute to innovation capability of supply chains and more over defines maturity levels which can be used as basis for strategy making to improve innovation capability across a supply chain.

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Tim Reckordt

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ACAP	Absorptive Capacity
BEIS	Department for Business, Energy and Industrial Strategy
CSM	Company Scoring Model
HoC	House of Commons
ICD	Innovation Capability Dimension
IF	Impact Factor
MaSCICMAF	Manufacturing Supply Chain Innovation Capability Maturity Assessment Framework
OEM	Original Equipment Manufacturer
PACAP	Potential Absorptive Capacity
RACAP	Realised Absorptive Capacity
RQ	Research Question
SCSM	Supply Chain Scoring Model
SCOR	Supply Chain Operations Reference (Model)
SME	Small and medium sized enterprises
UKRI	UK Innovation and Research
VRM	Value Reference Model

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DECLARATION OF AUTHENTICITY AND AUTHOR'S RIGHTS

Some materials in this thesis have been presented/published in the following journals and conference proceedings:

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I declare that this thesis, except where stated by reference or acknowledgement, is a presentation of my original work, written by me, and has not previously been submitted for an award at this, or any other, university.

Tim Reckordt

Edinburgh, 22/09/2023

Chapter 1

Introduction

This thesis was written in unusual times during the Covid-19 pandemic. Therefore, this is an unusual thesis. The original idea of this thesis was developed before the Covid-19 pandemic and will be the main academic contribution focussing on the measurement of innovation capability of manufacturing supply chains within the UK. The Covid-19 pandemic, however, unexpectedly provided a practical application which could be used as field test and validation. In this part of the thesis the main focus lays on how innovation capability can be improved in a Scottish aerospace supply chain. This will be the validation of the academic research contribution and subsequently main practical contribution. But let us start the journey from the beginning…

1.1 The background story of this thesis

The research to this thesis started in late 2019. At this point in time the 2008 crisis and its still lasting impact on productivity were still omnipresent topics in the UK. The UK faced a productivity gap compared to leading industrial nations like the United States, Germany, or Japan. Whereas these countries also were impacted by the 2008 crisis, the situation in the UK was particularly worrying (OECD, 2015).

In the end, rising productivity directly leads to rising living standards – a stagnation leads to a decrease in living standards (Jones, 2016). Following Goodridge et al. (2018) and Krugman (1997)'s explanation about factors influencing total factor productivity, there are several ways of increasing productivity. One way consists in raising the overall worked hours. That little productivity growth that was achieved lately can mainly be explained by immigrants coming to the UK raising the overall number of worked hours. However, Brexit and hostile immigration policies are likely to slow down that development (Jafari and Britz, 2020). The other factor is innovation performance. However, even before Covid-19 the UK was described repeatedly as innovation follower rather than innovation leader compared to other countries. Also, public spending in innovation were considerably lower than in for example Germany, the United States and China (Arundel et al., 2015). The global innovation index (Hollanders et al., 2016) suggests that there is little innovation output in the UK although there is a high innovation input. Thus, the UK as an economy is not able to capitalize broadly on its innovation investments (Ates, 2016). Having a high input but a low output suggests that firstly, there is a motivation for innovation, but also secondly, that there is just a low innovation capability. This is referred to as the UK innovation gap (Dekkers et al., 2019). Dekkers et al. (2019) further state that especially in Scotland companies hold shortsighted views an innovation. Even though the Scottish society regards entrepreneurship as something positive, the country is not regarded entrepreneurial as there are few aspiring entrepreneurs and risk taking is scarce (Mwaura et al., 2021).

In this context the manufacturing industry is of special interest. Manufacturing is important because the sector and the associated supply chains are vital for the UK economy and society (Ates, 2016). Especially high value manufacturing is important as the UK competes more on quality than on price. High value manufacturing is also important to combat megatrends of the future like for example sustainability, aging populations, energy costs etc (MacBryde et al., 2013, Huaccho Huatuco et al., 2019, MacBryde et al., 2009). A long period of offshoring and outsourcing of manufacturing capacities has led to a significant loss of manufacturing capacities and related capabilities in the UK. Along with it, a hollowing out of entire supply chains has occurred. The UK economy has realised this negative trend and has shifted to bringing manufacturing capacities and capabilities back to the UK. The strengthening of the supply chain has several positive outcomes for economic development. The manufacturing industry as a driver of the UK economy is much more robust against global political uncertainty, if it has a complete national manufacturing supply chain (Ates, 2016). The FAI (2019) states that manufacturing and its supply chains account for about 18% of the Scottish GDP and account for about half of all Scottish exports. In the whole of the UK, it is about 8% (HoC, 2022).

Political thriving before the Covid-19 pandemic was directed at supporting and attracting fast developing industries like electronics, bio engineering or green energy. However, these industries rely on supply chains offering high value manufacturing. Nowadays, organizations in general are increasingly competing on the basis of supply chains rather than firm performance (Ates, 2016). Within this context, best value supply chains are emerging as a means to create competitive advantage and superior performance (Ketchen and Hult, 2007). However, this development has left the UK manufacturing value chain hollowed out resulting in a UK manufacturing industry which cannot compete internationally (Bailey and De Propris, 2014).

In summary, UK high value manufacturing had fallen behind international competition while the availability and capabilities of whole supply chains instead of single companies increasingly matter (Farahani et al., 2014). This also means that innovation is seen as an outcome of collaborative efforts rather than the outcome of a single entity (Bouncken, 2011), therefore demands a joint effort of stakeholders to work together. Narasimhan and Narayanan (2013) highlight the fundamental role a supply chain has in leveraging the resources individual firms hold. Thus, establishing a collaborative supply chain structure is a necessary condition in support of innovation, which in turn benefits all the stakeholders in the entire supply chain. In this context, existing supply chains need to be innovative to raise the competitiveness of a whole supply chain within the UK. Being innovative requires innovation capability of the supply chain. But what is innovation capability of a supply chain – this question lays at the heart of this research and will be evaluated within the first part of this thesis.

And then, in early 2020 the Covid-19 pandemic hit Europe and the rest of the world. For this research it meant a sudden very practical importance and an opportunity to validate the research into innovation capability of supply chains. The focus shifted from the whole of the UK to Scotland alone. This decision was made as the manufacturing sector in Scotland differs from manufacturing in England. Further, the devolution of the UK derived nations gave the Scottish Government significant power over measures against the Covid-19 pandemic in Scotland without UK government interference. Additionally, based on the location of the researcher at the University of Strathclyde and the national manufacturing institute of Scotland (NMIS) and its roots in Scottish manufacturing and their significant ties with the Scottish Government, the decision was made, that the most implications for supporting the sector could be made if the focus was moved to Scotland alone.

The consequence of Covid-19 arriving, was a national lockdown in Scotland and in many other countries around the world bringing whole economies to the edge of collapsing. The Scottish Government reported a 10% recession in 2020 (ScotGov, 2021a). Even though through the first lockdown in early and mid-2020 and through successive lockdowns later in 2020 and 2021, many manufacturers in Scotland were able to continue production as they were regarded essential businesses, many more manufacturers which were not considered essential businesses were shut during the first lockdown. Consequently, the Scottish Government reported that nearly half of all manufacturing firms have reported a decrease in turnover as a result of Covid-19 and that manufacturing output contracted by 23.1% over the first 12 months of the pandemic (ScotGov, 2021b).

Given the background of low innovation performance even before the Covid-19 pandemic, it was feared that either during the pandemic or in the aftermaths companies could file for bankruptcy which are essential for supply chains to operate. If the number of such bankruptcies was too high, other companies might not have been able to fill the arising gaps anymore and lasting damage could be done. Such damage could have resulted in high numbers of job losses and in lasting impacts on competitiveness of Scottish manufacturing. To stabilise the situation the Scottish Government and the UK Government created policies to stabilise the economic situation. Schemes like furlough helped moderating the impact of the pandemic on bankruptcies. The result was a more positive development than originally expected even though in August 2022 the GDP had still not reached before pandemic levels in Scotland (ScotGov, 2022a). For the manufacturing sector the Scottish Government created a manufacturing recovery plan (ScotGov, 2021b), outlining four key areas of intervention. Area one is collaboration and networks, area two is supply chains and competitiveness, area three is adaptation and transformation, and area four is skills and workforce.

Here, the present research comes into play. In a situation where bankruptcy waves are still not unlikely, this research aims at addressing areas of the manufacturing recovery plan one and two, creating an understanding of how innovative manufacturing supply chains are in Scotland. It precisely aims at analysing supply chains which have been impacted the most by the Covid-19 implications respectively those which potentially benefit the most.

Of special interest are three manufacturing sectors in the context of this thesis. The first sector is the aerospace sector. The sector exports about 95% of its produce and therefore contributes significantly to the Scottish foreign trade balance (ADS, 2019). The aerospace sector was one of the hardest hit sectors by the Covid-19 pandemic worldwide with international travel being halted almost completely. With planes not flying manufacturer's business models are also impacted as the sector is built on leasing business models for a large part where flight hours get charged. The sector had already been in turmoil before the Covid-19 pandemic with large OEMs in complicated economic situations. Early during the first lockdown large OEMs like Rolls Royce or GE announced large redundancies and in the case of Rolls Royce even site closures in Scotland (McGeoch and Spowage, 2020).

Of special interest is also the food and drink sector. The food and drink sector is by far the biggest manufacturing subsector in Scotland. This sector, just like the aerospace sector, was impacted by Covid-19 immediately when the first lockdown was put in place closing down all restaurants, pubs, and public events. The whole of the UK food and drink industry operates at a medium level of automation which is actively thought to be raised by UK policy (Affairs, 2020). However, the part of the sector that supplies hospitality has relatively quickly bounced back after the first lockdown when Covid-19 rules were introduced allowing restaurants and pubs to open with restrictions. This is an industry that already struggles to attract talent. The Covid-19 distancing rules are difficult for many to put into place while maintaining a similar operational level. The sector also is significantly impacted by Brexit as about 25% of workers come from EU countries and the sector highly depends on free trade with the EU (ONS, 2021b).

The third sector of special interest is the chemicals and pharmaceuticals industry. The sector is very diverse including the manufacture of commodity and bulk chemicals, speciality chemicals, polymers and consumer chemicals. The sector has complex supply chain flows with multiple border crossings of intermediate products in the supply chain. Further, the industry in the UK is believed to be innovative (HoC, 2017). The industry has been hit hard as a supplier for other hard-hit industries like automotive or aviation. On the other hand, due to the nature of the Covid-19 pandemic, this sector has seen a significant raise in business as there were shortages of crucial pharmaceutical supplies which has caused companies to relocate production of these products back to the UK like PPE production (PwC, 2020). Development and production of vaccines and a raised demand for medical devises also supported the overall positive development of the sector. However, the sector faces a large Brexit impact as the EU is the largest importer of UK chemicals. Further, production of non-critical products will be more expensive due to tariffs on multiple border crossings of supply throughout the supply chains (FTIConsulting, 2020).

The manufacturing industry subsector for which innovation capability measurement of its supply chains shows the most practical relevance, will be analysed and a strategy will be developed to improve the current state of innovation capability. The aim is to contribute to the stabilisation of the current economic situation and the preparation to seize opportunities in the future.

The next sections lay out which exact research question have been derived and what the general approach of this thesis is. The chapter concludes with a description of its structure as guidance throughout the whole thesis.

1.2 Aims and research questions of the study

The aims and research questions reflect the two parts of this research. The first part focusses on academic research that was started before the Covid-19 pandemic. The second part focusses on the validation of said research through practical application within the Covid-19 pandemic context. The second part also aims at building practical relevance of the research beyond academia as the research output is meant to be practically applied.

The academic aim of this research focusses entirely on innovation capability of supply chains analysing, what exactly it is and how its maturity can be measured. Hence, research question RQ-A1 is:

RQ-A1) How can innovation capability maturity of manufacturing supply chains be determined?

The result to this research question will be a maturity model representing different innovation capability maturity stages for manufacturing supply chains. Why exactly there is a need for in depth research to answer this research question, will be deducted in the literature review chapter 2.

The second part of the thesis focusses the validation of the developed framework. However, to build practical relevance in times of Covid-19 a structured approach is taken for maximum practical impact. In a first step, the impact of Covid-19 on manufacturing supply chains in Scotland needs to be analysed to build a basis for where the application of the framework has the highest impact. Even though there are many studies on how companies reacted to the Covid-19 implications, these mainly focus on finance in detail or economic aspects in general. What remains under researched is the impact of Covid-19 on the innovation behaviour in the manufacturing sector in Scotland. Especially in times of disruption, innovation and the capability to innovate is considered key to survival of companies (Damanpour, 1991) in the short term and key to future recovery and success by taking advantage of changed conditions in the long-term. As there was significant fear that supply chains could collapse if single companies go bankrupt, it has to be investigated how manufacturing sectors which struggle the most with innovation and innovation capability can be supported. Supporting whole supply chains and their companies in becoming more innovative raises supply chain resilience. Thus, this way the Covid-19 impact on manufacturing supply chains could be moderated just like on single companies.

In line with supporting the Scottish Government, their manufacturing recovery plan (ScotGov, 2021b), and the planned future Scottish innovation strategy (TechnologyScotland, 2022), the research has to focus on for which manufacturing sector it makes the biggest impact to be relevant. Therefore, in a first step, the effect Covid-19 has on innovation and innovation capability on different manufacturing sectors in Scotland should be investigated further in more detail as there are no in depth studies available. Of special interest are the food and drink, aerospace, and chemicals and pharmaceuticals sectors as explained in the background to this research chapter. Hence research question RQ-P1 is:

RQ-P1) How did the Covid-19 pandemic change the view on innovation in Scottish advanced manufacturing supply chains and which sectors especially need innovation capability support?

Once different sectors have been investigated, the hardest-hit sector is further investigated throughout this thesis and one supply chain is taken as an example. In the present case, this is the aerospace sector. In order to generate suggestions of how innovation capability can be improved in this supply chain, there is a number of investigation steps that need to be executed.

As a foundation the current state of innovation capability maturity in this supply chain has to be analysed. This is where the before developed innovation capability maturity model comes into play as a tool. Hence research question RQ-P2 is:

RQ-P2) What is the status quo of innovation capability in the aerospace supply chain?

The main academic reason for applying the framework to the supply chain is to validate it in the field as assessment tool.

Once the status quo is established, improvement strategies for innovation capability in this supply chain has to be developed. These strategies will function as base for later advise for policy making. Hence, research question RQ-P3 is:

RQ-P3) How can innovation capability be improved in this aerospace supply chain?

The main academic reason for strategy development is to use the framework as strategy guidance and validate it beyond only being an assessment tool for the status quo of innovation capability but also for serving as guidance for future development of directed innovation capability building.

On the basis of the answer to RQ-P3, suggestions can be derived for policy making to support aerospace supply chains in Scotland. This is where the primarily practical relevance of this research is created. The developed suggestions for policy making are based on the determined status quo and thus, the improvement strategies can be precise and targeted. Hence, the main practical research question of this research is:

RQ-P4) How can policy makers support innovation capability improvement in this aerospace supply chain?

In summary, answering research question RQ-A1 aims at developing an academic understanding of what innovation capability and its maturity is in the context of supply chains and how it can be measured. Research question RQ-P1 aims at understanding the Covid-19 impact on innovation better and decide in which sector innovation capability improvement makes the biggest practical difference. Research questions RQ-P2 and RQ-P3 aim at establishing a status quo of innovation capability of a chosen supply chain in the aerospace sector as hardest hit manufacturing sector in Scotland and developing improvement strategies. But RQ-P2 and RQ-P3 mainly serve as field validation for the developed framework. Finally, as the main practical research question, RQ-P4 itself aims at deriving suggestions for policy making to support the analysed supply chain to realise the developed improvement strategies.

1.3 Approach of this thesis – The systems perspective to supply chains and the SCOR model

Following the aims and the research questions presented in the last section, the approach to innovation capability of supply chains is discussed in this section. The approach for this research is to view supply chains through the lens of a systems approach. Systems approaches are used regularly when analysing supply chains as Holland (1995) and Behdani (2012) state. Holland (1995), for example, characterises a supply chain as a system consisting of different interacting organisations. Behdani (2012) follows this view, and analyses different paradigms within the systems theory that define a supply chain more detailed. For this research, Behdani (2012)'s approach to supply chains is followed and supply chains are considered socio-technical systems. Socio-technical systems are systems that contain complex physical aspects and interdependent human actors as De Bruijn et al. (2009) say. The behaviour of a socio-technical system can solely be sufficiently analysed and improved if both social and technical aspects and interdependencies are considered (Ottens et al., 2006). Behdani (2012) argues that a supply chain is the composition of technical interconnected subsystems like manufacturing facilities and warehouses throughout the whole supply chain. The interaction between supplier and customer along the supply chain is characterised by human decision making.

Decision making refers to which supplier to choose, which manufacturing strategy to adopt, which innovation activities to follow, etc. Interactions can depend on each other. They might be of formal nature for contractual purposes, or they might be of informal nature in terms of trust building.

At the same time, Behdani (2012) points out that while considering supply chains as socio-technical systems, it is also necessary to respect their complex and adaptive nature. There is a high level of complexity because of numerosity (Simon, 1962) and heterogeneity (Miller et al., 2008) of companies operating in a supply chain. The adaptive nature refers to the evolution or emergence of a system. Companies change their behaviour as a reaction to their behaviour in the past and changes in environment (Kauffman and Macready, 1995, Surana et al., 2005). It is also important to recognise that the supply chain as a system is not only adaptive but also dynamic (Holland, 1995). Different supply chains can show different levels of dynamics. Consequently, the supply chain is considered a complex, adaptive, dynamic socio-technical system for this study and, thus should be managed as a system for better outcomes as Baxter and Sommerville (2011), Carter et al. (2015), Choi et al. (2001), and Frankel et al. (2008) suggest.

Following a systems approach explicitly enables the researcher to look at innovation capability of a supply chain as the whole system but as well it enables the look at only parts of a supply chain down to only researching a particular node or company (Behdani, 2012). The systems approach ensures that the research is valid on all system levels. Hence, the research conducted can be used in many different contexts moving on.

A systems approach always relies on modelling the system. There are many approaches to supply chain modelling. Demand driven or lean supply chain modelling for example aim are widely spread in academia and practice. Lean supply chain modelling aims at the elimination of waste along a supply chain, demand driven supply chain modelling aims at optimising meeting changing demands at all times. Lean supply chain modelling has widely been criticised for its focus on efficiency, effectively put a supply chain’s resilience at risk (Pagell and Wu, 2009). Furthermore, in lean philosophy, innovation activities would be regarded as waste. Hence, this approach is not suitable for the current research. Demand driven modelling focusses on forecasting.

More holistic approaches to supply chain modelling are the supply chain operations reference (SCOR) model and the value reference model (VRM). Both aim at modelling operations along the supply chain from a generic point of view, standardising these operations across industries. Both use a systems approach to supply chains. VRM, based on the idea of value chains raised by Porter (1990), only focusses on operations contributing to value. Besides potentially missing opportunities for innovation in operations that are not directly related to value creation, VRM has been criticised for being not granular enough to model activities on an operational level (Yusuf et al., 2004). It has also been criticised for ignoring important operations that do not directly add value but might be important starting points for innovation (Yusuf et al., 2004).

SCOR on the other hand, offers a granular description of standardised operations covering all operations including value generating activities, forecasting, and it also allows lean thinking. The SCOR model is the standard model for describing supply chain operations since the early 2000s. The SCOR model is a framework that addresses supply chain management practices and business process reengineering (Wang et al., 2010, Lockamy and McCormack, 2004, Ntabe et al., 2015). Besides providing a reference for measuring performance and efficiency along the supply chain and setting a frame for improvement of the business process architecture (Li et al., 2011), it provides a methodology for supply chain management and supply chain strategy development (Wang et al., 2010, Lockamy and McCormack, 2004, Turhan et al., 2011, Li et al., 2011). The model has been widely adopted in many companies in a wide field of industries, e.g. electronics, chemicals, automotive, aerospace, and food and drink (Zhou et al., 2011, Delipinar and Kocaoglu, 2016).

The SCOR model is divided into fife processes on different levels. The systems nature of SCOR allows a look into the intra supply chain within a company and even into only certain processes on this level, as well as the inter supply chain as connection of different companies on a higher level Hence, SCOR in its nature is aligned with the systems considerations made for this research.

The SCOR processes are plan, source, make, deliver, and return (Ntabe et al., 2015). The plan process is an overarching process and is concerned with designing and planning a supply chain. Traditionally, demand forecasting and assigning what do produce where and what to source from where are conducted within this process. This process also includes the collaboration and communication with suppliers and customers and the planning of change. As Krishnan et al. (2021) state, this is the level where the development of innovations along a supply chain happens primarily. Hence, they suggest that research into innovation in supply chains should focus on the planning process. The second process level including the processes, source, make, deliver, and return are more concerned with the day-to-day operations of the supply chain to fulfil demand and customer satisfaction. On this level, Krishnan et al. (2021) state, that mainly continuous improvement activities happen as opposed to innovation.

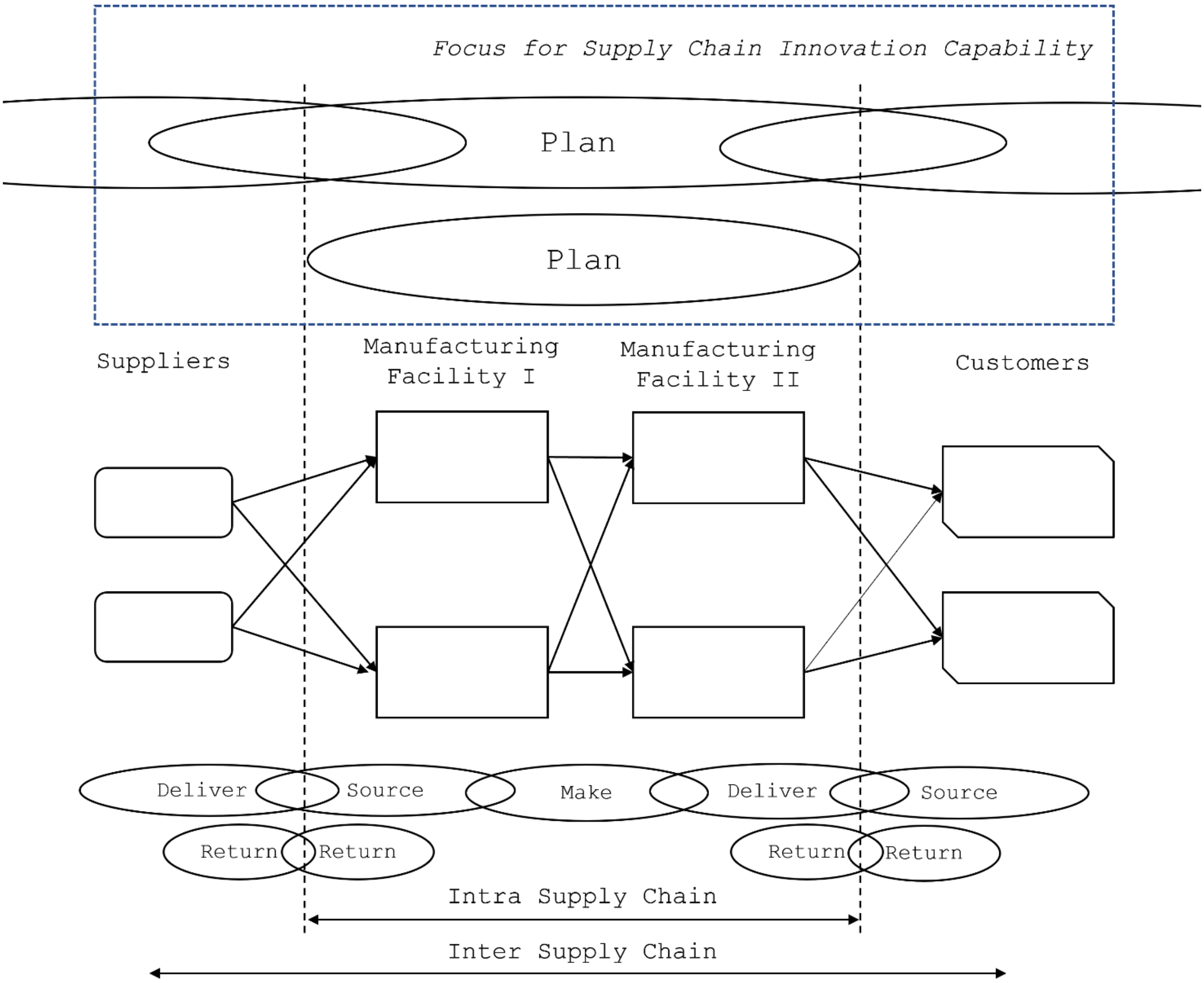


Figure 1-1: SCOR supply chain model with the planning level for internal and external activities (Huan et al., 2004)

Besides providing the needed frame for the present study, the SCOR model has been chosen because it has been used for similar research into change and innovation within supply chains. For example, Abderrazak and Youssef (2022) analyse risks and risk management in supply chains related to innovations using the SCOR model. Krishnan et al. (2021) use the SCOR model to base an analysis of collaborative innovation efforts in the food supply chain on.

They focus on the planning level. Ehie and Ferreira (2019) develop a digitalisation and change framework for supply chains based on the SCOR. In summary, this research will adopt a systems approach based on the SCOR model to innovation capability of supply chains focussing on the planning level of SCOR.

After clarifying the research questions in the section before and after clarifying the general systems approach to supply chains based on the SCOR model in this section, the next section outlines how the thesis is structured.

1.4 Structure of the thesis

This thesis follows a structured approach to present the research at its heart. The presentation of the research is divided into 9 chapters. These are structured into academic research which started before the Covid-19 pandemic and the validation of said research during the pandemic which also led to practical applications and impact of the research. These two parts are reflected in the research questions at the heart of this thesis. The thesis' structure is visualised in Figure 1-2. It starts with an introduction in chapter 0 to the research and sets out the research questions. Chapter 3 lays out the methodological approach on which this thesis is based. The chapter discusses different methods to generate answers to all research questions and highlights how the different chosen methods tie into each other.

Chapters 2 and 4 present the academic part of the research. Chapter 2 starts with a literature review which aims at developing an understanding of existing concepts of innovation capability in supply chains. It ends in the recognition of a need to develop an innovation capability maturity model for supply chains. This maturity model is developed in chapter 4 answering research question RQ-A1.

Chapters 5 to 8 represent the validation of the framework and the practical application for relevance building of the research beyond academia. In chapter 5, findings about how different sectors changed their innovation behaviour in response to Covid-19 are presented and research question RQ-P1 is formally answered, presenting the aerospace sector in Scotland as the sector that is in most need of innovation capability building support. In chapter 6, the before developed innovation capability maturity model is applied to an aerospace supply chain in Scotland and its current maturity is determined. This is the formal field validation of the framework and forms the answer to research question RQ-P2.

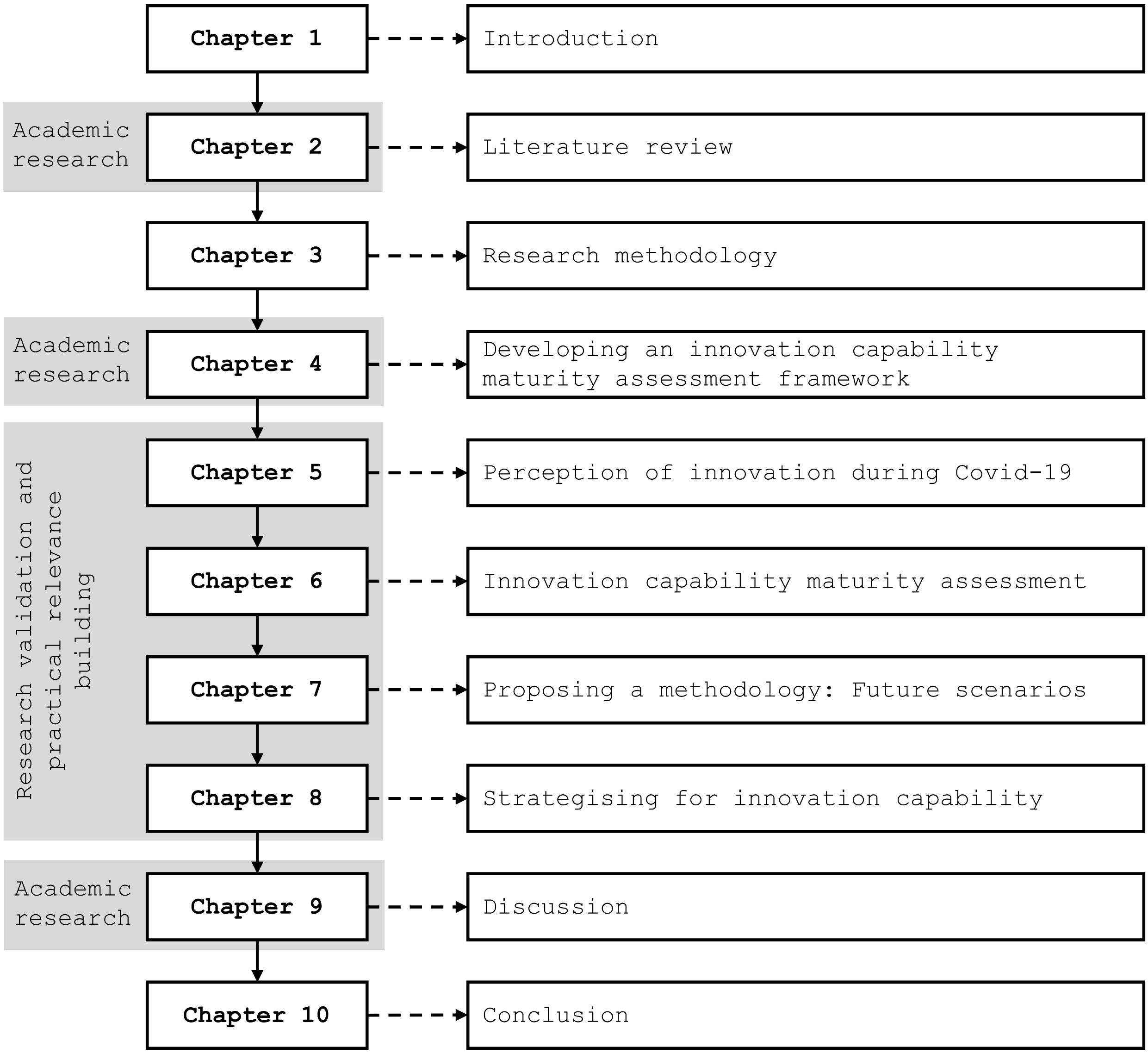


Figure 1-2: Thesis structure

In order to generate strategies for improvement, an in between step is taken in chapter 7. In this chapter general scenarios are developed about how manufacturing in Scotland could develop until the year 2036. These scenarios form the basis for innovation capability improvement strategies developed in chapter 8. This chapter does not only derive improvement strategies as answer to research question RQ-P3, it also provides derived suggestions for policy making to support these strategies and hence answers the main research question RQ-P4 of this research. In this capacity, this chapter also aims at confirming the framework not only as a diagnostic tool but also as guidance for strategy making.

Chapter 9 summarises all findings and places them and their meaning in the wider academic context in the form of a discussion. The thesis ends with a conclusion in chapter 10 in which all results are summarised and what implications they have on the academic community as well as on the practitioner community. Limitations of the current research and avenues for future research are highlighted as well.

CHAPTER 2

LITERATURE REVIEW

This chapter aims at generating an understanding of the state of research into innovation capability of supply chains. However, before, groundwork has to be executed. In detail, this chapter firstly aims at clarifying terminologies as they are not used coherently in academia and research. This chapter starts with asking the question of what innovation is and providing a definition which is used throughout this thesis. Then the question is asked of why innovation matters, and innovation is placed in the context of dynamic capabilities, competitiveness, and supply chain resilience. Laying this groundwork is necessary to generate and communicate the academic understanding of the basics of innovation at the heart of this research.

Afterwards it is looked at what enables and hinders innovation from happening as next step towards understanding innovation capability. It is looked at single organisations and how innovations are produced internally. It is also looked at innovation in networks in general and how network structures influence innovation.

Then, as the main aim of this chapter, the term innovation capability is introduced to lay the academic state of research in this precise field. This will serve as basis for why there is a need for a new innovation capability framework for supply chains. To analyse the state of research a systematic literature review approach is followed to ensure that the state of research is covered fully and accurately.

2.1 What is innovation?

Innovation has become a topic of interest not just in academia but in many aspects of society and business. In a fast-changing world innovation is considered vital for businesses to survive. Also, on an economy level innovation is being considered important as driver of overall economic development. Baregheh et al. (2009) state that to sustain a competitive advantage in a globalising world, economies and organisations have to innovate and promote innovation. Therefore, governments in many countries have introduced support mechanisms for innovation (Watkins et al., 2015). On business level, innovation has become an important part of strategy development. However, the term innovation is used differently in different contexts (Baregheh et al., 2009). The aim of this chapter is to clarify different definitions and important aspects of innovation to finally provide a practical definition for use in this research.

2.1.1 Different understandings of innovation

The term "Innovation" was first used by Schumpeter (1950). He argues that a business should innovate to increase the value of its assets. Even though the term innovation had not been defined earlier, the concept of the importance of a renewal of businesses and technological change were perceived as important (Schumpeter, 1934).

Innovation is closely connected to change. Businesses use innovation to either react to a changing environment or to influence and cause change in its environment (Damanpour, 1991). Consequently, innovation can be a process and an outcome (Saunila, 2019). However, there is not a single definition of innovation. It has been studied in different disciplines creating different perspectives from different angles (Damanpour and Schneider, 2006). An early definition of innovation was developed by (Thompson, 1965)p.2) stating: "Innovation is the generation, acceptance and implementation of new ideas, processes, products or services". (West and Anderson, 1996) p.2) more recent but still quite similar definition is: "Innovation can be defined as the effective application of processes and products new to the organization and designed to benefit it and its stakeholders". In 2005 the OECD first introduced a general definition for holistic application across Europe: "An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organization or external relations" (Baregheh et al., 2009). Even though these definitions are quite similar, they refer to different areas and different aspects of innovation. More recently an attempt has been made to create an ISO norm for innovation management. This norm, ISO 56000:2020 (3.1.1) defines innovation in an abstract way as "new or changed entity, realizing or redistributing value". Whereas this definition intends to be holistic, no broad adaptation of the norm has taken place yet. Hence, there is no unified and holistic definition of innovation that is used commonly.

2.1.2 Important aspects of innovation

For a better understanding of innovation, different aspects of it have to be clarified more in detail. One aspect is the differentiation of areas of application for innovations. All three above mentioned definitions refer to either a new "product" or "service" or "organisational change". However, they all have a different set of areas of application. The set of areas has evolved over time becoming more holistic. Schumpeter (1934) himself developed the first differentiation of application areas and proposed a framework of five different categories of innovation: new goods or processes, new sources, the exploitation of new markets and new ways to organize business. Building on Schumpeter's proposal Keeley et al. (2013) suggest their widely recognised and up to date most holistic approach of expanding the concept to ten different types of innovation. At first, they break down the ten types of innovation into the categories "configuration", "offering" and "experience". Configuration focusses on the internal side of the business, on how the business makes money. Namely these are the profit model, network, structure, and processes. Offering refers specifically to the actual products a company provides. Still internally focussed, this category deals with how a product is created and delivered. Experience is the external part of a business facing costumers directly. This is the way in which companies try to improve customer experience by enhancing the performance capabilities, perception of value and utility of a product. The different types of innovations in this category are namely services, channels, brand and costumer engagement (Keeley et al., 2013). An overview over Keeley's classification is provided in Table 2-1.

All definitions have in common that an innovation must be implemented. Without implementation it is simply an invention or an innovative idea. Just if stakeholders benefit from it in practice, it is considered an innovation (Baregheh et al., 2009). Christensen (1997) introduced a way of categorising innovation according to effects the implementation of an innovation has on growth of a business. He suggests three different kinds of innovations: market creating innovations, sustaining innovations and efficiency innovations.

Table 2-1: Ten types of innovation (Keeley et al., 2013)

Category	**Type of innovation**
Configuration	Profit model
	Network
	Structure
	Process
Offering	Product performance
	Product system
Experience	Services
	Channels
	Brand
	Costumer engagement

Market creating innovations are the type of innovations, which aim at developing new markets and thereby create growth and jobs. Sustaining innovations are those, which improve margins. However, this this the level of innovation needed to sustain business performance at a steady level in a changing environment. Efficiency type innovations aim at improving processes within an organisation. They lead to a better business performance. However, they tend to destroy jobs. An overview over Christensen's kinds of innovation can be found in Table 2-2.

Table 2-2: Christensen's kinds of innovation (Christensen, 1997)

Kind of innovation	**Effect on business growth**
Market creating innovations	Leads to development of new markets and create growth and jobs
Sustaining innovations	Leads to improvement of processes for stable business performance and might create a small number of jobs
Efficiency innovations	Leads to substantially better business performance but destroys significant number of jobs

The three definitions all refer to something "new" or "substantially improved". This can be referred to as different natures of innovation. For this kind of differentiation most studies divide technological innovations into two categories. Their names have changed over time. The first category refers to revolutionary, discontinuous, breakthrough, radical or disruptive innovations. The second category describes evolutionary, continuous or incremental innovations (Yu and Hang, 2010). For further consistent use, category one innovations will be referred to as being of disruptive nature and category two innovations will be addressed as being of incremental nature.

The term disruptive innovation was popularised by Christensen (1997). Disruptive innovation is considered strategically important as it is a powerful tool for developing new markets. The newly introduced technology has the potential to disrupt existing market structures (Christensen, 1997, Christensen and Raynor, 2003, Adner, 2006). Christensen (1997) and Christensen and Raynor (2003) characterise disruptive innovation as a process. Initially the term disruptive innovation mainly focussed on solely disruptive technologies. Disruptive technologies provide different values compared with already existing, in markets widely accepted technologies. Disruptive technologies in their early stages are inferior to established technologies. Therefore, an early-stage disruptive technology can just be successful in a niche market with customers willing to use a new technology with a new set of attributes and values. These markets accept the technology's low level of maturity and its inferiority in performance to established technologies. Further development of the technology can raise its performance significantly. However, it might not draw even with established technologies. Nevertheless, the disruptive technology offers a different set of values. Once mainstream customers start shifting to using the disruptive technology for the additional value, market disruption takes place. Consequently, the established technology is replaced over time. In 2003, Christensen and Raynor expanded the concept to not only cover technologies but other types of innovation as well and coined the term disruptive innovation. However, Yu and Hang (2010) identified that a number of slightly different views on details of this process and its preconditions have emerged which lack a clear common understanding.

In contrast to radical changes causing market disruption innovation can also be incremental – a substantial improvement of performance of something already existing, rather than replacing something existing with something entirely new (Ali, 1994). Christensen and Raynor (2003) argue that incremental innovations are rather developed by established companies targeting directly mature markets whereas disruptive innovations serve niche markets in the beginning. See also Table 2-3 for a brief comparison of disruptive and incremental innovation.

Table 2-3: Comparison of disruptive and incremental innovation (Christensen, 1997)

Nature of innovation	Characterisation
Disruptive	Development of a new solution targeting a niche market in the beginning, but further development and additional value leads to replacing existing solutions and access to mainstream markets
Incremental	Continuous improvement of an existing solution usually serving mainstream markets

2.1.3 Innovation – a practical definition

As shown earlier there are many different definitions for innovation out there in academic literature. Innovation has been defined from different perspectives and definitions have evolved over time, not leaving a single everywhere accepted definition. Thus, a practical clear definition has to be developed for further use in this research.

Thompson (1965), West and Anderson (1996), and OECD (2015) definitions – as many more – have three aspects of innovation in common. They all refer to a (1) type of innovation in terms of the application area of an innovation, they all refer to (2) a kind of innovation meaning the innovation implementation and its impact on business performance, and they all refer to (3) the nature of an innovation in terms of being new or substantially improved. Condensing the three definitions and adding Keeley et al. (2013) concept of types of innovation addressing (1), Christensen (1997) kinds of innovation tackling (2) and the differentiation between disruptive and incremental (3), innovation can be defined for practical use as:

> *"Innovation is the implementation of something new or substantially improved in an organisation that creates value for its stakeholders."*

2.2 Why does innovation matter?

After clarifying what innovation is, the question emerges 'what is it good for?' or 'why does it matter?'. Schumpeter (1934) says that businesses have to renew themselves or in other terms innovate in order to react to changes in the market to stay viable and competitive as a business. However, innovation can also be proactive. Proactive innovation is a tool to develop a competitive advantage in an industry in the first place. Nevertheless, markets change constantly, and a competitive advantage might be lost quickly. Therefore, the aim must be to develop an ability to constantly innovate.

In this section, the relationship between innovation and competitive advantage is explained, outlining how companies create competitive advantage under the resource-based view in academia. It also draws the connection between sustained competitive advantage and the idea of dynamic capabilities like the capability to innovate. In the second part of this section, the academic perspective of the importance of innovation for supply chain resilience in light of the Covid-19 pandemic is clarified.

2.2.1 Innovation and competitive advantage - The resource-based view

Schumpeter (1934) says a company needs to constantly innovate to remain competitive, i.e. develop and sustain a competitive advantage. There are a number of theories to consider about how to generate and what constitutes a competitive advantage.

There is the stakeholder theory, that proclaims that developing and maintaining good relationships with stakeholders lead to competitive advantage. Freeman et al. (2010)'s original theory focusses on the importance of ethical alignment between an organisation and its stakeholders. The institutional theory refers to strategic decision making of organisations that might not only be grounded in economic rationality but might be influenced by sociological and societal norms and expectations. Fulfilling such expectations and adhering to norms proactively leads to competitive advantage (Raynard et al., 2015). The resource dependency theory refers to how organisations behave in order to get access to crucial resources. The theory explores mainly the power aspect of dependency of formally independent organisations once they hold or not hold limited resources (Pfeffer and Salancik, 2003). These three theories all focus on external factors of an organisation. Critics point out that especially a focus on the institutional theory might lead to missing out on changes in the market and failing to sustain competitive advantage (Raynard et al., 2015).

However, for the present research an approach is required that also looks inwardly. This approach is the resource-based view (RBV). The resource-based view assumes that an organisation uses its resources to create a competitive advantage. Resource can be tangible resources and intangible resources like capabilities. Some capabilities can be classified as dynamic capabilities. These are capabilities which are used to develop new capabilities. An important dynamic capability is the capability to innovate (Zott, 2003). RBV in fact is used as a basis for many capability related studies beyond innovation. Examples are Helfat and Peteraf (2003) for general capabilities and Kozlenkova et al. (2014) for marketing capabilities in particular.

The resource-based view is a framework that aims at explaining how a firm achieves a competitive advantage. RBV emerged during the 1980s and 1990s and is based on the three main academic contributions (Wernerfelt, 1984, Hamel and Prahalad, 1990, Barney, 1991). Whereas other views on competitive advantage look at the competitive environment in an industry (Porter, 1990), RBV focusses on the internal factors of a company. These factors are referred to as resources. Wernerfelt (1984) claims that a company in fact is made up of resources which are created by organisational activities over time and accumulate. If such a resource is valuable, rare, inimitable or non-substitutable (VRIN) a sustainable competitive advantage can be created Barney (1991). The framework is shown in Figure 2-1.

In detail resources of value exploit opportunities or neutralise threats, rare resources are difficult to acquire, inimitable recourses are difficult to copy, and non-substitutable recourses cannot be replaced by any other recourse (Lockett et al., 2009). The competitive reward as a result can vary (Montgomery and Collis, 1995). However, academic literature focusses predominantly on financial aspects (Grant, 1991, Barney, 1991, Hitt et al., 2016).

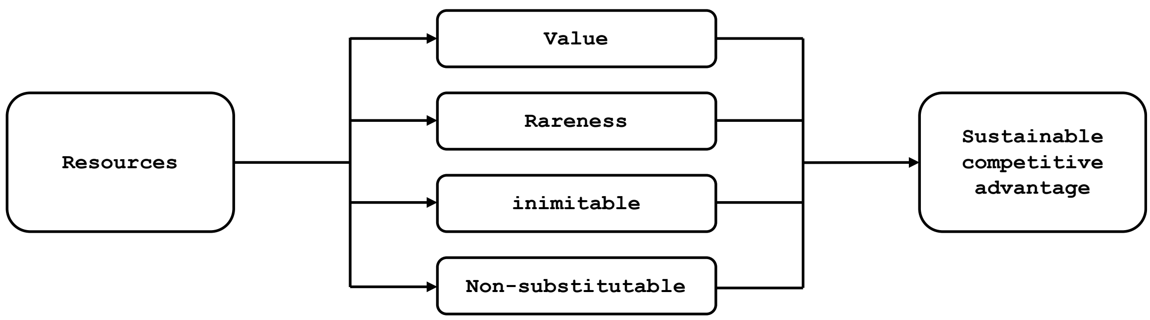


Figure 2-1: How to create competitive advantage under the resource based view (Barney, 1991)

Rashidirad et al. (2017) state that it is not simply the availability of resources that is important but moreover it is vital to have the capabilities to exploit the recourses. Consequently, it is the combination of resources and capabilities that can lead to a competitive advantage (Nath et al., 2010). Special focus lays on those capabilities which allows a company to identify and exploit the 'right' resources and on the 'right' combination of capabilities (Lockett et al., 2009).

From this, the topic of dynamic capabilities has emerged (Eisenhardt and Martin, 2000, Hitt et al., 2016). Resources and capabilities can lose their significance for competitive advantage over time (Wójcik, 2015, Lin and Wu, 2014). The dynamic capabilities approach acknowledges this timely development and suggests that companies

> '*integrate, build and reconfigure internal and external competencies to address rapidly changing environments'* (Teece et al., 1997).

Consequently, dynamic capabilities are capabilities which result in the creation of new capabilities to exploit resources. Teece (2007) introduced three types of dynamic capabilities sensing activities, seizing activities and transforming activities.

2.2.2 Innovation and supply chain resilience

A supply chain is a very heterogeneous system. Many different companies form part of such a system. These companies vary in many aspects. For example, they have a different perspective on risk (Hearnshaw and Wilson, 2013). Consequently, the risk one takes can lead to threats affecting the entire supply chain. If a company goes bankrupt, it might lead to a disruption in a supply chain. A supply chain disruption is the interruption of the flow of goods or service along the supply chain. Thereby, customers further down the supply chain might not be able to produce anymore, and suppliers might not be able to sell their products or services (Craighead et al., 2007). Risk management in supply chains aims at limiting the impact of such a disruption. A common approach to mitigate the impact is the creation of resilience against disruption (Melnyk et al., 2014). Melnyk et al. (2014) state that the higher the capability to build resilient supply chains within a company, the more resilient the supply chain as a system. Kamalahmadi and Parast (2016) define supply chain resilience as:

> *"the adaptive capability of a supply chain to reduce the probability of facing sudden disturbances, resist the spread of disturbances by maintaining control over structures and*

functions, and recover and respond by immediate and effective reactive plans to transcend the disturbance and restore the supply chain to a robust state of operations."

Going more into detail, Melnyk et al. (2014) state that resilience has two critical elements:

(1) resistance capacity, the ability of a system to diminish the impact of a disruption by avoiding it entirely or by decreasing the time between the onset of a disruption and the start of recovery from that disruption.

(2) recovery capacity, the capability of a system to determine a path to return to a steady state of functionality once a disruption has taken place.

Sabahi and Parast (2020) state that even though resilience is important to manage supply chain disruption, there is little research in how a company, or an entire supply chain can develop it. However, there is substantial evidence that innovation and the capability to innovate have a significant impact on supply chain resilience (Reinmoeller and Van Baardwijk, 2005, Golgeci and Ponomarov, 2013). Akgün and Keskin (2014) found empirical evidence for the influence of continuous product innovation on continuous supply chain resilience and economic performance. Kamalahmadi and Parast (2016) state that innovation is in particular important for resilience to disruption. Sabahi and Parast (2020) analysed how exactly a company builds resilience through innovation. Based on their research they argue that it is mainly the influence of innovation capability that influences flexibility, agility, and the willingness to share knowledge that in return influences supply chain resilience.

2.2.3 Conclusion

Innovation as a driver for building supply chain resilience and innovation as driver for competitive advantage is a very important dynamic capability in times of high market disruption caused by e.g., Covid-19. To stabilise supply chains in a short-term perspective building supply chain resilience can help mitigating the direct impact of the disruption. On a longer-term perspective innovation capability can help renewing and reorienting businesses to seize new opportunities and build a competitive advantage in the future.

2.3 Innovation within single organisations

After clarifying what innovation is and why it matters, this section looks at innovation in the context of single organisations. It is looked at what enables or hinders innovation in single organisations on different levels. It also examines and clarifies academic concepts of the innovation process in an organisation.

2.3.1 Innovation barriers and enablers in single organisations

Innovation barriers can be divided into two categories, barriers within the control of an organisation and barriers out with the control of an organisation (Shi et al., 2008, Thun and Müller, 2010). Internal barriers refer to organisational internal topics like resource allocation and company culture whereas external barriers refer to the wider business environment an organisation operates in like a supply chain or an industry (Hadjimanolis, 1999). This section only refers to internal barriers, external barriers are explained in the section 2.4.

For internal barriers, Hueske and Guenther (2015) divides barriers into organisational barriers, team barriers, and individual barriers. They find that on organisational level internal inconsistencies cause most friction and hamper innovation. This refers to inconsistencies in strategy and operations. Missing long-term business strategies or unclear strategies are innovation barriers just like inconsistent operation strategies and performance measurement. Company structures and bureaucracy are other barriers which are frequently mentioned. The most common barrier to innovation is a lack of resources. This can mean a lack of financial resources, time allocation, or lack of skills and expertise (Evangelista, 2010). Further, Hueske and Guenther (2015) states that if there is a lack of willingness to adapt and execute change on an organisational level, innovation is hampered. Hueske and Guenther (2015) state that even though SMEs and large enterprises are fundamentally different the size in both cases cause produces innovation barriers. On a team level, innovation barriers include team sizes (Antony et al., 2008), the potential temporality of teams (Lederer and Sethi, 1992), and the climate of collaboration. The team constellation and the skills of team members, their characteristics, and team leadership in terms of innovation processes and style matter as well (Hoonakker et al., 2010, Martini and Pellegrini, 2005). On individual level, professional skills and leadership skills are as important as in a team setting. On an individual level, the attitude towards innovation and change matters even more (Delgado-Ceballos et al., 2012).

The before mentioned enablers and barriers are of general nature. However, every company is a unique case. Nevertheless, companies of similar size in similar industries tend to have face similar barriers (Galbraith et al., 2017). Company size always comes with advantages and disadvantages Hueske and Guenther (2015). Therefore, in the following a differentiation between SME and large enterprise barriers and enablers is undertaken.

In terms of knowledge management, manufacturing SMEs are unlikely to have formal knowledge management systems or databases. Consequently, knowledge is not explicitly expressed and separated from the person holding it in the organisation. This means that the knowledge in its full is just accessible for that person and if that person leaves the organisation the knowledge leaves the organisation as well. Quick informal communication and decision making makes it possible for most employees of an SME to participate in idea generation. But a formal way of managing these ideas mostly does not exist and ideas of high potential might be simply forgotten over time (Posch and Wiedenegger, 2014). Large companies normally use knowledge management systems and have the knowledge separated from the knowledge holder enabling everyone to access the knowledge. However, communication and decision making often takes a long time. Participating and sharing ideas to the people that matter can be difficult as well (Pellegrino, 2018).

Collaboration is a topic where large companies usually hold an advantage over SMEs. SMEs usually operate rather locally than internationally although exceptions confirm the rule. Within the local community these SMEs are usually well connected and have established direct personal contact with their suppliers and their direct customers and use them as external knowledge source. Further, they are usually active in industrial associations (Bird and Wennberg, 2014, Llach and Nordqvist, 2010). SMEs still tend to have lower outside connections than larger firms. On especially a national and international level SMEs fall short. SMEs of the long tail of the manufacturing value chain in the UK for example might be well embedded in their direct business environment but they might not have any contact to OEMs or Tier 1 or 2 companies (Galbraith et al., 2017). A considerable number of SMEs also engages with universities and public innovation support programmes as source of knowledge, external skills and external funding opportunities. However, public support mechanisms seem to be unclear to some SMEs which results in frustration and finally to a withdrawal from collaboration. The reasons for this can be found in a lack of innovation knowledge not just on SME side but also on public innovation support programme development side as Galbraith et al. (2017)

show. Further, the non-existence of such support in some geographical, industry or business areas can result in serious barriers to innovation (Galbraith et al., 2017, Ates, 2016, Davies and Michie, 2011). However, a considerable number of SMEs does not engage with universities and does not use public innovation support. A possible reason is a lack of environmental scanning to identify support mechanisms (Zhang et al., 2006).

The organisational culture is usually an enabler of innovation in SMEs whereas it is a barrier for larger enterprises. The small number of employees of SMEs and usually just one firm location enable informal quick communication and decision making (Posch and Wiedenegger, 2014). However, leadership is rather a barrier to innovation in SMEs. Ates (2016) argues that a multitude of studies show that the organisational culture in many SMEs compared to larger companies offers just a low tolerance for failure. Especially in established manufacturing SMEs leadership does not support innovation and creativity (Galbraith et al., 2017). Low budgets for innovation intensify this attitude. Further, low budgets lead to a lack of access to necessary expensive technological recourses (Hewitt-Dundas, 2006, Kamasak, 2015). Consequently, resource availability is one of the main practical barriers for innovation in smaller firms (Harris et al., 2013). A general mindset of rather training employees in efficiency than innovation is also a frequently found barrier to innovation in SMEs and larger corporations alike (Galbraith et al., 2017).

Specially manufacturing SMEs face barriers related to the dimension of individual creativity, skills and learning. There is little understanding of innovation theory throughout many manufacturing SMEs (BEIS, 2017). This comes along with a significant lack of technological expertise for innovation activities. Especially the knowledge of how to acquire and internalise external knowledge is usually not established (Lin et al., 2012, Mitchell et al., 2014). Further, SMEs seem to be not as attractive for potential new employees as larger companies. Especially in more peripheral regions in the UK, this results in an unavailability of skilled workforce to fill in skill gaps (BEIS, 2017, Galbraith et al., 2017). Consequently, SMEs have to concentrate their activities on building innovation related knowledge and skills internally whereas larger corporations have less challenges hiring the right skilled workforce (Saunila and Ukko, 2014).

One of the most important barriers to innovation in SMEs is a perceived low value of innovation (Ates, 2016, Chesbrough, 2012). Failing to see its importance for overall business sustainability, many SMEs spend very little on innovation (BEIS, 2017). However, little spending on innovation does not enable leadership to provide the necessary resources to enable innovation. Even if innovation is perceived as important, many SMEs struggle to secure enough funding for innovation projects. Especially when dependent on external private funding, larger innovation projects are considered too risky for the overall business performance and consequently never realized. However, as mentioned earlier, there are public innovation support programmes which provide public funding and expertise to apply for such funding. Although, many SMEs are either not aware of these options or they are organisationally not prepared enough for innovation to apply successfully for public funding (Galbraith et al., 2017).

Afterall SMEs and large corporations face different innovation barriers and can build on different enablers. It is important to have this differentiation present.

2.3.2 The innovation process and the concept of absorptive capacity

After clarifying which barriers and enablers influence innovation, this section focusses on the innovation journey, meaning the innovation process itself. There are many concepts and many tools out there describing how an innovation can be developed. Significant contributions have been made especially by e.g. Tidd and Bessant (2018). For this research, however, it makes sense to look at the meta processes behind innovation processes to keep innovation capability independent of the exact tools and methods that are used for innovation development.
Precisely the concept of absorptive capacity is of interest as the theoretical approach to how organisations learn and commercialise knowledge. Originally based on organisational learning literature (Volberda et al., 2010), Cohen and Levinthal (1990) created the concept of absorptive capacity. Cohen and Levinthal (1990) define it as:

> *"Absorptive capacity constitutes in identify, and value, assimilate and exploit external information".*

Absorptive capacity has been analysed and enriched by many scholars and has become a broadly accepted concept (Volberda et al., 2010). It has found broad application mainly in the fields of strategic management (Lane and Lubatkin, 1998), technology management (Schilling, 1998) and innovation (Cohen and Levinthal, 1990).

A company constantly and continuously accumulates knowledge. The level to which it does, determines the absorptive capacity (McAdam et al., 2010). Zahra and George (2002) reconceptualized the original concept by Cohen and Levinthal (1990). They argue that a company needs to develop capabilities to increase its absorptive capacity. They understand ACAP as a dynamic capability to create other organisational capabilities like marketing or production and, thus, create a competitive advantage. Zott (2003) characterises dynamic capabilities as organisational processes enabling organisational change and evolution in response to changed market conditions. Moreover, Lane et al. (2006) explicitly argue that absorptive capacity needs to evolve over time to remain capable of reacting to changes, and, thus, highlighting the dynamic capability nature of absorptive capacity further. Zahra and George (2002) propose a concept consisting of the four different stages knowledge acquisition, assimilation, transformation and exploitation. These stages comprise all three types of dynamic capabilities (sensing activities, seizing activities, and transforming activities) as described by Teece (2007). Zahra and George (2002) divide their four stages into two subsets as shown in Figure 2-2.

Zahra and George (2002) describe knowledge acquisition as a company's capability to identify and acquire external knowledge. Acquisition capabilities are influenced by the intensity and the speed of new knowledge identification. However, there are limits in speed since learning cycles are difficult to shorten and knowledge sources can be difficult to access. Also, the direction of accumulating knowledge impacts the acquisition capability, meaning what knowledge to look for and how to look for it. To successfully adopt external technology, different areas of expertise is needed in an organisation.

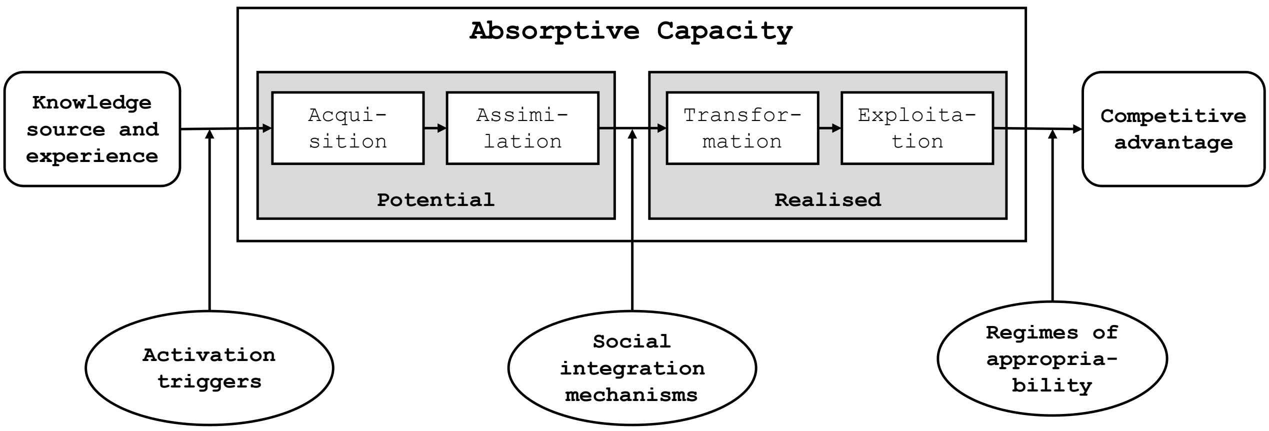


Figure 2-2: Absorptive capacity concept (Zahra and George, 2002)

Assimilation is a company's ability to analyse, interpret and understand information acquired from external sources (Zahra and George, 2002). However, if a company may find information beyond its search scope it might overlook it (Rosenkopf and Nerkar, 2001). External knowledge may be based on heuristics unknown to the company or depends on the context in which it was created or applied before. Thus, comprehension of outside knowledge can be very challenging (Barton, 1995, Szulanski, 1996). However, comprehension itself supports the capability of assimilation (Zahra and George, 2002).

Transformation refers to a company's capability to combine new and existing knowledge. This can mean to add knowledge, to delete knowledge or to interpret existing knowledge in a new way. This capability shapes entrepreneurial action and enables a company to recognise entrepreneurial opportunities (Zahra and George, 2002).

Zahra and George (2002) add the stage of exploitation to Cohen and Levinthal (1990) initial ACAP framework. They define it as a capability to exploit knowledge rather than an ACAP outcome as Cohen and Levinthal (1990) do. In detail, exploitation is the capability of how to include knowledge in daily operations and routines (Van den Bosch et al., 1999). Exploitation routines lead to innovation whereas the type of innovation can vary depending on the exploitation of knowledge Zahra and George (2002). Table 2-4 provides an overview over the different stages of ACAP and the components influencing them as capabilities.

As shown in Figure 2-2, Zahra and George (2002) describe knowledge sources and experience as the antecedents for ACAP. Getting access to a variety of knowledge sources is essential to acquire new knowledge. Possible ways of access are acquisition, purchasing through licencing, R&D collaborations or open innovation, and freely accessible sources (Volberda et al., 2010, Vermeulen and Barkema, 2001, Zahra and George, 2002). However, just being exposed to knowledge does not lead to higher PACAP itself. Just if it is complementary to a company's prior knowledge it is likely that that company builds PACAP out of it Zahra and George (2002). Further, past experiences influence how a company searches for knowledge sources. It is likely that they keep looking in directions where they had success in the past (Christensen and Raynor, 2003).

Table 2-4: ACAP stages and their components concept (Zahra and George, 2002)

Stages / Capabilities	Components
Acquisition	Prior knowledge Intensity Speed Direction
Assimilation	Comprehension
Transformation	Conversion
Exploitation	Use Implementation

There are outside factors influencing ACAP. e.g., triggers to start the ACAP process. Triggers are events that cause a company to look for outside knowledge. These triggers can be internal or external. Internal triggers can be e.g., organisational issues, like insufficiently good performance or a simple change in entrepreneurial strategy. External triggers are events happening outside the company but having a direct impact on its performance. These can be e.g., the development of disruptive innovations or policy changes. Especially when a trigger keeps persisting or when multiple triggers are activated at the same time, companies start searching for outside information (Zahra and George, 2002). The intensity of the triggers influences the will to invest in developing the necessary capabilities to acquire the external knowledge (Ring et al., 2005). The trigger itself has an impact on the kind of information and on where a company looks for it (Tegarden et al., 1999). Social integration is another factor influencing ACAP. Following Zahra and George (2002) social integration is the link between PACAP and RACAP. Companies using especially formal mechanisms to make employees aware of the PACAP available in that company are more likely to exploit it more efficiently than others. Zahra and George (2002) state that the outcome of ACAP is a competitive advantage. They further state that companies which perform well in RACAP are more likely to build a competitive advantage and companies performing well in PACAP and maintain a high efficiency factor η_{ACAP} are likely to sustain that competitive advantage. Competitive advantage is usually understood as the capitalisation on innovation. Regimes of appropriability are another outside factor influencing, this time, the outcome of ACAP. Regimes of appropriability are defined as the level to which a company can protect its exploitation of knowledge. Just if a company can prevent or at least delay the duplication of its innovation, it can profit from it (Hurmelinna-Laukkanen et al., 2008). High appropriability regimes mean that in innovation can be copied more easily and there are competitors who will try to copy it. In this case innovations are usually protected by e.g., patens. Low appropriability regimes in contrast are characterised by innovations with cannot be copied that easily. As defence mechanisms rather secrecy as isolation mechanism is chosen over expensive patenting which might not pay off in the end (Hurmelinna-Laukkanen et al., 2008). Zahra and George (2002) argue that there is just a positive relation between RACAP and a sustained competitive advantage either if there is a high appropriability regime or if a company takes action to protect its knowledge by isolation under a low appropriability regime.

2.3.3 Conclusion

In conclusion it can be said that innovation and what affects innovation in single organisations is a complex matter. Many studies have analysed what hinders and what enables innovation. Every company is different and has its own advantages and disadvantages for generating innovations. However, there are many common enablers and barriers of innovation. Depending on the size of a company barriers can become enablers and the vice versa.

2.4 Innovation beyond single organisations

After clarifying different perspectives on innovation and barriers and enablers of innovation in single organisations, this section focusses on innovation beyond single organisations or innovation in networks or systems. This becomes necessary as every single company operates in a wider industry and economy context which influences the business (Porter, 1990). How innovative a company is depends on how such an innovation network is organised and how a single company interacts with the wider network (Porter, 1990). For this purpose, academic concepts are presented about innovation in general networks. In light of the objectives of this research, innovation is then considered through the lens of a supply chain and the supply chain is characterised as a special innovation system.

2.4.1 Academic approaches to innovation in networks

In academia there are many different concepts which have evolved over time describing how innovation works beyond single organisations. The business cluster or innovation cluster concept raised by Porter (1990), the triple helix model by Leydesdorff and Etzkowitz (1998), and the concept of innovation (eco-) systems all look at innovation through a systems perspective on multiple organisations. The innovation cluster concept focusses on local proximity of collaborating companies. This is extended to other forms of proximity by the innovation (eco) system. The triple helix model focusses on collaboration of governments, universities and industries. The section is closed with the concept of open innovation for holisticness. Open innovation is a concept of developing innovation in collaboration with other organisations. In contrast to the before mentioned concepts, open innovation is not a holistic systems approach to an industry or system. It is a company internal view on how to use external collaboration. However, it is important to realise that the terms innovation or business cluster, innovation system or ecosystem, and open innovation are used interchangeably in everyday language (Granstrand and Holgersson, 2020). In the following, the meaning of each term is clarified.

2.4.1.1 The business cluster or innovation cluster idea

Porter (1990) raises the idea of local business clusters to foster innovation. Local proximity of companies working in the same sector, local proximity of suppliers and customers, support collaboration and the development of innovation. Porter (1990) also states that local proximity to universities increases their collaboration as well. Knowledge transfer is essential to translate research into new business cases within organisations. Easier access to skills, customers, suppliers, information, and complementary products and services leads to an advantage of creating innovation. The geographical aspect can be understood in a local, regional level like the Silicon Valley in the United States, but it can also be understood as a national ecosystem in a global context, like the German automotive industry.

For cluster development public institutions and policy making are immensely important. Public institutions provide the resources and incentives to create such clusters. This can mean providing funding for a sector or funding of special research projects or tax incentives in return to creating jobs in a certain region.

2.4.1.2 The innovation (eco) system approach

The idea of innovation systems emerged from the business cluster or innovation cluster idea as stated in Porter (1990). This approach is the formal application of systems thinking to innovation 'systems'. Different innovation systems as interesting to academic research have evolved. These are regional and national innovation systems referring directly to Porter

(1990) innovation clusters, sectorial including supply chain innovation systems, and corporate innovation systems (Granstrand and Holgersson, 2020).

The term innovation system was extended to the term innovation ecosystem to highlight the transformation of matter and energy through the process as it is done in ecosystems (Oh et al., 2016, Granstrand and Holgersson, 2020). The term innovation ecosystem has become a common term in public and policy making. Papaioannou et al. (2007) and Oh et al. (2016) criticise the use of the term 'eco'- system as it suggests a faulty analogy with bio inspired ecological systems. They argue that biological ecosystems are natural systems which naturally evolve, innovation systems, however, are artificial systems which are human made. Papaioannou et al. (2007) points out that the main differences are that innovation systems are developed for a purpose, and that they need governance to function. Biological ecosystems do not have either. Nevertheless, innovation systems evolve over time. For this reason, in this research the term innovation system is used instead of innovation ecosystem.

Granstrand and Holgersson (2020) argue that even though substantial research has been carried out analysing how system actors collaborate, the existence and the acknowledgement of the existence of competitors within the system is important.

2.4.1.3 The triple helix model of innovation

The triple helix model of innovation is a macro economic model describing how the interaction of industry, universities, and the government enable innovation. This model was first described by Leydesdorff and Etzkowitz (1998). The basic message behind the model is that innovation and innovation performance of single organisations are influenced by education and research practices at universities and by government policy design. This is based on the basic roles these three model elements hold. Industry produces goods, universities do research and education, and the government regulates the market. This triple helix is shown in Figure 2-3.

Over time the different elements can either move closer together or further apart. To foster innovation Leydesdorff and Etzkowitz (1998) argue that moving closer together and collaborating opens up space for the creation of hybrid organisations which can increase the collaboration even more. Thus, it is made sure that all elements know the needs and requirements of each other and can actively create conditions to foster innovation.

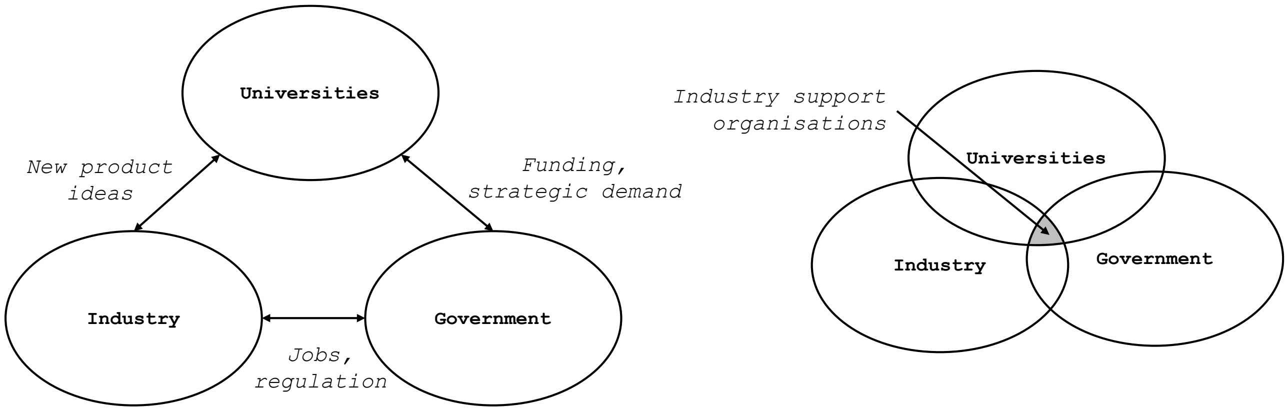


Figure 2-3: Triple helix model of innovation (Leydesdorff and Etzkowitz, 1998)

Interactions between universities and industry are primarily characterised by providing basic research and education. Education aims at developing the next generation of workers for the industry. Basic research provides the basis for future products and services. However, Leydesdorff and Etzkowitz (1998) argue that to foster innovation the exchange of knowledge beyond these basic activities should take place. Universities should be made aware of the requirements of industry as new research gaps open up and potential workforce is required to learn new skills and knowledge to be useful for the industry. They argue that the transfer of people themselves between universities and industry has a major impact on knowledge exchange.

Interactions between the government and universities are characterised by policy making for the higher education and research sector. If universities are mainly publicly funded the government can actively shape funding programmes and can actively decide what gets support. If funding is predominantly available through private organisations the government's lever is limited. Either way, Leydesdorff and Etzkowitz (1998) argue that funding and policy making must be relevant to progresses in academia and in industry alike.

Interactions between government and industry are mainly shaped by market regulation policy making. The spectrum goes from very little involvement of the government including little funding of potential innovation, to high involvement. Leydesdorff and Etzkowitz (1998) argue that high regulation is a hinderance while providing funding for innovation and start-up company development is helpful.

How much overlap of the three elements there is depends on a government and on the different industries within an economy. However, Leydesdorff and Etzkowitz (1998) that all three elements should aim at developing a system that creates said overlap (see Figure 2-3). If all three elements collaborate a shared space can be generated where new organisations can evolve. Such organisations then can foster the collaboration even more. Examples for such organisations can be public industry support organisations or private science parks.

2.4.1.4 The concept of open innovation

For holisticness the concept of open innovation is mentioned here. Open innovation is effectively the single company perspective on innovation in networks, whereas the before mentioned concepts are holistic approaches from a systems perspective. Originally innovation was seen as a company internal topic. Over time the attitude towards this has changed and has fundamentally changed innovation management. Innovation is now considered an internal and external topic. This opening up of innovation processes to external shareholders, sources of information, etc is called open innovation (West and Bogers, 2014). Chesbrough (2003) defines open innovation as:

> *"a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market as the firms look to advance their technology."*

Following this definition companies should share information with partners. This opens up new pathways for innovation. First of all, just if a significant number of companies shares data and insights with the wider industry, politics, and universities the idea of a shared space under the triple helix model is possible to arise. Further, access to outside data can stimulate internal ideation. Sharing own issues with an innovation idea can lead to outsiders sharing expertise to solve such a problem. Hence, open innovation activities can be inbound and outbound. Both approaches, support innovation to a point where new business models around open innovation and data sharing become viable but new issues come along with the openness of a company (Hossain et al., 2016). The main concern is around intellectual property. How intellectual property can be protected depends on how and with whom data is shared. If data is shared in open innovation competitions with the public, protection is difficult whereas the reached audience is the biggest. If data is solely shared with another single organisation, intellectual property protection is a matter of contracts. The reach of potential experts is limited, however. Governing data sharing in innovation systems can be complex if many organisations are involved. To gain the trust of companies to share needed information, fair treatment and intellection property regulations are key (West and Bogers, 2014).

Open innovation has been a buzzword word for over a decade. Especially during the 2010s the concept of open innovation has gained much popularity with some academics and practitioners hailing it as the future of innovation. However, Birkinshaw et al. (2011) label this as one of five myths of innovation. They state that open innovation will be a part of the future of innovation and therefor it is important, but there will be many other aspects relevant for successful innovation. The takeaway message of Birkinshaw et al. (2011) is that innovation has to be approached in a holistic way from many perspectives, otherwise not all opportunities can be identified leading to business decisions with potentially negative impacts.

2.4.2 Supply chain as innovation ecosystem

After looking into the nature of different innovation systems in general, the focus of this section lays on supply chains as special innovation systems. The supply chain perspective prompts a number of assumptions which are not necessarily true for general innovation systems. First of all, a supply chain is a system of different actors or companies which are contractually bound to each other (Jacobides et al., 2018). Second of all, all actors along a supply chain generally work on a common goal for mutual success whereas general innovation systems can show high levels of competition (Oh et al., 2016).

Chopra and Meindl (2007) define a supply chain as:

> *"consisting of all parties (manufacturers, suppliers, transporters, warehouses, retailers, and customers) and, within each organization, all the functions involved, directly or indirectly, in fulfilling a customer request."*

In respect to innovation this means that an existing supply chain needs to be able to innovate as a system to serve changes in end costumer wants and needs and stay competitive but it also needs to innovate to react to other impacts on the system to stay functional (Melnyk et al., 2014). Granstrand and Holgersson (2020) describe a supply chain as a special sectorial innovation system. Such a system can as well be local or national, or both in different parts of a supply chain. This research focusses on local and national supply chains as the focus lays on the Covid-19 impact on innovation in Scotland.

It is important to distinguish the terms supply chain, supply base, and industry. A supply chain is an organised connection of actors to fulfil a common purpose, to rephrase Chopra and Meindl (2007) definition. The supply base is the entirety of companies which are capable of generating a special supply. A supply chain is aware of their existence and actively manages them. The supply base can provide replacement suppliers if needed (Choi and Krause, 2006). An industry is a group of companies providing similar end products or services, not all companies within an industry might be known to a supply chain or might be irrelevant, hence are not actively management and thus not part of the supply base (Porter, 1997).

As the supply chain is a subsystem of the industry, the assumptions of the triple helix model remain valid. This means that innovation in a supply chain is influenced by interactions with universities and government.

2.4.3 Conclusion

In conclusion it can be said that innovation in networks is a complex matter adding to the complexity of innovation in single organisations. However, companies are part of networks and systems and therefor this approach has to be taken. How innovation works in networks depends highly on how different organisations interact with each other. This does not only include different companies but also universities, policy makers, and industry support organisations.

The support infrastructure for companies in Scotland and the wider UK is complex and inefficient. The complexity is argued needs to be reduced especially for SMEs to be relevant for them. Funding rules are criticised to not provide enough support for market near developments and joint value creation in supply chains (Bailey et al., 2019).

2.5 Innovation capability of supply chains - a critical review of academic literature

After looking into the topics of innovation in single organisations and innovation beyond single organisations, this section aims at precisely looking into what is innovation capability and what is innovation capability of supply chains. A structured literature review is conducted. The methodological approach followed is described before findings are presented, and the research gap is highlighted.

2.5.1 Approach of literature review.

A snowball and reverse snowball method are used following Wohlin (2014). Snowballing and reverse snowballing is frequently used to conduct structured literature reviews. They are especially helpful to explore broad topics like innovation capability of supply chains in an economic way. Snowballing refers to an approach where an initial paper or set of papers of special relevance to a topic are selected and their references are used to collect data, and then the references of the references. References can mean either relevant referenced papers or authors or both. As snowballing alone is only a chronologically backwards search, reverse snowballing was introduced to identify later published literature. The idea is to identify papers that reference the starting set and then papers referencing the referenced papers in the starting set. This way relevant up and downstream literature can be identified (Wohlin, 2014). This approach has been criticised for a chance of missing relevant papers if different research strings are not connected (Snyder, 2019). However, it has also been argued that an initial preparatory unstructured literature search should mitigate this risk. Explicitly, a structured content analysis has not been followed as the search focus is too broad and has resulted in thousands of papers to analyse.

For the present research a snowballing and reverse snowballing approach is used, following the four step approach that Wohlin (2014) suggest as shown in Figure 2-4.

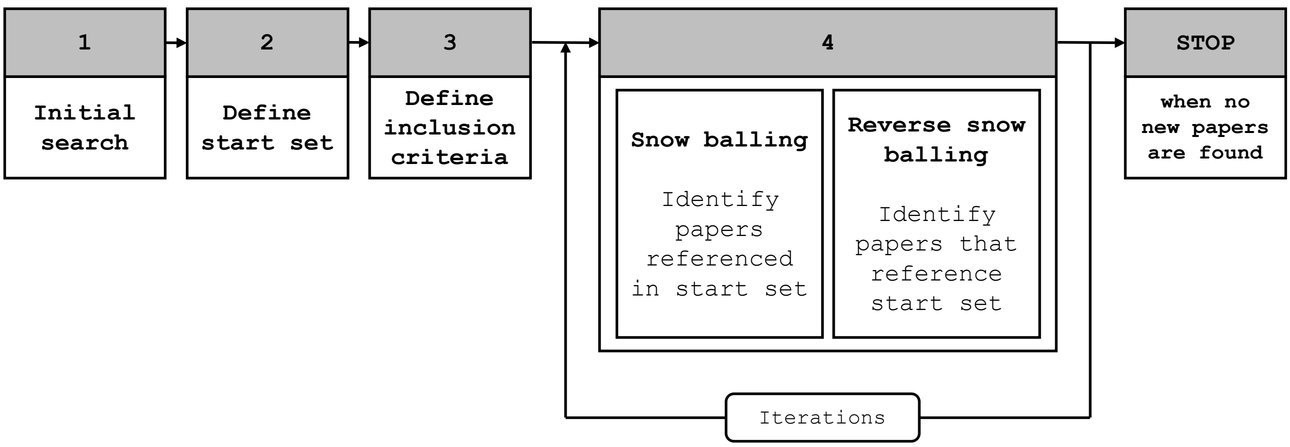


Figure 2-4: Process of snowballing used in literature review (adapted from Wohlin (2014))

Step 1 refers to conducting an initial preparatory unstructured review with an initial search term. For this study the search term 'innovation capability of supply chains' is used. Additionally, the search databases have to be defined. Here, the University of Strathclyde Library database is used. Based on the results in step 2, a starting set of papers is identified from where to start the iterations of searching. These are usually especially relevant results (Wohlin, 2014). The formal starting point for the literature review is Iddris (2016) as this is the only paper fulfilling the search terms 'innovation capability' and 'supply chain' on the University of Strathclyde library database. Step 3 aims at setting inclusion criteria for literature, in the present case literature was included if title or abstract content references to supply chain and or innovation capability. Only peer reviewed articles are considered to ensure validity and reliability of this literature review. Step 4 is the actual execution of the literature search going in iterations up and downstream from the initial set of literature. In the present case after 3 downstream iterations and 5 upstream iterations no new relevant literature could be identified. A total of 17 relevant papers could be identified published between 2001 and 2021. No dominant journals could be identified; however, two main literature strings can be identified. One is innovation capability of single organisations research and supply chain integration for innovation research.

Data analysis is executed using a thematic coding approach. Precisely inductive coding is used, where a codes or themes emerge during data analysis as described by Mayring (2004). The identified themes are innovation capability definitions, innovation capability of single organisations, and supply chain integration for innovation capability. As a summary, Table 2-5 shows an overview over the methods used for this literature review.

Table 2-5: Overview over methods and their application for literature review

Research stage	Application
Data collection	Structured literature review using snowballing / reverse snowballing
	Starting point: Iddris (2016)
	Literature inclusion criteria:
	Iterations: 3 downstream, 5 upstream
Data analysis	Inductive thematic coding with following emerging codes:
	Innovation capability definitions
	Innovation capability of single organisations
	Supply chain integration for innovation capability

Overview identified literature	17 papers Published between 2001 and 2021 No dominant journal Two dominant research strings: innovation of single organisations and supply chain integration for innovation

2.5.2 Innovation capability of supply chains – two approaches

Innovation capability of supply chains is not a topic that has been extensively covered in literature, even though competition taking place more on the basis of supply chains and supply chain capabilities rather than single companies and their capabilities (Farahani et al., 2014). However, there are two lines of research that have ventured into the field. The first one is research into innovation capability of single organisations which has been studied in hundreds of studies (Mendoza-Silva, 2021) with a handful extending the scope to supply chains (Iddris, 2016, Saunila, 2019). The second one is the supply chain management field that focusses on improving supply chain operations. In this context, innovation capabilities on an interorganisational level have been analysed in a few studies (Zhu et al., 2018). This research string speaks of supply chain integration influencing innovation capability. The term supply chain integration in this context also only refers to joint value creation, not to traditional incorporation of businesses (Chapman et al., 2003).

The innovation capability of single organisations literature argues that there is no clear consensus on how to define the term innovation capability in the first place. Saunila (2019) argues that there are two different approaches. The first approach considers innovation as an output or an input-output-relation rather than a process. In this context, innovation capability is understood as the capability to produce a distinct type of innovation. Most of Keeley et al. (2013)'s types of innovation have been analysed in studies (Saunila, 2019). Rahman et al. (2015) criticise this approach as being just a snapshot in time. For a solid sustainable business performance, a company has to be innovative continuously. This approach has also been criticised for applying imprecise measures when analysing innovation capability. Common measures used in this context are return on investment or return on research (Becheikh et al., 2006), spending on research and development or innovation activities (Jung et al., 2008), or number of patents (Bellamy et al., 2014). Generally, these measures have been criticised to only capture input or successful output of innovation which makes it impossible to derive meaningful insights about efficiency (Rahman et al., 2015, Boly et al., 2014). These measures are not only imprecise, but they are also too narrow and do not capture innovation capability in its entirety, as especially behavioural and organisational culture aspects are not reflected (Saunila, 2019, Mendoza-Silva, 2021, Samson et al., 2017, Edmondson and Harvey, 2018).

The other approach defines innovation capability as a process referring to innovation as a process. This approach conceptualises innovation capability as the potential to create innovative output. An often used definition is the one by Lawson and Samson (2001) who describe innovation capability as “the ability to continuously transform knowledge and ideas into new products, processes and systems for the benefit of the firm and its stakeholders.” Keskin (2006) adds the readiness to test new ideas. This approach broadens up the understanding of innovation capability beyond the measures used in the first research string. It is argued that many factors influence innovation capability on a company level, including factors that are intangible and therefor challenging to measure. Hence, more recent studies have investigated which factors impact innovation capability on a company level in general (Saunila, 2017b, Iddris, 2016). However, there is no consensus on what these dimensions are (Saunila, 2019). Generally, they are based on innovation barriers and enablers. For measurement, some studies have moved to applying the maturity concept to innovation capability and the factors influencing it. This approach has been suggested for example by Samson et al. (2017) and Mendoza-Silva (2021) to make intangible factors measurable. No dominant holistic maturity model or its innovation capability dimensions can be identified. They all have shortcomings or limitations. Enkel et al. (2011) only focus on open innovation, Arends and Advisory (2018) do not consider the innovation process as part of innovation capability, and Esterhuizen et al. (2012) do not validate their model. It has to be noted that also in this line of research many studies aim at understanding innovation capability directed at only single types of innovation at a time (Saunila and Ukko, 2014) or they focus on special sectors or company sizes (Iddris, 2016).

In a more direct relation to the objective of this research, to analyse innovation capability of supply chains and not only single organisations, a number of studies have been carried out. Identifying these requires differentiating the difference between supply chain innovation and innovation developed along or within a supply chain. Supply chain innovation refers to innovations around supply chain operations and management (Dubey et al., 2012). The focus of the present research is on the development and the ability to develop innovation along a supply chain. Even though there is no definition for innovation capability of supply chains available in literature, for the present research the definition for single organisations developed by Lawson and Samson (2001) can be adopted to supply chains and sharpened by including the working definition of innovation as described in section 2.1.3. Hence,

> *"Innovation capability of supply chains is the supply chain's ability to continuously transform knowledge and ideas into the implementation of something new or substantially improved in a supply chain and its member organisations that creates value for its stakeholders."*

Innovation capability in a supply chain context has obtained attention mainly over the last decade (Faghat et al., 2020, Iddris, 2016, Iddris, 2018, Yunus, 2018, Delbufalo, 2015, Tan et al., 2015, Ferrer et al., 2011). Ferrer et al. (2011) analyse the relationship between competence and innovation capability in supply chain relationships which results in that sharing competence and flexibility positively influence innovation capabilities for supply chain relationships. Delbufalo (2015) analyses the relationship between innovation capability of a single company and its supply network structure. Yunus (2018) focusses on the impact of different forms of communication with suppliers and customers on the development of different types of innovation. Tan et al. (2015) focus on the impact of digitalisation on innovation capability of supply chains, especially in terms of data mining. Faghat et al. (2020) focus on how to manage shared value creation in a supply chain. They explicitly only focus on value innovation in terms of a benefit for the end user of a product, development of technology as disruptive innovation, for example, is explicitly excluded. Iddris (2016) and Iddris (2018) are the only two papers, one building on the other, that effectively aim at establishing a framework for innovation capability of supply chains. However, innovation capability of supply chains here is seen through the lens of a single company. Iddris (2018) explicitly focusses on the direct supply chain of a company. He adopts Mentzer et al. (2001)'s understanding of this direct supply chain as the direct suppliers and customers. In other terms, the full supply chain from end to end, or ultimate supply chain as Mentzer et al. (2001) call it, is not a matter of Iddris' research.

Approaching innovation capability of supply chains through the avenue of supply chain integration for value creation, a similar picture can be painted. Whereas there are many studies on supply chain integration for general supply chain operations (Damanpour, 1991, Rhee et al., 2010), there is only a handful of studies directly addressing innovation capability (Seo et al., 2014, Ayoub et al., 2017). Flynn et al. (2010) and Zhu et al. (2018) describe supply chain integration as the strategic integration of both internal and inter organisational processes with the aim to work collaboratively together to gain mutual beneficial outcomes and provide better value to end customers. The integration does not explicitly mean that a supply chain member is absorbed by another supply chain member. The focus lays on collaboration. Zeng et al. (2010) and Seo et al. (2014) find that the cooperation and integration of supply chain partners play a significant role in the innovation process and innovation capability building. Didonet and Díaz (2012) and Ayoub et al. (2017) specifically identify that supply chain integration with suppliers and customers improve design, production, delivery, and enhance innovation. Dewick and Miozzo (2004) argue that interaction and mutual relationships between an organization and its suppliers, customers, and designers play an important role in the production process and process innovation. Zhu et al. (2018) highlight that interorganisational learning is important for value creation. Learning requires knowledge distribution which can take place, both, throughout an organisation or internally and externally throughout the supply chain (Soosay and Hyland, 2004). Internal integration refers to the extent to which a manufacturer re-engineers its own organisational strategies and processes across departments into synchronised internal processes to better meet customers' needs (Wong et al., 2011). External integration refers to the integration of other organisations along the supply chain. Typically, these are key suppliers and key customers. Information sharing and strategy alignment for manufacturing in the present and future are key components of external supply chain integration (Seo et al., 2014). Customer integration enhances market expectations and opportunities, leading to more precise and faster responses to customer needs (Swink et al., 2007). Flynn et al. (2010) stress that all three components, internal, supplier, and customer integration are necessary for successful performance improvement. Lii and Kuo (2016) go a step further and conclude, that if a company is more innovative, it is more likely to push supply chain integration. However, Zimmermann et al. (2016) say that all research into supply chain integration for innovation is solely of qualitative nature and Freije et al. (2022) and Zhu et al. (2018) both call for more investigation into evaluation systems of how supply chain integration supports innovation capability.

2.5.3 Research gap

Reflecting on the findings on innovation capability of supply chains, it can be concluded that there are significant limitations of the exiting literature. For one, the amount of research being done into innovation capability of supply chains is very small. All research that was identified is of qualitative nature.

Innovation capability literature generally focusses only on single organisations. Even though the research community has largely moved towards multi-dimensional approaches to innovation capability to include non-tangible influence factors like culture and behaviour, there is no consensus on what these dimensions are exactly (Saunila, 2019).

Existing research into innovation capability only focusses on niches, like the impact of sharing knowledge with suppliers (Yunus, 2018), impact of digitalisation across a supply chain (Tan et al., 2015) or only on certain types of innovation. Supply chain integration literature mainly focusses on the integration of processes with immediate suppliers and customers from a single company supply chain management perspective.

At this point it makes sense to go back to the very beginning of this thesis. There, the trend was highlighted that companies and whole economies compete more and more on the capabilities of their supply chains (Farahani et al., 2014). Especially from an economy perspective, it is important to consider a full end-to-end supply chain for even policy support. However, existing literature cannot give a precise or holistic answer to what constitutes innovation capability of an end-to-end supply chain. Hence, here is the research gap that needs to be addressed. The research gap is highlighted in, which visualises work being done in the field of innovation capability in single organisations, work being done in supply chain integration, and work being done on end-to-end supply chain as systems.

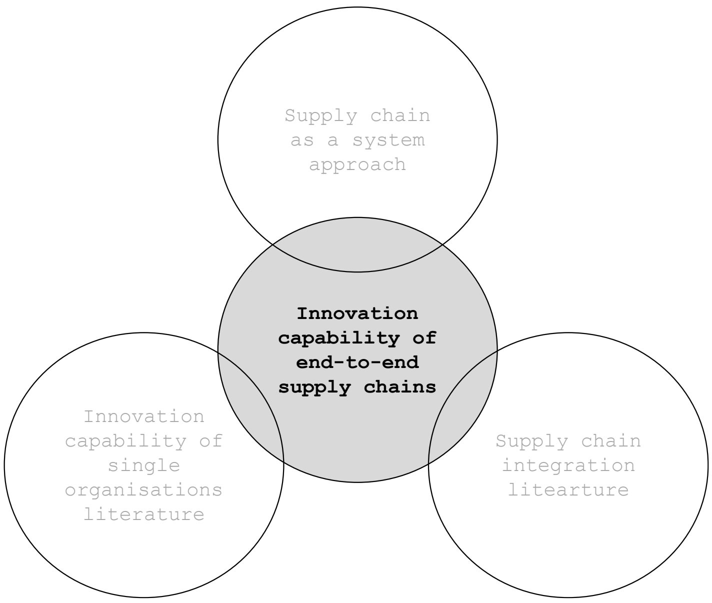


Figure 2-5: Research gap as Ven diagram

2.6 Deriving the research question

Summarising the research gap, available literature does not describe what innovation capability of an end-to-end supply chain is. Either there is a focus only on a single organisation (Saunila, 2019), or there is a focus only on a certain type of innovation (Mendoza-Silva, 2021), or there is only a supply chain focus in terms of the immediate supply chain with direct suppliers and customers (Yunus, 2018, Iddris, 2016). In times when economies and companies compete on the basis of their supply chains capabilities, the focus needs to be broadened up. Companies need to be able to determine the innovation capability of their entire supply chain to support not only direct suppliers and create more resilience along the entire supply chain. In terms of decision making such understanding can be important as well. In case a company wants to invest in new sites, the question of where full supply chains with high innovation capability are available, becomes interesting as such decision making is often in parts based on future resilience of operations (Farahani et al., 2014). Here, being able to determine what innovation capability of an end-to-end supply chain is, becomes interesting for policy makers. If they had the means to determine such innovation capability and improve it in a targeted way, they might make the economy of a country or region more attractive to investments from the inside and from the outside. Hence, there is a real value in knowing a supply chains innovation capability in terms of strategic decision making, attracting investments, and raising resilience which single companies and a whole economy could benefit from.

The question that needs to be asked is what innovation capability of a supply chain is. However, to make this more suitable for strategy makers and policy advisers, and generally to add meaning, a measurement dimension should be added, to be able to determine if innovation capability of a supply chain is in fact good or bad.

As capabilities are usually analysed using maturity levels and as the maturity approach has gained attention within the innovation capability literature for single organisations (Mendoza-Silva, 2021), this approach is taken for the present research as well. Hence, the main research question of this thesis is:

RQ-A1) How can innovation capability maturity of manufacturing supply chains be determined?

After this research question is answered in the next chapter and an appropriate maturity model is created, the framework will be used to analyse the status quo of innovation capability in a supply chain and as guidance for strategy making for its improvement. This serves as a case study for the application of the framework and in this capacity as its field validation. Within this process, the other subsequent practical research questions of this study as mentioned in chapter 1.2, will be answered one by one.

CHAPTER 3

RESEARCH METHODOLOGY

The research methodology explains which way is chosen to answer the objectives of this study (Johnson and Gill, 2010). Therefore, it is important to explain how the research questions are defined, how they are solved, and why a specific research methodology is believed to be more suitable than others (Denzin and Lincoln, 2005). This chapter starts with clarifying the conception of the term 'research methodology' before explaining how a methodology is chosen. This is elaborated by explaining which methods are used to answer which research question and why. The chapter ends with ethical considerations as the nature of this research includes people and social aspects.

3.1 Conception of research methodology used in this research

It is important to clarify the conception of the applied research methodology at the beginning. Within academic business and management literature many research methodology conceptions exist for different purposes (Bell et al., 2022, Johnson and Gill, 2010, Saunders et al., 2016). The aim of this section is to derive a definition which suits the aim of the study. For the present study the term research methodology is used as Swartz et al. (1998) define it:

"The research methodology is the procedural framework within which the research is conducted".

This framework defines reliable research methods to use, and, further, the right procedures to carry out the research (Bell et al., 2022, Johnson and Gill, 2010, Saunders et al., 2016).

3.2 Choosing a research methodology

In business and management literature in general and in innovation literature in particular a wide range of research methodologies is applied. In general, three types of methodologies and respective methods for data collection and analysis can be distinguished. These are a qualitative research methodology, a quantitative methodology, and a mixed method approach combining both. In innovation literature qualitative methodologies are usually used. However, the overall diversity of research methodologies in innovation suggests that there are different reasonable options. Hence, a discussion on choosing an appropriate research methodology is needed.

Textbooks on business research like Saunders et al. (2016), Bell et al. (2022) Johnson and Gill (2010) and peer review articles on research methodology like Bono and McNamara (2011) suggest that the choice of research methodology depends on the nature of the research questions. Further, it depends on how the researcher views and interprets the phenomenon at the heart of the research. Two categories can be differentiated. There is firstly, theory development that aims to uncover the nature and elements of a phenomenon, and secondly, theory testing and validation of constructs that aim to provide prediction or generalisation. Theory development is usually connected to qualitative and theory testing to quantitative research (Saunders et al., 2016). The research questions at the heart of this study are related to uncovering a phenomenon. Therefore, a theory development methodology needs to be adopted. Shepherd and Suddaby (2017) identify two possible approaches. The research can either aim at exploring theories and existing research related to the subject, develop a framework and conduct empirical research, or it can aim at exploring a practical phenomenon and develop a theory based on practical insights. Theory development in the former is a deductive process, in the latter it is an inductive process. There is also the option of combining both approaches to abductive theory development. Whereas all approaches have their justification, the present study is built on a solely inductive theory building approach. It has been selected for the two following reasons.

The main research questions RQ-A1, or how to measure precisely the innovation capability of a supply chain is an unexplored subject. The same is true for the subsequent practical research questions. Hence a bottom-up approach to create theory is needed. The second reason lays in how the researcher constitutes and interprets the phenomenon underpinning the research question. This is usually referred to as research philosophy. To understand how this research is interpreted, it is important to know the philosophical standpoint at the core of it.

In natural science as well as in general quantitative research a positivist standpoint is the norm, where researchers claim to be objective and claim that just a single truth exists (Saunders et al., 2016). The present research, however, is management related and therefore sociology related and at its core of qualitative nature. Hence, positivism as philosophy cannot be applied.

This leaves an interpretivist standpoint and a pragmatist standpoint for further discussion. Both take social factors and personal experience of researched people and the influence of the researcher as a person into account. Pragmatism aims at pragmatically deriving knowledge from circumstances, leading to pragmatic knowledge that is true in and only in this circumstance. Interpretivism aims at deriving knowledge that is holistically true and not only circumstantially (Saunders et al., 2016). An overview over interpretivism and pragmatism divided into the three dimensions of philosophical dimensions ontology referring to the nature of truth, epistemology as what is considered acceptable knowledge, and axiology as the role of values, is shown in Table 3-1.

It is argued, that especially in a sociological setting, different believes, different circumstances, cultures, and the relationship of people in a society are important to understand the truth. It is also argued that the researcher as a human being interacting with others forms part of the same society he or she is investigating. Therefore, all interpretation of research can only be subjective. This in return means that different truths can exists depending on different interpretations of the same research (Glaser and Strauss, 2017).

Table 3-1: Overview interpretivism (adapted from Saunders et al. (2016))

Philosophical dimension	Interpretivism	Pragmatism
Ontology (nature of reality)	Complex, rich, Socially constructed through culture and language Multiple meanings, interpretations, realities flux of processes, experiences, practices	Complex, rich, external 'Reality' is the practical consequences of ideas Flux of processes, experiences an practices
Epistemology (what is acceptable knowledge)	Theories and concepts too simplistic Focus on narratives, stories, perceptions and interpretations New understandings and worldviews as contribution	Practical meaning of knowledge in specific contexts 'True' theories and knowledge are those that enable successful action Focus on problems, practices and relevance Problem solving and informed future practice as contribution
Axiology (role of values)	Value-bound research Researchers are part of what is researched, subjective Researcher interpretations key to contribution Researcher reflexive	Value-driven research Research initiated and sustained by researcher's doubts and beliefs Researcher reflexive

Afterall an interpretivist standpoint is adopted, because of the nature of the main research question RQ-A1 which aims at uncovering a truth which should be valid across all manufacturing supply chains under no specific circumstances. Pragmatism could have been a valid approach if the main aim of the research had been to analyse the innovation capability of only one supply chain at a given moment as the practical research questions do. However, this is only means to validate the framework.

In summary, this research is of qualitative nature and follows an inductive approach under an interpretivist research philosophy setting.

3.3 Research design

The research design is the operationalisation of the research methodology. It ensures that the selected methods effectively address the research questions (Swartz et al., 1998). In the context of qualitative research and an abductive approach the research design supports selecting appropriate qualitative research methods for the present study. This includes data collection methods as well as data analysis and interpretation methods.

Understanding the implications of Covid-19 on innovation is a widely unexplored field due to its sudden occurrence. Furthermore, innovation and supply chain management are highly interdisciplinary topics. Therefore, the research design of this study is based on the principal of 'intellectual arbitrage' (Van de Ven and Johnson, 2006).

Intellectual arbitrage refers to the need to address complex problems from different angles. Van de Ven and Johnson (2006) argue that just a single perspective would lead to a partial, incomplete, inherently biased understanding of a situation. To address this issue, they suggest to co-produce knowledge and engagement with other scholars. Based on this, the term intellectual arbitrage means that the more scholars and practitioners with different perspectives engage in understanding a problem the more holistic the understanding will be and the less likely it will be to miss out important perspectives. Van de Ven and Johnson (2006) describe it as a risk mitigation strategy which leads to an 'optimal' understanding of a problem. The idea of intellectual arbitrage is widely used in business and management studies, even though it is not explicitly stated (Van de Ven and Johnson, 2006).

Intellectual arbitrage reflects the fundamentals of the chosen research philosophy of interpretivism. Interpretivism explicitly acknowledges different perspectives and different understandings of the same problem. Therefore, it is reasonable to adopt the intellectual arbitrage research design idea for the present study. Nevertheless, intellectual arbitrage puts the emphasis on combining insights and perspectives of theory and practise (Van de Ven and Johnson, 2006). In particular, this means to combine scholars' and practitioners' opinions together in a way that the research questions can be answered. Relating to intellectual arbitrage again, the idea is that both groups produce distinct but different and complementary knowledge about the same problem. In business and management literature many scholars suggest combining theory and practice for research (Kelemen and Bansal, 2002, Pfeffer and Fong, 2002, Tranfield and Starkey, 1998). This approach has become more used after criticism arose that business and management research fails to solve practical problems.

3.4 Research methods

To include different perspectives and competencies in a study Hibbert et al. (2014) suggest the two options of engaging otherness and enacting connectedness. Engaging otherness means to actively look for different perspectives and competencies to answer the research questions. Enacting connectedness describes the organisation of a collaborative community which connects the different perspectives and competencies.

These two options are both employed in this study. Multiple research methods are used to gather data from different perspectives and through different competencies. This refers to theory and practice alike. Data collection of each method is designed in a way that all needed data can be collected. Where possible research methods are chosen which enable direct engagement between the researcher and research participants. In detail there are four different methods employed in this study: expert interviews, capability maturity model development, case studies, and future scenario strategizing. The structure and how it relates to the research questions is shown in Figure 3-1.

A capability maturity model is developed to create an assessment system for innovation capability of supply chains to answer academic research question RQ-A1. For validation of the framework is applied as a diagnostics tool and as a strategy tool in a supply chain as a case study. To determine in which supply chain the application would provide the most relevance, i.e., which sector in Scotland is in most need of innovation capability building support, a pre-research step needs to be executed. To answer research question PQ-R1 expert interviews have been chosen to gain a better understanding of how the Covid-19 pandemic has affected innovation in different manufacturing sectors in Scotland and which supply chains are in need of special support. The innovation capability maturity model is then applied to a manufacturing supply chain in Scotland that needs special support to answer research question RQ-P2 as the first part of the case study. In relation to research question RQ-P3 the maturity model is used to provide guidance for further development of innovation capability in said supply chain. For strategic innovation capability development, a future scenario strategizing approach is followed to cover different potential futures representing different macro trends affecting the supply chain. Derived from these strategies, suggestions are derived for policy making to support the development of innovation capability building in this supply chain answering research question RQ-P4.

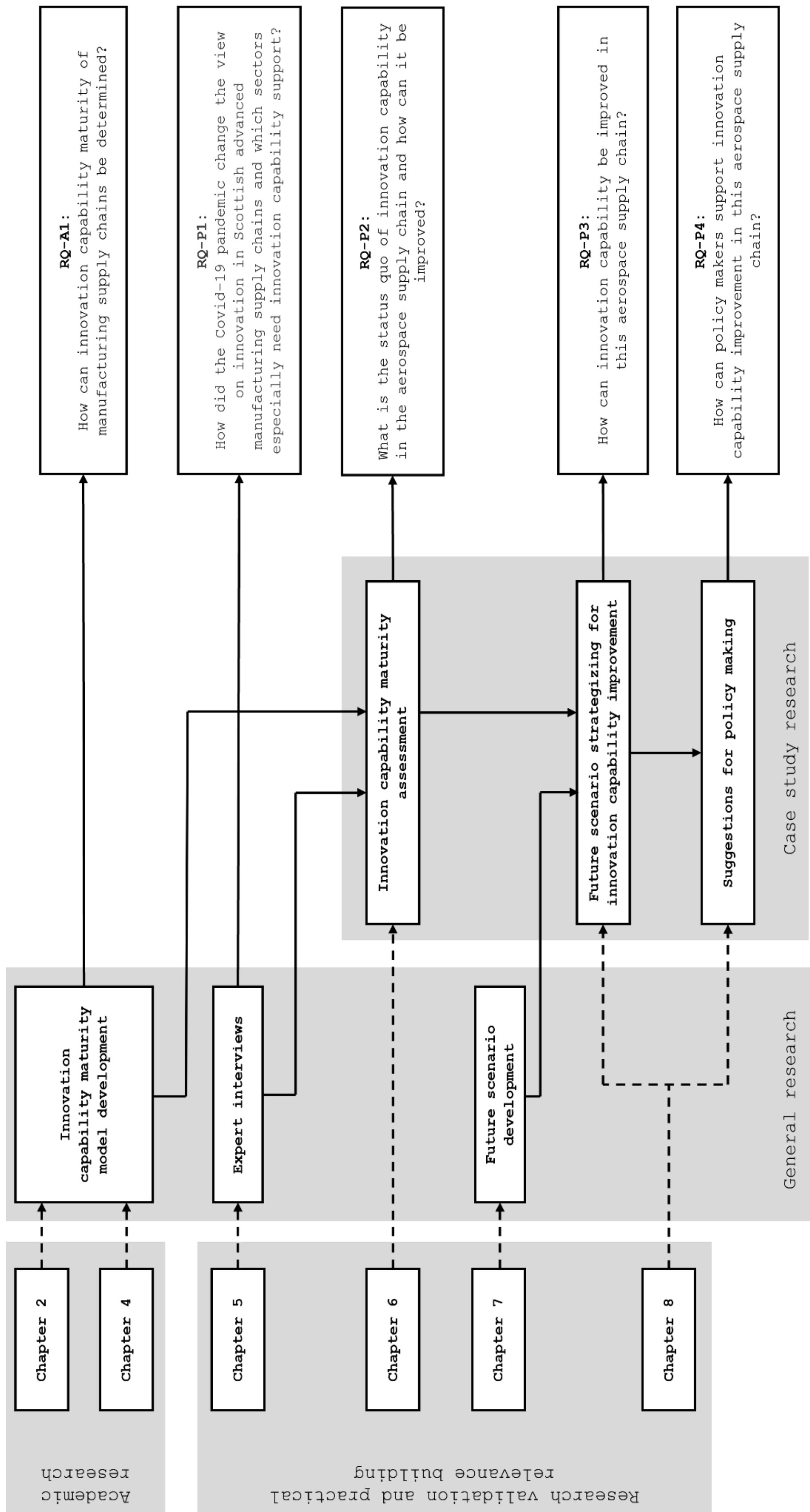


Figure 3-1: Research methods

In the following, a description of all these methods is provided to how they are executed within this research and to why they have been chosen. A summary of the relevant methods applied in each chapter is provided at the beginning of the respective chapters.

3.4.1 Method maturity assessment

Maturity models have become a standard method to describe the development of capabilities in an entity (Wendler, 2012). This entity can be an individual or a systemic organisation like a company or a supply chain (Klimko, 2001). One of the main domains for application has become the area of capabilities. The basic concept is that the higher the maturity of a certain capability the better the performance. Maturity models use discrete simplified levels of maturity describing characteristics of a capability in reference to each maturity stage (Becker et al., 2009). Becker et al. (2009) define maturity models formally as:

> *''A maturity model consists of a sequence of maturity levels for a class of objects. It represents an anticipated, desired, or typical evolution path of these objects shaped as discrete stages''.*

Maturity models offer two advantages which are highly relevant for the present research. Maturity models can be used as an assessment tool for the capability of interest, and they can be used as guidance or reference frame for how to develop the status quo of said capability. Hence, maturity models can give orientation in complex capability development situations (Kohoutek, 1996, McBride, 2010). Consequently, the capability maturity model method enables the researcher to analyse the current state of innovation capability in a supply chain and derive strategies for improvement alike. Other approaches to capability assessment are considered to not measure performance of a capability in a suited way. For innovation capability metrics like spending on research and development or the number of patents were used in the past, this approach, however, provides no indication of how efficient an output was reached. It also assumes that all innovation is patented, which simply does not happen (Boly et al., 2014, Rahman et al., 2015). Hence, such a metrics approach is considered inferior to the capability approach in reference to the versatile nature of innovation and its capability.

For the present research, the methodology for developing maturity models developed by De Bruin et al. (2005) is used. This methodology emerged from different specialised maturity assessment methodologies like for example capability maturity model integration (CMMI). The reason for using De Bruin et al. (2005)'s methodology and no specialised methodology like the CMMI lays in the nature of innovation capability. De Bruin et al. (2005) allow a holistic approach including all factors impacting capability maturity. Specialised methods like the CMMI only allow other capabilities to be included in the creation of a new capability maturity model. Innovation capability in its nature, however, is highly influenced by factors which are not directly capabilities. For example, the availability of funding plays a major role for innovation capability (Saunila, 2019), supply chain structure (Zimmermann et al., 2016) or regulation (D'Este et al., 2012). De Bruin et al. (2005) methodology consists out of six different stages which are shown in Figure 4-1.

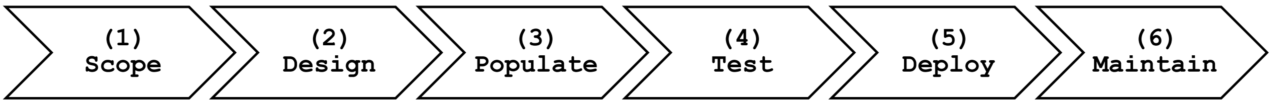


Figure 3-2: Methodology for the development of maturity assessment (De Bruin et al., 2005)

In phase (1) the scope of the assessment has to be defined. The scope in this context refers to the focus of the assessment and the development stakeholders. These decisions influence all later phases. Phase (2) aims at designing the maturity assessment framework respectively define its architecture. In phase (3) the content of the framework is developed. This contains what will be measured and how it will be measured. It is important to note that the framework is solely built on existing literature, no direct behavioural research is carried out. Phase (4) ensures that the framework is tested for validity and reliability. This includes the framework content as well as the assessment system. Phase (5) consist in the application of the maturity assessment. This also includes ensuring the broad availability of the maturity assessment. Phase (6) aims at constant improvement and constant use of the maturity system. Phase (6) is excluded from this research because only 1 supply chain is analysed as a case study and pilot application of the framework. Application in different contexts and further development after the completion of this research is highly encouraged but out of scope of this thesis.

3.4.1.1 Scope

To define the scope, De Bruin et al. (2005) suggest defining the focus of the assessment framework and the development stakeholders. For defining the focus, it has to be decided if the maturity assessment framework should be of general nature or if it is meant to be specific for a certain domain.

3.4.1.2 Design

The design phase aims at defining the architecture of the maturity assessment framework. De Bruin et al. (2005) state that the framework must meet the needs the applicants of the framework have. This means that the framework must reflect the questions who applies the framework and why, how the framework can be applied and who is needed to apply it, and what can be achieved by applying it.

The architecture of the 84framework can be freely determined. However, as it is a modelling approach a suitable model needs to be developed that that represents the topic of interest in a suitable accuracy (De Bruin et al., 2005). To ensure this, a systems approach is used describing a supply chain as a socio-technical system (Behdani, 2012), as described in chapter 1.

To convert the framework architecture into a maturity framework, maturity levels have to be defined. Wendler (2012) points out that many maturity frameworks use a five-level maturity approach, however, it is possible to use as many maturity levels as needed to fulfil the purpose of the framework. Testing ensures that the maturity levels are suitable for this purpose.

3.4.1.3 Populate

During the populate phase the architecture of the maturity assessment framework is populated with content. For the present research this means that different dimensions of innovation capability have to be identified. Since no dominant concepts of innovation capability dimensions could be identified in chapter 2, a deeper analysis of literature has to be conducted in order to holistically identify dimensions of innovation capability. This deeper analysis is carried out as a content analysis. How it is carried out and why it is a suitable method is explained deeper in the following subchapters. The definitions of maturity stages build on existing definitions found in literature for similar dimensions as far as possible. However, some of the identified dimensions of innovation capability are no direct capabilities. These will be included as success factors as De Bruin et al. (2005) suggest. Descriptions of definitions matching the three maturity stages are developed and validated. However, they do not build on exiting maturity models but on the included literature describing which dimensions influence innovation capability and what characteristics they need to show to be supportive or not supportive.

3.4.1.3.1 Approach of content analysis

Even though content analysis was used mostly for quantitative research Holsti (1969), scholars like Krippendorff (2018) argued more recently that it is applicable for qualitative research as well. For a qualitative approach the content of textual data can be categorised rather than counting real quantitative measures (Al-Debei and Avison, 2010). Moldavska and Welo (2017) argue that an abductive procedure can be used for a qualitative content analysis. An abductive procedure uses pre-set concepts like a deductive approach but also adapts these concepts based on collected data and further research results as an inductive approach would suggest (Saunders et al., 2016). In short, pre-set concepts are combined with recurring themes emerging from collected data.

3.4.1.3.2 Process of content analysis

For the present research an abductive approach is followed. As abduction is the combination of deduction and induction, the process of the content analysis is divided into two parts. The first part is the deductive approach. This will be carried out as coding. Deductive coding means to develop a coding frame based on the subject of interest prior to the literature search. Then the literature is analysed based on the pre-set codes. The coding frame includes:

- Innovation capability dimensions
- Innovation barriers

The second step is the inductive approach. Textual data is retrieved from relevant literature and categories within the frame of coding and unit of analysis are developed. To create categories a thematic analysis approach is used. Such an approach usually consists of three steps (Mayring, 2004, Miles and Huberman, 1994):

(1) creating provisional categories and first-order codes based on findings in the selected literature,
(2) integrating first-order codes and creating higher order categories and
(3) delimiting the categories by aggregating their theoretical dimensions.

The low-order codes and categories are just assigned to a higher category only if they satisfy the following conditions:

(1) the categories or subcategories refer to the similar idea or concept,
(2) the contextual settings are complementary and
(3) the categories express a unique compositional aspect of a main category.

Additionally, if a category shows quantitative aspects, as frequency, these are analysed as well.

Special relevance of a content analysis has gathering data (Seuring and Gold, 2012). For this study a systematic approach is followed for comprehensive inclusion of all relevant literature. Tranfield et al. (2003) suggest a three-stage approach consisting of planning, executing, and reporting.

For planning as search engine, the University of Strathclyde library resources is used. University of Strathclyde library resources are chosen because it provides a broad access to freely available journal articles and literature purchased through the University.

The execution stage consists of defining selection criteria and the identification of innovation capability measures. The chosen selection criteria for this study are:

(1) As described earlier, definitions and the use of terms vary significantly in innovation literature, even though they describe similar things. Therefore, a variety of terms need to be included into the search. Used combinations are shown in Table 3-2. Each term of the first column is combined with each term of the second. Articles are just included if any of these combinations appear either in the title, the abstract, or the keywords.

Table 3-2: Selection terms for general content analysis

Term 1: Innovation capability relation	Term 2: Measurement relation
Innovation capability	Measurement
Innovation capacity	Measuring
Innovation performance	Dimensions
Innovativeness	

(2) Exclusively literature in English language is included.

(3) Just literature of the type 'journal article' is included to rely on peer review for quality of information.

3.4.1.3.3 Description of included literature

This section shows a descriptive analysis of the included literature. Starting with the literature resulting from the general search, in total 51 articles could be identified. A first round of screening the titles and abstracts of these articles left 43 suitable articles. Exclusion criterion is the scope of the paper. In a second round of screening all remaining articles are read in full leaving 35 relevant papers. Reasons for exclusion of screening round two vary. Three papers are excluded because they use outdate measures for innovation capability like solely financial or patent measures. Two papers are excluded because they focus on innovation as a process. This perspective however is covered by the absorptive capacity approach later in this chapter and is not part of innovation as input output relation. Two papers do not define appropriate innovation capability dimensions and one paper could not be accessed through University of Strathclyde sources. Figure 3-3 shows the distribution of publications by year of publication. The first paper about innovation capability measurement was published in 2003. The next articles were published six years later initiating a phase of more academic interest in the topic. No specific journal seems to dominate the topic of innovation capability measurement. In fact, with 23 the number of journals is almost as high as the number of publications itself. With three publication 'Measuring Business Excellence' is the journal with most citations.

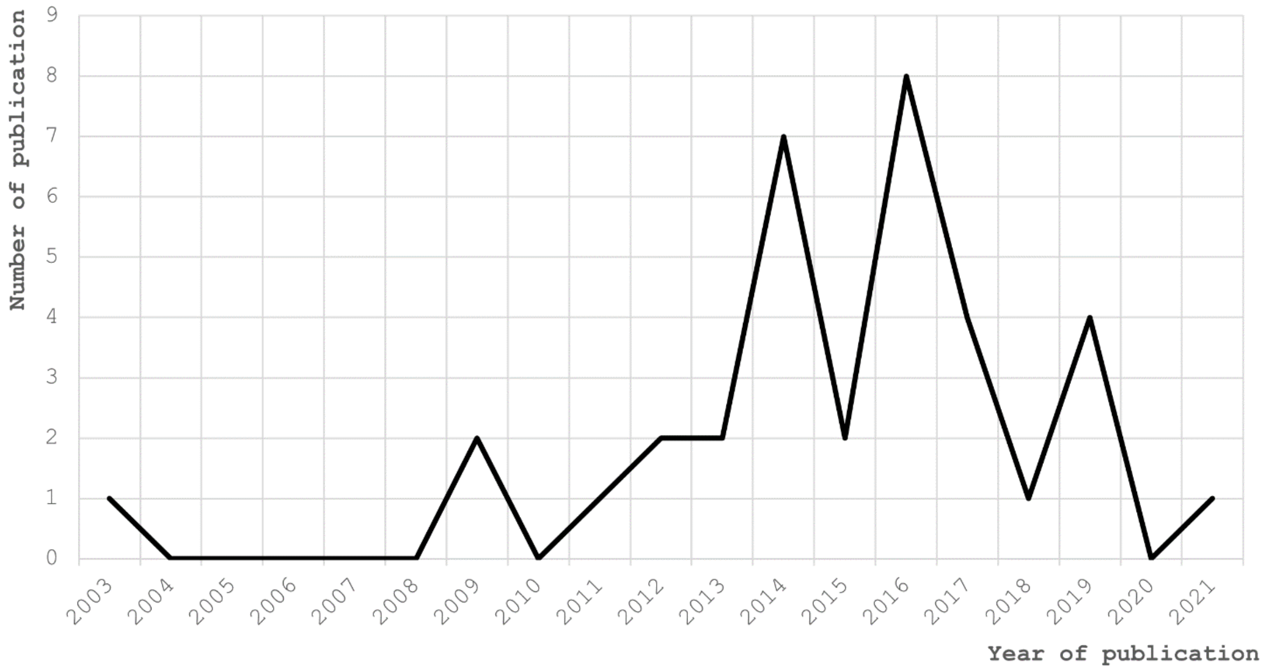


Figure 3-3: Distribution of publications included content analysis by publication year

3.4.1.4 Test

The maturity assessment framework must be tested for relevance and rigor. In order to do so both the framework content and the assessment system have to be tested for validity and reliability. Content validity aims at assessing how completely the subject of interest is covered (De Bruin et al., 2005). This is proven in two steps. Step one refers to the choice of methods used to create the maturity assessment framework. For the present research a systematic structured content analysis is used to ensure that all literature referring to the search terms could be identified and analysed. Therefore, the content respectively the identified innovation capability dimensions are valid. Part two is a focus group interview is conducted with experts as De Bruin et al. (2005) suggest. Apart of further content validation, the frameworks architecture and maturity level descriptions are tested and validated. This is done through voting on validity of the architecture, the identified innovation capability dimensions, and the maturity stage descriptions individually. It has been decided to invite academics as well as practitioners to participate in the focus group interview. This way the idea of intellectual arbitrage (Van de Ven and Johnson, 2006) is applied, and the validity and reliability are tested from different perspectives. In detail five specialists with different backgrounds take part in the focus group interviews. Details can be found in Table 3-3.

Table 3-3: Focus group interviewees

Specialist	Area of expertise	Occupation
Specialist 1	Innovation management	Academic
Specialist 2	Innovation management	Practitioner
Specialist 3	Entrepreneurship	Academic
Specialist 4	Supply Chain Management	Practitioner
Specialist 5	Supply Chain Management	Academic

Testing the reliability of the framework aims at testing if the assessment methodology or the application of the framework results in the desired data and that the framework measures what it is supposed to measure. De Bruin et al. (2005) suggest the use of a pilot case study for field validation of all desired applications of the framework. For this purpose, the framework is applied to a supply chain in chapter 6. How it is applied, and an evaluation of its application using a feedback questionnaire as Wendler (2012) proposes are given in the chapter 3.4.3.

3.4.1.5 Deploy

The deploy phase aims at making the maturity assessment available to organisations in order to carry out assessments and ensure that the framework is used widely and constantly. The assessment is applied in one supply chain as a pilot case study. The application can be found in chapter 6. Further application in other supply chains is needed in the future to establish MaSCICMAF as a standard tool.

3.4.2 Method expert interviews

To answer research question RQ-P1 the method of expert interviews has been selected. Expert interviews are frequently used to investigate general topics of interest in exploratory studies (Saunders et al., 2016, Goffin et al., 2006). Expert interviews offer an informal way of interacting with relevant knowledge holders. Important roles hold both the interviewer and the interviewee. The researcher who acts as interviewer is considered an expert of theoretical knowledge in the field of investigation. The interviewee is considered the holder of practical knowledge. Conclusions are drawn based on both perspectives (Saunders et al., 2016). Expert interviews offer the advantage of directly engaging with the knowledge holder and thereby, extract in-depths information. Saunders et al. (2016) states that expert interviews often result

in detailed descriptions of phenomena. Hence, this method is useful for the present research. The alternative would be surveys which do not allow the option of going into detail and tailoring questions to the interviewee. Whereas the survey method reaches more potential participants, return rates are usually low and were expected to be even lower during the height of the pandemic, as managers are occupied keeping business afloat.
Precisely, two types of expert interviews are applied, in-depth and semi-structured interviews. In-depth interviews aim at exploring an individual's specific perception of a topic of interest. Usually, a small number of in-depth interviews is carried, expecting each interview to have a different focus of interest based on different backgrounds (Saunders et al., 2016). The in-depth interviews aim at exploring the research question in a broad way to select industry sectors for further investigations. For such a broad approach Saunders et al. (2016) recommends this method. Usually, the interview is started with an initial question and developed from there.

The semi-structured interviews are used to analyse sectors of special interest. The semi-structured nature provides the option to leave pre-set questions and enter an open conversation. However, the semi-structuring ensures that key topics are covered (Bell et al., 2022). This way a phenomenon can be investigated in detail depending on the interviewee's standpoint. Thus, data can be maximised, and detailed descriptions can be deducted (Saunders et al., 2016). Consequently, collected data varies from interview to interview depending on the interviewee's background and the context of the interview (Srivastava and Thomson, 2009). However, the semi-structured nature also provides comparability to a certain extent. The freedom of going of script while keeping comparability is an effective method to investigate a qualitative exploratory topic after the first point of contact (Saunders et al., 2016).

Two interview series are carried out. Interview series one takes place between February and April 2021 capturing the Covid-19 impact of the early stages of the pandemic. Interview series two takes place between April and July 2022 capturing the second half of the pandemic and the industry's view of the future beyond the pandemic. Both series are divided into two parts. Part one, aims at identifying the Covid-19 impact on the manufacturing sector in Scotland in general. For this purpose, industry support organisations are interviewed using the in-depth approach. This meta-approach has been considered a suitable way of collecting the desired data, as these organisations have good insights into the sector through the companies they work with while they can put insights of single companies into perspective of the wider manufacturing sector. Part two, aims at analysing innovation behaviour and barriers over time in the aerospace, the food and drink, and the chemistry and pharmacy sector in particular using a semi-structured approach. These three sectors have been chosen as sectors of special interest following the initial investigations with the in-depth interviews. Three sectors are chosen, aerospace, food and drink, and chemistry and pharmacy. Three companies of each of these sectors are interviewed to obtain first-hand insights into their innovation behaviour and their particular challenges as sample companies from the sector in addition to the results from the general interviews in part one. For clarification, Figure 3-4 shows the organisation of the interviews.

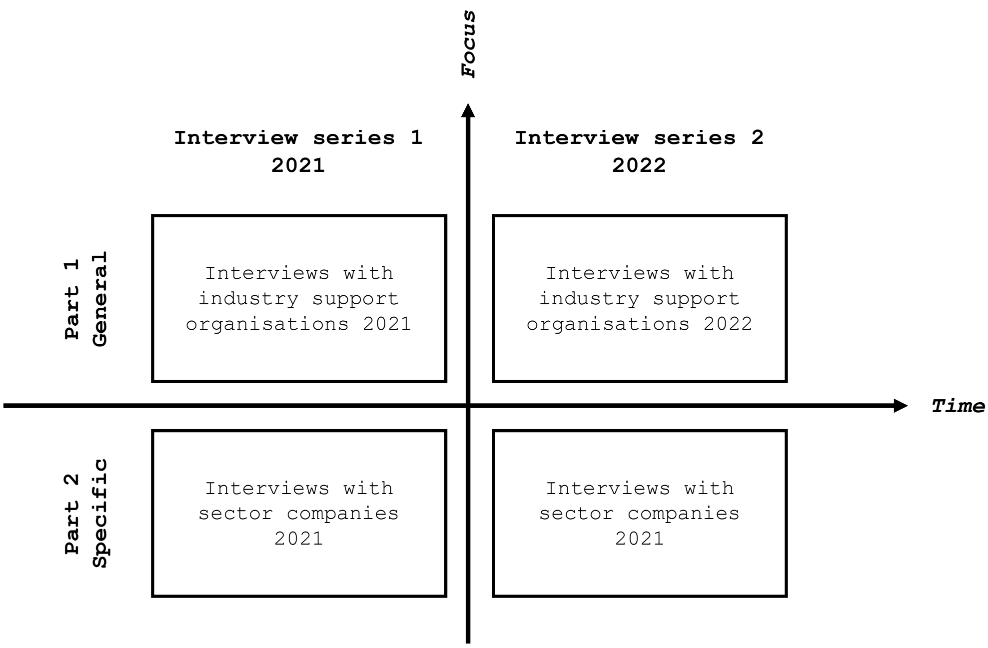


Figure 3-4: Interview organisation divided into time and focus

In the following the processes for the in-depths interviews with industry support representatives and the semi-structured interviews with industry representatives are presented. The processes are similar; however, differences are highlighted where they occur.

3.4.2.1 Process of in-depth expert interviews

The process of in-depth interviews is divided into three different parts. These are the development of an initial question to start the interview, the recruitment of interviewees and the conduction of the interviews and analysing the data. These steps are explained in the following.

3.4.2.1.1 Initial question development

An in-depth interview usually starts with an initial question. Saunders et al. (2016) suggest designing this question as general as possible while being precise enough to enter the specific topic of interest. For the research of this thesis, this question directed at industry support organisations is:

> *How have the companies you support experienced the Covid-19 pandemic, how have they been impacted and how have they reacted?*

3.4.2.1.2 Interviewee recruitment and conduction

To select interviewees a non-probability sampling approach is used. Thus, the researcher can choose the most relevant interviewees based on theoretical pre-set parameters. For the present research these parameters relate to broad knowledge about the manufacturing industry in Scotland and the level of engaging with companies operating in the industry. Further, the suitable interviewee has detailed insights in how the Covid-19 pandemic affected the industry and how different sectors reacted. This includes the innovation behaviour. Suitable experts are identified as senior managers at Scottish industry support organisations being in a strategic position as they hold the general overview over Scottish manufacturing and the relevant connections across the industry that is required. Thus, first-hand information and second-hand information can both be accessed through participants. Potential interviewees are contacted through email. If there is general interest in participating a pre-call is carried out to ensure that the potential interviewee holds the necessary knowledge. In the end two experts from two major Scottish manufacturing industry support organisations agree to be interviewed. The list of participants and their roles are shown in Table 3-4. The nature of exploratory research and qualitative analysis does not require statistically viable sample sizes (Zikmund et al., 2010). It rather requires collecting data until a point of saturation (Saunders et al., 2016). This saturation is reached with two interviewees from industry support side. The interviews are carried out as video chats using Microsoft Teams software between February and April 2021 for the first round of interviews and between April and July 2022 for the second round of interviews. The interviews typically last about one hour. Provided the interviewee's consent the interviews are recorded for transcription and analysis.

Table 3-4: Participants of first interview series

Interviewee No	Organisation Type	Interviewee Role
1	Public industry support (Engineering)	CEO
2	Public industry support (Manufacturing)	CEO

3.4.2.1.3 Data analysis

To analyse the processed data a thematic analysis approach will be used. Braun and Clarke (2006) refer to this as the foundation method for qualitative analysis. It can be used as well in a deductive as an inductive setting. Thematic analysis provides a systematic but flexible approach to analysing qualitative data. The approach can be used for larger as well as smaller data sets. Daly et al. (1997) describe it as the search for themes that emerge as being important to the description of the phenomenon. Fereday and Muir-Cochrane (2006) characterise the process as a form of pattern recognition by reading and rereading the data.

Even though some scholars argue that thematic analysis is too subjective and not useful for deep analysis and framework building (Saunders et al., 2016), Fereday and Muir-Cochrane (2006) argue that thematic analysis demonstrates enough rigor for the systematic description of a phenomenon, as aimed for in this study. However, to ensure the rigor a systematic analysis approach has to be followed. In the present research the method of coding is used as Fereday and Muir-Cochrane (2006) suggest. This method allows the researcher to identify recurrent information (Braun and Clarke, 2006, Charmaz, 2008). Saunders et al. (2016) characterise coding as the categorisation of data with similar meaning. Codes can refer to actions, behaviours, believes, interactions, ideas etc. and can emerge from the data itself or through theory in line with the inductive nature of the overall research.

Coding itself takes place in a four-step process adopted from Williams and Moser (2019) which is shown in Figure 3-5. Their first step is the preparation of data which means preparing transcripts and cleaning them up. Step two and three is the development of codes in two orders.

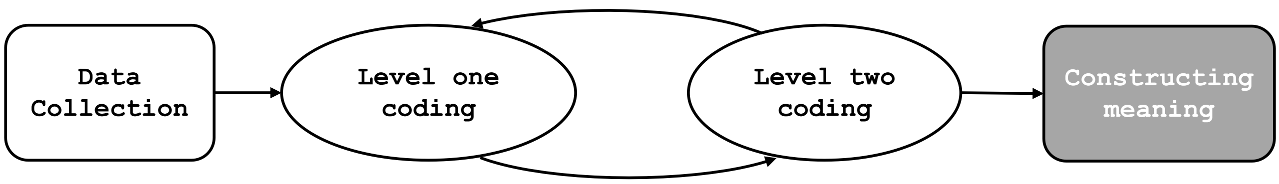


Figure 3-5: Coding process (adapted from Williams and Moser (2019))

Order one coding refers to analysing the row data and labelling it with initial codes. Order two coding refers to labelling codes with codes or grouping order one codes. They are also referred to as themes. The development of codes is a non-linear cyclic process enabling the evolution of codes through constant data comparison. Once a final set of codes is generated, step four aims at deriving meaning from the data and reporting it. This meaning is presented in the findings and discussion section of this chapter. The final set of codes for interview series 1 and 2 is shown in Table 3-5. Findings are presented in chapter 5 using the order 2 codes.

Table 3-5: Coding framework in-depth interviews for interview

Interview series	**Order 1 Codes**	**Order 2 Codes - Themes**
Series 1	Commercial sector impact	Remote working
	Operational sector impact	Manufacturing operations adaptation
	Instant reaction	Differentiating impact of Brexit and Covid-19
	Planned longer term innovation	Skills gap
	Opportunities	Government support
	Challenges	
	Public industry support perception	
Series 2	Commercial sector impact	The Shift to NetZero
	Operational sector impact	Diversification
	Innovation and change	Energy and trade issues
	Future development	Skills gap
	Public industry support perception	

3.4.2.2 Process of semi-structured expert interviews

The conduction of the semi-structured interviews in this research is divided into the three parts: questionnaire development, interviewee recruitment and interview conduction, and data analysis. The different parts are described in detail in the following.

3.4.2.2.1 Questionnaire development

A questionnaire in a semi-structured interview acts as a conversation starter on the one hand and it ensures comparability of different interviews (Saunders et al., 2016). In order with the exploratory nature of the present research, open questions are used. Further, in order to avoid researcher bias no specific technical terminology is used, as Saunders et al. (2016) suggest. There are two questionnaires, one for the first series of interviews and one for the second series of interviews. The questions themselves are based on research question RQ-R1.

Questionnaire one consists out of twelve questions with several possible follow up questions. The topics covered are the structure of the supply chain of interest, the economic situation of the supply chain before and during the Covid-19 pandemic, and the perception of innovation and change. Questionnaire two contains six questions about the development of situations covered by the first questionnaire and interviewees' outlook into the future after the Covid-19 pandemic. The wording of the questions is chosen carefully to not influence answers and avoid the respondent's bias. This is done through a validation with an interview expert. Both questionnaires can be found in the appendix A.C5.1 and A.C5.2.

3.4.2.2.2 Interviewee recruitment and interview conduction

To select interviewees a non-probability sampling approach is used again to choose the most relevant interviewees. The selection criteria for part 2 interviews (see Figure 5-1) relate to having detailed knowledge about either the aerospace, the food and drink, or the chemical and pharmaceutical sector. Selection criteria reflect the questions developed for the questionnaires in appendices A.C5.1 and A.C5.2. This includes knowledge about the economic situation of the company they represent as well as the sector as a whole, knowledge about supply chain structures and operations, and innovation behaviour. Following this, suitable experts are people working either in senior supply chain or operations management positions or innovation management positions in private companies in the respective sectors. Potential interviewees are contacted through email again. In the end experts from nine companies, three for each of the sectors, agree to be interviewed. Interviewees, their roles within their organisations, and their supply chain position are shown in Table 3-6.

Table 3-6: Participants of second interview series

Interviewee No	**Sector**	**Organisation Type**	**Interviewee Role**
3	Aerospace	TIER 1	Operations manager
4	Aerospace	TIER 2	Innovation manager
5	Aerospace	TIER 1	Operations manager
6	Food and Drink	OEM	CEO
7	Food and Drink	OEM	CEO
8	Food and Drink	OEM	CEO
9	Chemistry / Pharmacy	TIER 1	CEO
10	Chemistry / Pharmacy	TIER 1	CEO
11	Chemistry / Pharmacy	TIER 1	CEO

As for the in-depth interviews in exploratory, qualitative study, no statistic validity is required for semi-structured interviews either (Zikmund et al., 2010). The saturation point of information is reached after three interviews per sector. The interviews are again carried out as video chats using Microsoft Teams software between February and April 2021 for the first interview series as well as between April and July 2022 for the second interview series. The interviews also typically last about one hour and provided the interviewee's consent the interviews are recorded for transcription and analysis.

3.4.2.2.3 Data analysis

For data analysis the same approach as for the first interview series is used as well as it is described in 3.4.2.1.3. This approach is followed as the reasons for choosing this approach in 3.4.2.1.3 are valid for the second interview series as well. The type of coding does not depend on the type of interview (Saunders et al., 2016). Further, the aim of the research remains the same, just the unit of analysis is different. The coding framework is presented in Table 3-7.

Table 3-7: Coding framework semi-structured interviews

Interview series	Order 1 Codes	Order 2 Codes - Themes
Series 1	Commercial sector impact	Remote working
	Operational sector impact	Manufacturing operations adaptation
	Instant reaction	Differentiating impact of Brexit and Covid-19
	Planned longer term innovation	Skills gap
	Opportunities	Government support
	Challenges	
	Public industry support perception	
Series 2	Commercial sector impact	The Shift to NetZero
	Operational sector impact	Diversification
	Innovation and change	Energy and trade issues
	Future development	Skills gap
	Public industry support perception	

3.4.3 Method case study

The case study approach is particularly useful when there is a need to obtain an in-depth understanding of an issue, event or phenomenon of interest, in its natural real-life context (Crowe et al., 2011). Especially in business and management contexts case studies are frequently employed (Yin, 2009). Case studies in itself are always just a single case and do not lead to a universal understanding of a phenomenon. Within the boundaries of the case however, they lead to said deep understanding (Yin, 2009). To analyse innovation capability such a deep understanding of a company and a supply chain is required. As case study the before developed innovation capability maturity model is applied to a supply chain which functions as system boundary for the meaning of results. It is applied as an audit tool as well as, as strategy tool. The case study serves as field validation for both applications of the framework to confirm validity and reliability of the framework. Hence, the case study covers the testing step of the development methodology for maturity models. In this capacity the case study approach also aims at answering research questions RQ-P2 as well as RQ-P3 and RQ-P4.

3.4.3.1 Innovation capability measurement as semi-structured focus group interviews (chapter 6)

The innovation capability assessment is conducted as semi-structured focus group interviews. Focus group interviews are interviews were more than one person is interviewed at the same time. Focus group interviews are a common research method in business and organisational studies. They are especially used in contexts where the interviewees' opinion on topics matter. Focus group interviews are a suitable method to identify different interviewees' biases and allow open discussions from different perspectives (Saunders et al., 2016). Focus group interviews are usually conducted with interviewee groups of three to twelve people whereas generally the higher the complexity of the subject the smaller the focus group is kept (Bell et al., 2022). Expert interviews would not be useful as the different interviewees would not have the opportunity to communicate and develop ideas together, which are needed to validate the framework following the principle that the whole is more than the sum of its parts. Surveys are not suitable as no discussion at all could be fostered. Interviewees are usually selected using non-probability sampling and interviewees need to fulfil pre-set criteria. In general, interviewees are chosen who are believed to be information rich (Krueger, 2014). However, to maximise the data, every interviewee must be encouraged to speak. A safe environment must be provided, where personal or professional relations between interviewees do not negatively impact the willingness to share information (Saunders et al., 2016).

The semi-structured nature of the focus group interviews allows the interviewer to go off script and encourage discussions about a topic if it is needed. Thus, is an effective method to maximise data collection in qualitative exploratory topics like innovation capability in an organisation. At the same time the semi-structure ensures that all topics are covered which are meant to be covered (Bell et al., 2022).

The innovation capability diagnostics is conducted as semi-structured focus group interviews. Focus group interviews have been chosen to reflect different perceptions of different participants of the same situation and help minimize bias (Saunders et al., 2016). These interviews are semi-structured to allow a conversation to happen (Bell et al., 2022). The interview is led by an innovation capability expert who asks participants to choose from a set of statements which they believe apply to them. The statements are meant to provoke a discussion between the interviewer and the interviewees about each innovation capability dimension to understand the situation in either the company or the supply chain. After this discussion a maturity level of the framework is chosen. The set of statements is called questionnaire in this research. The questionnaires for the supply chain and the company scoring model can be found in the appendices A.C6.1 and A.C6.2. The statements are derived from the maturity stages for each innovation capability dimension of the framework.

These focus group interviews are embedded in a set of activities which are comprised to what is called a 'innovation capability audit workshop' in this research. This approach has been chosen, to prepare participants for the topic of innovation capability and the assessment itself. The interactive approach helps active thinking about the workshop topic and stimulates thinking outside of daily routines as Plattner et al. (2009) recommend for innovation related exercises. After a short introduction of the workshop and its agenda, an exercise is conducted, where the interviewees brainstorm what they consider important for innovation capability. The results are compared to MaSCICMAF to set the scene of the following innovation capability assessment as mentioned focus group interview. In the end, participants are asked which innovation capabilities and short comings of those they consider most relevant for improvement. The workshop finishes with an outlook of strategizing to develop innovation capability in another workshop. These workshops are explained in chapter 8. After the workshops participants are asked to provide feedback on the workshops. The agenda of the innovation capability audit workshop can be summarised as follows:

1. Workshop introduction and audit aims
2. Exercise: What is innovation capability for you?

3. MaSCICMAF: What is innovation capability in academic literature
4. Innovation capability audit: Focus group interviews
5. Exercise: Which innovation capability dimensions are most relevant for you?
6. Next steps: The strategizing workshop

Innovation capability audit Workshop Type 1 aims at analysing the innovation capability at company level. A non-probability sampling approach is pursued, ending in the identification of two companies which operate in the same aerospace supply chain in Scotland. They vary in size and position in the supply chain. Company 1 is a large international TIER 1 supplier. Company 2 is a SME operating in a TIER 2 position supplying company 1. For each company a separate workshop is carried out to ensure that the interviewees share the necessary information with the researcher and that there are no concerns about sharing company interna with another company. For the workshops the companies send three to four interviewees. Following a non-probability sampling approach again, these are senior managers with supply chain, research and development, operations, or general management backgrounds as these can provide the necessary information needed for the innovation capability assessment. Details about the participants from both companies can be found in Table 6-2.

Table 3-8 Pilot study participants on company level

Company	Size	Tier stage	Participant occupation
Company 1	Large multinational	TIER 1	Operations manager
			Operations manager
			Research and development manager
			Supply chain manager
Company 2	National SME	TIER 2	Managing director
			Research and development manager
			Research and development manager

For the supply chain scoring model of MaSCICMAF a single workshop is carried out. The sampling is non probabilistic here as well. A total of nine experts participates. These experts represent two different public industry support organisations, one private industry support organisation, and three different companies operating in or with the same supply chain as the companies analysed on the company level. The variety of backgrounds ensures maximisation of data from all relevant perspectives. More details about the background of these experts can be found in Table 6-2.

Table 3-9 Pilot study participants on supply chain level

Participant	Role	Organisation type
Participant 1	Aerospace supply chain specialist	Public industry support organisation 1
Participant 2	Manufacturing supply chain specialist	Public industry support organisation 1
Participant 3	Aerospace supply chain specialist	Public industry support organisation 2
Participant 4	Aerospace supply chain specialist	Public industry support organisation 2
Participant 5	Aerospace industry engagement officer	Public industry support organisation 2
Participant 6	Aerospace supply chain lead	Private industry support organisation
Participant 7	CEO	Private company 1
Participant 8	CEO	Private company 2
Participant 9	Managing director	Private company 3

All workshops are carried out as virtual workshops using Microsoft teams as communication tool and Miro as virtual note board. The decision for virtual workshops is based on the number of different interviewees' locations, time and cost implications. All workshops take place between December 2021 and March 2022 and last between two and three hours.

For field validation, observation as research method is used. In detail the participant as observer method is used. This is a suitable method for validation as the researcher can observe first-hand how the application of MaSCICMAF is conducted (Saunders et al., 2016). The workshop host is the observer in this case, meaning it is a participant as observer situation. The participant observer as research method alone has been criticised to lead to data limited in its validity and reliability. The participant observer might misinterpret situations because of personal experience or lack of experience in the situation that is observed (Saunders et al., 2016). To moderate these issues, secondary observation data is collected from other participants of the workshops as well. They reflect on their observation through a feedback questionnaire which can be found in the appendix A.C6.9. All different perspectives give a concise picture of the success of the application of MaSCICMAF in terms of the principal of 'intellectual arbitrage' (Van de Ven and Johnson, 2006). The participant observer also might influence the other participants in a way that the data becomes invalid (Spano, 2005). To avoid this issue, Saunders et al. (2016) suggest that the observer stays in the background as much as possible and just interferes with the other participants where needed.

3.4.3.2 Method future scenario strategizing – scenario development (chapter 7)

To validate the framework as a strategy tool a future scenario approach is taken. Future scenario strategizing is a methodology which is frequently used in business contexts to explore different alternative futures and how the business can react to these scenarios (Hiltunen, 2009, Schoemaker, 1991, Fontela and Hingel, 1993). This methodology creates scenarios which reflect all plausible futures and therefore, it helps future strategizing in a holistic way (Jetter, 2003). Kahn and Wiener (1967) define future scenarios as:

> *"a set of hypothetical events set in the future constructed to clarify a possible chain of causal events as well as their decision points".*

Innovation capability development as dynamic capability development affects many aspects of a business and a supply chain on the supply chain level. Such changes are not realised within a short period of time (Danneels, 2011). As the time scale is larger, external developments over time to a supply chain and its businesses become important. Mega trends might impact which aspects of innovation capability are more relevant to develop than others which changes over time. Thus, short-term static capability development methods are not useful for this study. Future scenario strategizing in contrast offers the necessary flexibility in strategy to react to these potential changes in megatrends over time. However, the future scenario strategizing approach has not been applied to innovation capability building yet in an academic setting.

Scenario strategizing enhances sense making, it moderates cognitive bias, and it especially supports informed decision making (Amer et al., 2013, Varum and Melo, 2010, Schoemaker, 1995). Wack (1985) states that scenario planning improves an organisation's capability to cope with uncertainty and is therefore the basis of all strategy planning. Schoemaker (1991) adds that future scenarios support challenging the status quo of businesses.

Future scenarios are a set of possible and plausible futures as reflecting an organisation's changing environment as a result of different trends and their combinations (Amer et al., 2013, Schoemaker, 1995, Fontela and Hingel, 1993). Scenarios aim at capturing all plausible future developments. The range of possible outcomes is a reflection of uncertainty of the future (Pillkahn, 2008). Reflecting all plausible futures, helps future strategizing in a holistic way (Jetter, 2003). Godet (2000) and Schnaars (1987) highlight that future scenarios are not a precise prediction of the future. It is a methodology that helps broaden thinking about the plausibility of different future developments. Future scenarios are also not the same as forecasting which aims to identify the most likely future. Forecasting is just useful for predictions for the near future where little uncertainty is prevalent. Forecasting usually requires high levels of details which scenarios cannot reach as the uncertainty is considerably higher on longer time scales (Schoemaker, 1991). Martelli (2001) states that future scenarios provide the most benefit when applied to a longer-term time scale. Average time scales are between ten and twenty-five years, however in theory they can be applied to any time scale.

Schoemaker (1991) states that scenarios reflect general political, social, economic, and technological developments. These macro scenarios can be tailored to the special requirements an industry might have, as some political changes might have different implications for different industries. The implications for the industry influence suppliers, customers, and competitors in that industry. This has implications for a single firm and influences decision making.

Future scenarios are built on the assumption that the future might not be similar to the present and that an organisation's environment might fundamentally change prompting strategic renewal. Schoemaker (1991) points out that a scenario is a representation in considerable detail of a possible future built on causal connections, internal consistency, and plausibility. Scenarios describe the development over time of different futures and not solely the end state. Normal time scales for scenarios are ten years or more. As innovation capability building might cause fundamental changes in business culture the planning horizon needs to be of a large scale and therefore scenario planning is a useful methodology in itself in the proposed strategy building methodology. Schoemaker (1991) highlights that Scenarios are used on different organisational levels, including a world level, a country level, an industry level, and an organisation level. Thus, this approach is applicable to the supply chain scoring model and the company scoring model of MaSCICMAF.

The methodology consists of two parts. Future scenarios need to be developed before the strategizing process itself can be conducted to answer research questions RQ-P3 and RQ-P4.

There are different methodologies for creating future scenarios in literature. Some methodologies are quantitative, some are qualitative. As this research is overall located in the qualitative realm, a qualitative methodology has been selected. Precisely the ‘Intuitive logics’ approach has been chosen. The intuitive logics approach is the most used approach in scenario development (Wright et al., 2013). The approach can be used to create internally consistent yet flexible scenarios with relatively little resources. However, the approach relies heavily on the knowledge, commitment, credibility, and communication skills of the team members creating the scenarios (Huss and Honton, 1987). The other two main qualitative approaches to scenario development, the ‘Probabilistic modified trends’ approach and the ‘La prospective’ or French approach, are not further considered, as they require either the use of quantitative tools or data (Wright et al., 2013).

For this research the intuitive logics methodology proposed by Wright et al. (2013) is used to create a set of four scenarios. A set of four scenarios is considered the best cost vs accuracy of scenarios ratio (Pillkahn, 2008). Wright et al. (2013)’s methodology consists of seven steps which can be found in Figure 7-2.

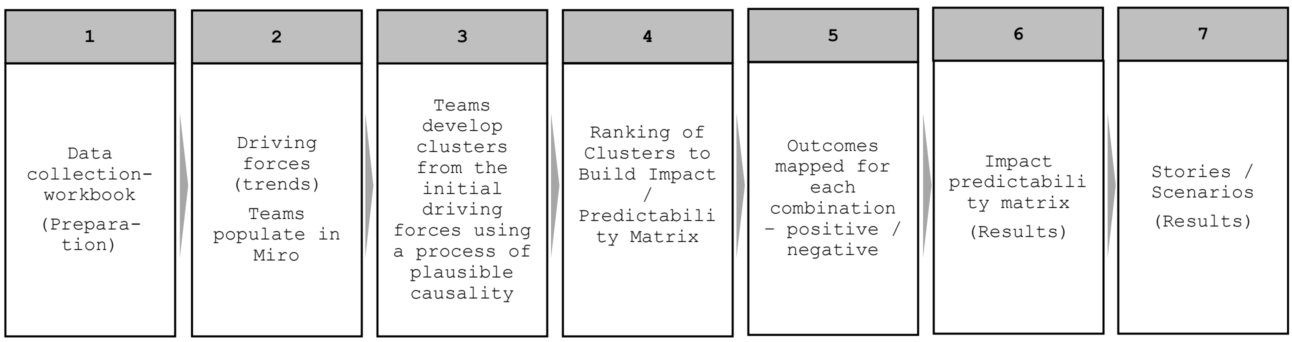


Figure 3-6: Scenario development methodology proposed by Wright et al. (2013)

Whereas the steps two to six are carried out by an expert team in workshops. As the scenarios aim at describing the future of manufacturing in Scotland for use in an innovation capability context, experts represent the fields of supply chains management, innovation, strategy, as well as one scenario development specialist who leads the development of the scenarios. All participants are based in Scotland and work directly in manufacturing or have a strong connection to manufacturing. Table 7-1 shows the experts’ backgrounds and professional roles in detail.

Table 3-10: Expert panel for developing scenarios for the future of Scottish manufacturing

Expert	Area of expertise	Role
1	Innovation and operations management	Academic
2	Innovation and operations management	Practitioner
3	Innovation ecosystems	Academic
4	Corporate strategy	Academic
5	Corporate strategy	Academic
6	Supply chain management	Practitioner
7	Supply chain management	Practitioner
8	Scenario development	Academic

The first step in preparation of the workshops is the creation of a workbook. The workbook is a collection of literature sources describing different possible national and international factors affecting Scottish manufacturing. These resources cover developments in technology, economy, politics, society and can be academic and non-academic. The workbook functions as a basis of knowledge for the development of the scenarios.

Step two is the first step which is completed by the expert panel during a workshop. From the factors described in the workbook, the experts select the trends which they consider most important. Step three aims at clustering these trends to driving forces. Within a driving force plausible causality connections are drawn between trends. Thus, cause effect chains can be established, reinforcing the credibility and reliability of the scenarios. Step four consists in the ranking of these driving forces for their impact on Scottish manufacturing and for the predictability of the real impact that the driving forces might have.

Step five aims at identifying the two critical driving forces with the highest impact and highest uncertainty of future development. Step six is the creation of the impact predictability matrix, which sees the two critical driving forces opening up a two-dimensional qualitative grid. The axes cover positive and negative developments of the respective driving force. The result is a grid with one quadrant showing a positive development for both main driving forces, two quadrants with a positive development for one of the main driving forces and a negative for the other, as well as a negative development for both critical driving forces. For each quadrant all driving forces are described in relation to the quality of the two critical driving forces. Step seven sees the translation of the short descriptions of the quadrants into narratives. Part of step seven is the validation of plausibility and internal consistency of all narratives. This is validated by each expert individually.

Due to the Covid-19 pandemic the workshops are executed online using Microsoft teams for communication and Miro as a virtual note board. In total, three workshop sessions, each 2 hours long, are carried out in June 2021. The researcher acts as participant while an external expert facilitator leads the scenario development process.

3.4.3.3 Method future scenario strategizing - strategy development (chapter 8)

Scenario strategizing aims at creating strategies for scenarios. In detail, each created strategy should be an organisation's internal reaction to the external impact that the developments stated in each scenario have on the organisation. Scenario strategizing is the extension to the future scenario approach discussed in chapter 7.
For scenario strategizing, the approach by Wright et al. (2013) is followed. This is the extension of the scenario development process used in chapter 7. This approach suggests creating strategic actions for each scenario for each driving force development. As the present research aims at developing innovation capability strategically, based on the results of the innovation capability audit in chapter 6.

Strategizing is conducted as a strategizing workshop. As for the innovation capability assessment, one workshop is conducted for each company for the company scoring model of MaS-CICMAF and one workshop is conducted for the supply chain level.

The strategizing exercise just like the audit exercise is embedded in other activities. Before the workshop, participants are asked to familiarise themselves with the in chapter 7 developed future scenarios in preparation for the strategizing workshop. The workshop starts with an introduction to scenario strategizing. After participants are reminded of the results of the innovation capability audit, the scenarios are presented. Participants can comment and suggest changes. This serves as further field validation of the scenarios. During the actual strategizing process.
This is the formal agenda of the strategizing workshop:

1. Workshop introduction and strategizing aims
2. Recap innovation capability audit results
3. Presentation and discussion of future scenarios for manufacturing in Scotland

4. Selection of innovation capability dimensions of interest for development
5. Develop strategic actions for each scenario
6. What support is needed from policy side?
7. Wrap up

After the workshop participants are asked to provide feedback on how useful they find the workshop, the scenario strategizing method in the applied way, and where they think improvements could be made. This feedback is a structured questionnaire. It serves as base of the pilot case study for validation of the scenario strategizing methodology.

The participants of each workshop are the same as for the workshops conducted for the innovation capability assessment. An overview of participants of both companies for the company scoring model can be found in Table 8-1.

Table 3-11: Workshop participants for strategizing for the company level

Company	**Size**	**Tier stage**	**Participant occupation**
Company 1	Large multinational	TIER 1	Operations manager
			Operations manager
			Research and development manager
			Supply chain manager
Company 2	National SME	TIER 2	Managing director
			Research and development manager
			Research and development manager

Participants of the supply chain group for the supply chain level, covering different public and private industry support organisations for the aerospace sector in Scotland and a total of three companies operating this supply chain, can be found in Table 8-2.
Once strategies are developed for the different companies and the supply chain for improving innovation capability, recommendations for policy makers in Scotland are developed. They are derived from the strategic actions as well as from the outcome of the status quo of the innovation capability assessment in chapter 6 and the results of the interviews conducted in aerospace sector in chapter 5.

Table 3-12: Workshop participants for strategizing for the supply chain level

Participant	Role	Organisation type
Participant 1	Aerospace supply chain specialist	Public industry support organisation 1
Participant 2	Manufacturing supply chain specialist	Public industry support organisation 1
Participant 3	Aerospace supply chain specialist	Public industry support organisation 2
Participant 4	Aerospace supply chain specialist	Public industry support organisation 2
Participant 5	Aerospace industry engagement officer	Public industry support organisation 2
Participant 6	Aerospace supply chain lead	Private industry support organisation
Participant 7	CEO	Private company 1
Participant 8	CEO	Private company 2
Participant 9	Managing director	Private company 3

As analysis method inductive thematic coding is used. Categories within the frame of coding and unit of analysis are developed. To create categories a thematic analysis approach is used following (Mayring, 2004, Miles and Huberman, 1994), The codes used are:

- Open innovation
- Supply chain resilience
- Funding
- Skills shortage and education

For field validation of the scenario strategizing methodology for innovation capability development, observation as research method (Saunders et al., 2016) is used again in the same way it is used in chapter 6. To ensure reliability and validity of the collected data, the intellectual arbitrage approach is followed again (Van de Ven and Johnson, 2006). The participant as observer method leads to primary data and the qualitative feedback from other participants leads to secondary data.

The workshops take place between March 2021 and May 2021. They are conducted online using Microsoft Teams and Miro digital note boards and take about three hours in total.

3.5 Ethical considerations

To ensure the credibility and integrity of this research and of the participating researchers, this study will be based on the following ethical principles as suggested by Saunders et al. (2016). The integrity of the researcher will always be maintained. This includes always being truthful, trustworthy and open while avoiding misrepresentation of data or findings. It is guaranteed that no conflicting interests arise during the conduction of this study.

This also means that participants are provided extensive information about the research, its goals, and methodology. Thus, an informed consent between researcher and participant is established. Participation in this research is entirely voluntary and the extend of participation can be changed at all times. No participant is at risk of physical or psychological harm at any time through the participation in this study and every participant is treated with respect.

Data is not collected beyond the scope of this research and not beyond individual participant's agreement. All collected data is handled confidentially to ensure the privacy of all participants. This includes that all data is anonymised and exclusively stored on university servers. After anonymisation it is not possible anymore to withdraw participation because the respective dataset cannot be identified anymore and therefore it cannot be deleted anymore. Just involved researchers have access to raw data. Findings are reported accurately even if they show contradicting results.

All research conducted for this thesis including explicitly the methodology, has been approved and supported by the University of Strathclyde Ethics Committee. All participants have been provided extensive information about the research, data collection, data analysis, and access to data in participation sheets. Every participant agrees to the conditions of participation by signing consent forms. Participation information sheets for the different research methods can be found in the appendix A.C3.1 and A.C3.2.

3.6 Summary

As this research aims at answering different questions of very different nature, at the end of this chapter a summary is provided over how it is sought to develop answers to these questions. Table 3-13 acts as such overview and summary of the main points of each applied method.

Table 3-13: Full overview over all applied research methods

	Capability maturity development	Expert interviews	
Method	Capability maturity development following (De Bruin et al., 2005)	In-depth interviews	Semi-structured interviews
Participants	Framework development: n/a Academic validation: 8	2	9
Selection criteria	Framework development: n/a Academic validation: experts in	Senior manager in strategic position with understanding of manufacturing sector working for industry support organisations	Senior managers with understanding of internal operation and strategies working for an aerospace, food and drink, or chemistry and pharmacy sector company
Time of data collection	Framework development: June to December 2020 Academic validation: June 2021	Series 1: February to July 2021 Series 2: April to July 2022	Series 1: February to July 2021 Series 2: April to July 2022
Length	Framework development: n/a Academic validation: 2 hours	45-60 min	45-60 min
Mode of data collection	Structured content analysis	Online using Microsoft Teams and transcription	Online using Microsoft Teams and transcription
Data analysis	Thematic coding	Thematic coding	Thematic coding
Role of researcher	Executing researcher/ facilitator	Executing researcher/ facilitator	Executing researcher/ facilitator

	Case study part 1: Focus groups 1	Future scenario development	Case study part 2: Strategizing workshops
Method	Focus group interviews with application of framework as	Scenario strategizing 1 (scenario development)	Scenario strategizing 2 (strategizing with developed scenarios)
Participants	Company 1: 4 Company 2: 3 Supply chain group: 9	8	Same as for focus groups 1
Selection criteria	One fully in Scotland located aerospace supply chain on a company level with TIER 1 and TIER2 company are interviewed, OEM and Raw material supplier rejected participation, and on a supply chain level with 9 participants		
Time of data collection	December 2021 to March 2022	June 2021	
Length	3-4 hours per focus group	3 workshops of 2 hours	3 hours per workshop
Mode of data collection	Online using Microsoft Teams and Miro boards	Online using Microsoft Teams and Miro boards	Online using Microsoft Teams and Miro boards
Data analysis			
Role of researcher		Participant, external facilitator and specialist in future scenarios hosted the process	

Further, certain clarifications need to be made in order to ensure overall validity of this research. The first remark is that for qualitative research, like the present one, Saunders et al. (2016) state explicitly that research does not have to fulfil statistical viability like within quantitative research. Merely, research in qualitative setting is considered valid and reliable based on the appropriateness of the research methods and how they are applied.

The chosen maturity framework development methodology by De Bruin et al. (2005) has been applied in many instances hence the methodology is valid and reliable. In detail, to ensure that the framework content and architecture are based on all available research, a structured content analysis with suitable search terms was carried out, which Saunders et al. (2016) deem as an approach to generate reliable output. The academic validation of the framework is carried out as suggested within De Bruin et al. (2005) methodology directly.

As in other contexts this form of validation has been considered reliable, in the present context this is considered as reliable as well. The field validation of the framework is carried out as a case study, again following De Bruin et al. (2005) methodology directly, creating reliability of the research output as a consequence. De Bruin et al. (2005) a successful application including adaptation of the maturity framework means formal validation in the field. However, they also state, that even though this is a formal validation, technically the results of the case study are only true for the case study setting. To increase the reliability the framework needs to be applied in different contexts or case studies over time.

As for the interviews, as there is only a limited number of interviews conducted, the selection of suitable participants significantly contributes to the validity and reliability of the research. The selection criteria here ensure that participants have significant insights into the manufacturing respectively one of the subsectors and into the internal strategy of the organisations they represent. Specially the industry support organisations have a pivotal role as they as an organisation need to know what is going on these sectors. As the number of participants is small, avoiding respondent's bias is important. Therefore, questionnaires and precise wording of questions are developed with an expert.

A few final remarks need to be made. Firstly, the researcher is facilitator of all research methods except the development of scenarios. Here an external facilitator was asked to conduct the research as more expertise was needed. The researcher acted as participant of the development of the scenarios.

Secondly, there is a certain crossover of participants of the different research methods. It is important to state that two of the people interviewed in chapter 5 also acted as participants for the focus groups and the strategy workshops. As the research objective of research question RQ-P1 in chapter 5 and the research questions RQ-P2 and RQ-P3 are not directly related, the overlap has no influence on validity of this research. The overlap is shown as a Ven diagram in Figure 3-7.

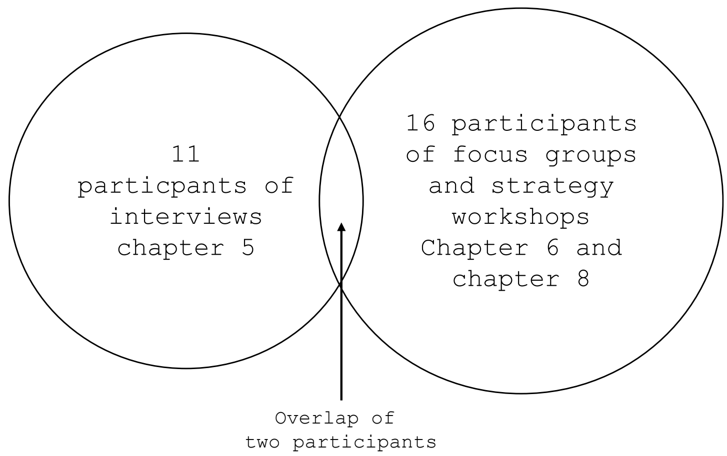


Figure 3-7: Overlap of participants of the different research methods

Research conducted within the case study, precisely chapter 6 the audit of the current status of innovation capability and the strategizing for future improvements in chapter 8 is carried out with the same group of people. This is because one builds on the other and both have different objectives. Hence, the hundred percent overlap have no influence on validity of the research.

And now it is finally time to look at the development of the maturity framework for innovation capability of supply chains in the following chapter…

Chapter 4

Developing an Innovation Capability Maturity Assessment Framework

After establishing the need for creating a maturity framework for innovation capability of supply chains in the last chapter, this chapter focusses on the systematic development of such a framework. Hence, formally, this chapter aims at answering the research question

RQ-A1: How can innovation capability maturity of manufacturing supply chains be determined?

To answer this question the manufacturing supply chain innovation capability maturity framework (MaSCICMAF) is developed. MaSCICMAF as maturity framework is based on the idea that the higher the capability maturity level the better the performance of the application of the capability (Crosby, 1996, McBride, 2010). Maturity frameworks are frequently used in qualitative study as analysis tool, they are also frequently used as management tool to plan developments of organisations. Hence, this chapter and MaSCICMAF build the foundation to analyse and plan strategies for improvement of innovation capabilities of supply chains in the following chapters. For MaSCICMAF, innovation capability is considered a dynamic capability under the resource-based view. This means that solely intangible aspects are considered, availability of materialistic resources is not considered. Funding and financial resources are not considered materialistic. The ability of accessing funding, however, is an important intangible aspect and is covered.

MaSCICMAF itself is aims at analysing innovation capability maturity of supply chains. Supply chains are considered socio-technical systems in this context following Behdani (2012), as described in chapter 2. Hence, MaSCICMAF is built on the idea of the combination of internal innovation capability of organisations operating in a supply chain and the innovation capability of the collaboration of these organisations along the supply chain as innovation system. MaSCICMAF further is built on a multidimensional approach to cover all relevant aspects of innovation capability. MaSCICMAF is a solely literature-based framework, that seeks practitioner relevance through validation and testing with practitioners.

This chapter is organised in the way that in the beginning the approach of maturity frameworks and maturity assessments is revisited as review of the methodology in chapter 3. Then results of the applied, methods, MaSCICMAF itself, is presented in section 4.2 and serves as the formal answer to research question RQ-A1. The chapter ends with a conclusion and critical assessment of MaSCICMAF. It is important to note that the framework evolved during the research and the different validation stages. Only the final result is presented in this chapter.

It is important to state that this chapter only presents MaSCICMAF in its final version after several rounds of reviewing and that it has been published in parts in the following conference publication:

Reckordt, T. (2021). Innovation Capability Measurement in Manufacturing Supply Chains-A Research Agenda. In *ISPIM Conference Proceedings* (pp. 1-12). The International Society for Professional Innovation Management (ISPIM).

4.1 Review of maturity assessment methodology

For the present research, the methodology for developing maturity models developed by De Bruin et al. (2005) is used. This methodology emerged from different specialised maturity assessment methodologies like for example capability maturity model integration (CMMI). The reason for using De Bruin et al. (2005)'s methodology and no specialised methodology like the CMMI lays in the nature of innovation capability. De Bruin et al. (2005) allow a holistic approach including all factors impacting capability maturity. Specialised methods like the CMMI only allow other capabilities to be included in the creation of a new capability maturity model. Innovation capability in its nature, however, is highly influenced by factors which are not directly capabilities. For example, the availability of funding plays a major role for innovation capability (Saunila, 2019), supply chain structure (Zimmermann et al., 2016) or regulation (D'Este et al., 2012). De Bruin et al. (2005) methodology consists out of six different stages which are shown in Figure 4-1.

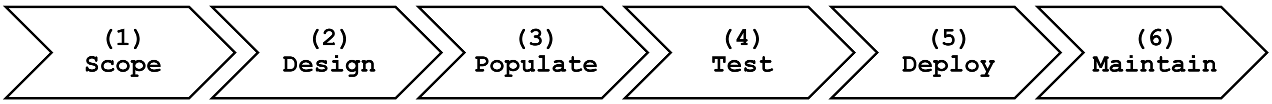


Figure 4-1: Methodology for the development of maturity assessment (De Bruin et al., 2005)p3

In phase (1) the scope of the assessment has to be defined. The scope in this context refers to the focus of the assessment and the development stakeholders. These decisions influence all later phases. Phase (2) aims at designing the maturity assessment framework respectively define its architecture. In phase (3) the content of the framework is developed. This contains what will be measured and how it will be measured. As basis for stage 2 and 3, a structured content analysis is used. Search terms are provided in Table 4-1.

Table 4-1: Selection terms for content analysis

Term 1: Innovation capability relation	**Term 2: Measurement relation**
Innovation capability	Measurement
Innovation capacity	Measuring
Innovation performance	Dimensions
Innovativeness	

As data base the University of Strathclyde library database is used. Analysis takes place using an abductive coding approach with the following pre-set codes:

- Innovation capability dimensions
- Innovation barriers

Phase (4) ensures that the framework is tested for validity and reliability. This includes the framework content as well as the assessment system. This is done in two ways. First, an expert panel examines the framework, then as field validation the framework is applied as audit tool and as strategy tool as case study. This is caried out in chapters 6 and 8. Phase (5) consist in the application of the maturity assessment. This also includes ensuring the broad availability of the maturity assessment. Phase (6) aims at constant improvement and constant use of the maturity system which is excluded from this research.
All details about the methodology can be found in chapter 4.

4.2 Answer to research question RQ-A1: The manufacturing supply chain innovation capability maturity framework (MaSCICMAF)

The answer to research question RQ-A1 is the 'manufacturing supply chain innovation capability maturity framework' (MaSCICMAF). Before MaSCICMAF is explained in detail, general requirements need be addressed. These are shown in Table 4-2.

After having set these constraints, the framework architecture itself shall be described. It is important to note that the framework and its architecture as described in this chapter represent a final state of the framework. A number of iterations for validation have been gone through at this point as described in chapter 3.4. The scope of MaSCICMAF is to analyse the current state of innovation capability maturity of a manufacturing supply chain, whereas the supply chain is considered a socio-technical system as Behdani (2012) suggest. The supply chain is understood as the physical supply chain which is directly involved in the production of goods. Service and finance providers are considered inputs to the system. The design is general enough to be applicable in different supply chains in different manufacturing industries. Different maturity stages provide not only the option of assessing the status quo of innovation capability of a supply chain. They also act as guidance for strategic improvements in different innovation capability dimensions (see chapter 8).

Table 4-2: Requirements the framework must meet

Criterion	Focus
1. Who is the framework for?	Management in manufacturing enterprises, industry support organisations
2. Why should the framework be applied?	For an organisation's internal innovation capability assessment and to identify areas for improvement on company scoring model or to analyse an entire supply chain and develop targeted support to raise innovation capability throughout the supply chain
3. How to apply the framework?	The assessment is a tool being applied with a specialist present
4. Who is needed to apply the framework?	For analysis of the results an innovation capability specialist is needed
5. What can be achieved?	Determination of current innovation capability of a company or an entire supply chain and future scenarios for improvement (applicable in a crisis or non-crisis context)

MaSCICMAF is based on a socio-technical system approach to supply chain as innovation system as it is described in chapters 1 and 2. This means that MaSCICMAF contains technological and social aspects. As it is important to connect MaSCICMAF to already existing approaches to supply chains in companies, the SCOR model is used as modelling approach, as it is the standard model in many industries (Li et al., 2011, Zhou et al., 2011, Delipinar and Kocaoglu, 2016) and has been used for similar purposes in similar studies (see: Abderrazak and Youssef (2022), Krishnan et al. (2021), Ehie and Ferreira (2019)). As Krishnan et al. (2021) state, the development of innovation along a supply chain takes places in the two SCOR planning levels, the intra planning level of single companies (L1) and the inter planning level (L2) along the supply chain (see Figure 4-2). The other SCOR levels refer to everyday supply chain operations (Ntabe et al., 2015) and are, hence, not relevant for the creation of MaSCICMAF.

MaSCICMAF addresses both intra planning level (L1) as a systems agent level and the inter planning level (L2) as the interaction of the system agents. Less abstract, this means that the agent level refers to innovation capability of organisations operating within the supply chain. For MaSCICMAF, this is referred to as the company scoring model (CSM). The context and ecosystem level describes the interaction of agents within the supply chain and the wider context the supply chain operates in. Within MaSCICMAF this level is called the supply chain scoring model (SCSM). Each supply chain within the same industry is influenced by the same industry factors. These industry factors are modelled as system input. Supply chain modelling for MaSCICMAF is at an abstract level as MaSCICMAF requires a broad approach covering different supply chain setups. This means that it is recognised that the different agents within a supply chain are connected in a certain way. In which way they are connected is not reflected. This, approach allows straight supply chains, it allows loops, and it allows complex supply networks to be covered. A graphic representation of the supply chain model is shown in *Figure 4-2*.

MaSCICMAF follows a multidimensional approach as used by Iddris (2016) and Iddris (2018) to develop a holistic framework that covers all relevant aspects of innovation capability. The structured content analysis has led to a set of innovation capability dimensions (ICD) for CSM and SCSM. Following the homogenisation and abstraction approach by Wade and Heydari (2014) to reduce complexity, ICDs are divided into two sections. Thematic similar ICDs are clustered, clusters forming the top-level section of ICDs. These are shown in Table 4-3. It is recognised that these ICDs are not independent and influence each other. Nevertheless, it can be said that the innovation capability of a supply chain is the qualitative combination of the innovation capability of the individual firms operating in the supply chain and the innovation capability of the supply chain as innovation eco system by reversing the systems approach.

*Table 4-3**:** Innovation capability dimensions (ICD) for the company scoring model and the supply chain and industry level*

Company scoring model	**Supply chain scoring model**
C1 Organisational culture und leadership	SC1 Supply chain structure and governance
C2 Entrepreneurship and strategy	SC2 Supply base
C3 Knowledge management and technology adoption	SC3 Public supply chain support
C4 Innovation strategy, communication, and open innovation	
C5 Organisational learning and absorptive capacity (innovation process)	
C6 Individual skills and learning	

These ICSMs contain capabilities and impact factors. This differentiation is important as not all factors impacting innovation capability are capabilities themselves, yet they play significant role for enabling innovation and building capability. In different terms, they relate to innovation barriers. This differentiation is possible in the present case, as the methodology for maturity framework development by De Bruin et al. (2005) explicitly includes this option.

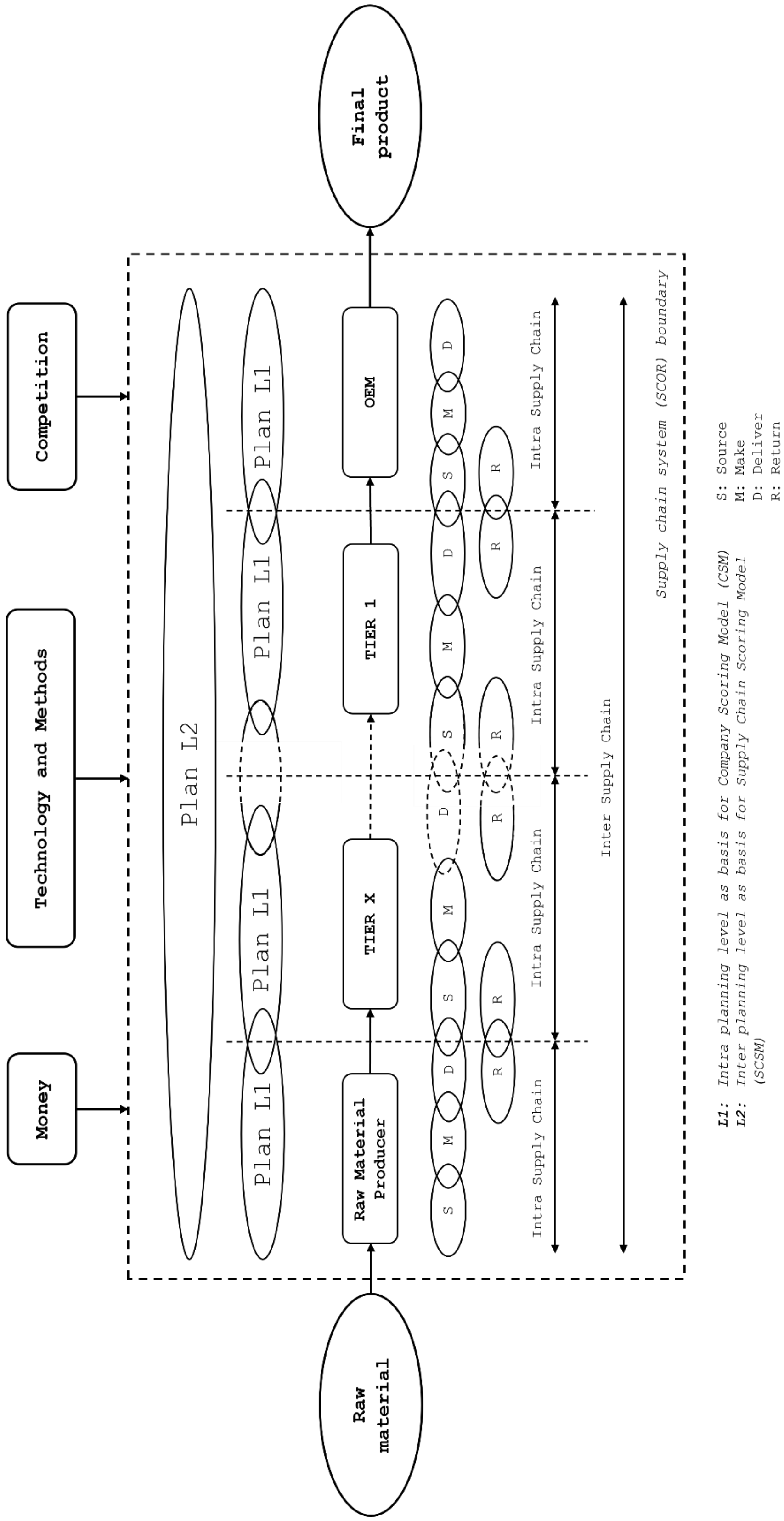


Figure 4-2: Adapted SCOR model MaSCICMAF is based on

Figure 4-3 shows the graphic representation of MaSCICMAF. It is divided into the supply chain scoring model and the company scoring model. System input into the supply chain as a system is represented as well. The graphic representation only shows the ICDs for one company exemplarily. This representation is the same for all companies operating in the supply chain.

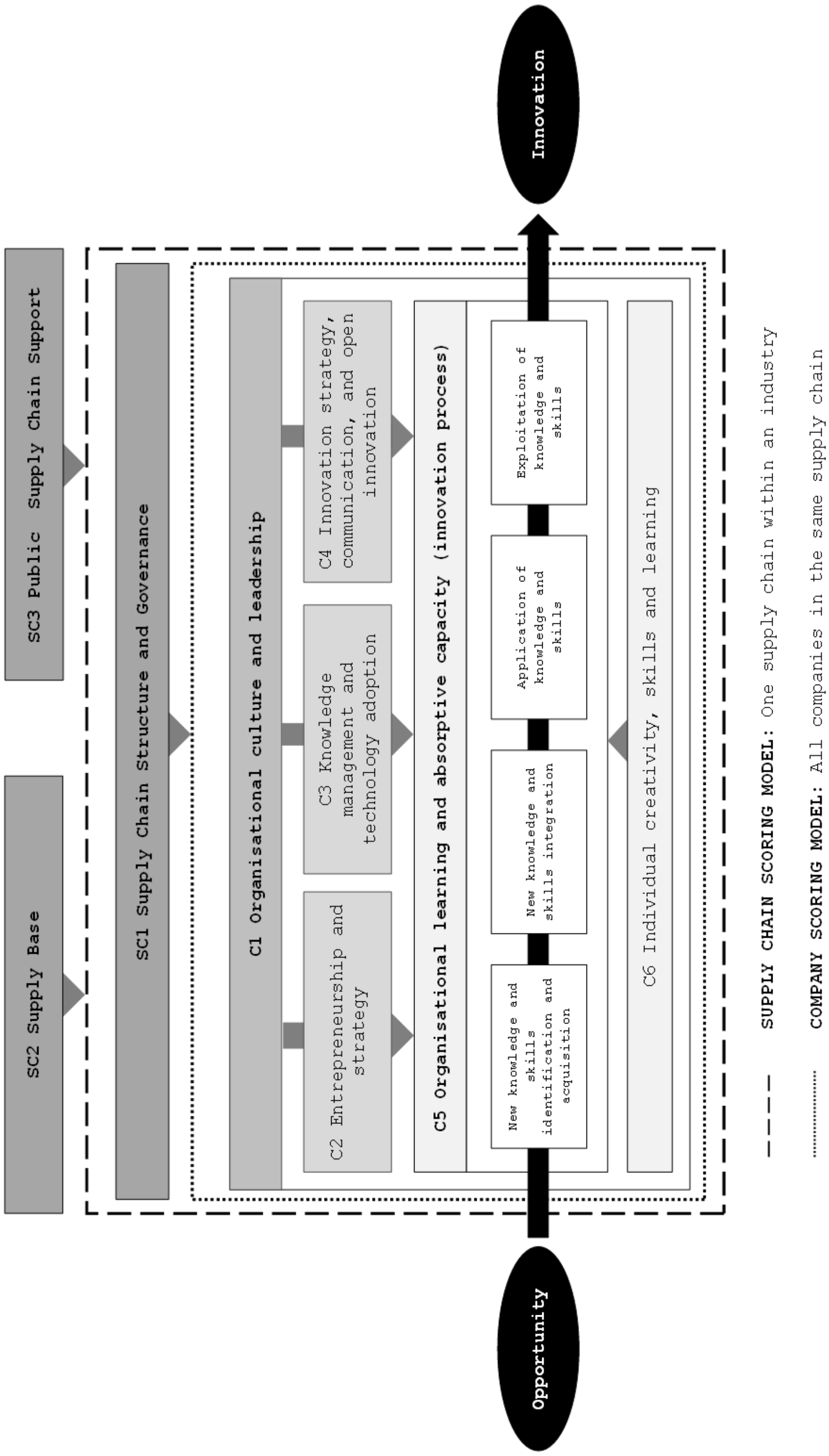


Figure 4-3: Framework architecture of MaSCICMAF showing all ICDs with system and agent boundaries, as well as system input

The framework consists of three different maturity stages. Even though many maturity models use five stages, Wendler (2012) clarifies that the number and characteristics of maturity stages can be freely chosen. Due to high complexity of the framework the stages are limited to three. These stages are shown in Table 4-4. They describe a stage of innovation capability either being reactive, adaptive, or proactive. In consecutive research more maturity stages could be developed for more granularity.

Table 4-4: Maturity stage definitions

Maturity level	Definition
1 – reactive	Innovation takes place as a reaction to changing external conditions. Innovation is considered a one-time project. No formal management of innovation exists. Innovation success factors are just occasionally used to support innovation.
2 – adaptive	Innovation is a systematically managed process that constantly occurs. Innovation success factors are used to systematically support innovation.
3 – proactive	Innovation is used proactively to create competitive advantage. Innovation management is systematic and constantly improved. Innovation success factors are constantly improved to support innovation.

In the following it is explained what exactly the different ICDs are, if they are a capability or an impact factor (IF), and what academic source refers to them from the literature search. Following the architecture of MaSCICMAF, the company scoring model ICDs are explained, then the supply chain scoring model ICDs. The definitions for the different maturity stages for each ICD can be found in the appendix chapter 4 where the full framework is accessible.

4.2.1 The company scoring model

For the company scoring model the first dimension C1 'organisational culture and leadership' refers to the attitude of leadership and the general organisation towards innovation and change. 'Organisational culture and leadership' is the basis that influences all other dimensions as an organisation's culture and leadership make or influence decisions which impact all other dimensions of innovation capability. Little surprisingly, the promotion of innovation and the living of a change culture positively influence innovation capability as Fell et al. (2003) find. Sankowska and Paliszkiewicz (2016) add that personal employees' openness towards innovation and change is as important as organisational promotion. Saunila (2017a) states that a well-managed risk-accepting and a risk-taking culture positively influences innovation capability. Nilsson and Ritzén (2014) and Weissenberger-Eibl and Schwenk (2009) argue that especially a participatory leadership style and decision making have a positive influence. Additionally, Iddris (2016) highlights the importance of direct informal communication of initiatives, whereas Saunila (2017a) emphasis the impact of communication of successful innovation initiatives throughout the organisation. These subdimensions, including if they are capabilities or impact factors supporting capability building can be found in Table 4-5. All subdimensions are considered capabilities as they represent activities which lay within the firm's responsibility, and which can be executed by the firm itself.

Table 4-5: Subdimensions of ICD C1 - Organisational culture und leadership

Subdimensions	Capability or IF	Source
C1.1 Risk acceptance and risk management	Capability	Saunila (2016), Iddris (2016), Chang et al. (2012), Saunila et al. (2014), Haldma et al. (2012), Rahman et al. (2015), Direction (2019), Sankowska and Paliszkiewicz (2016), Saunila (2017a), Durst and Ferenhof (2016)
C1.2 Ambition, promotion of innovation and change, openness towards change, and communication of success	Capability	Iddris (2016), Chang et al. (2012), Saunila et al. (2014), Haldma et al. (2012), Sicotte et al. (2014), Purwanggono and Amalia (2019), Fell et al. (2003), Sankowska and Paliszkiewicz (2016), Lee et al. (2014), Saunila (2017a), Friedrich and Hiba (2016), Arzubiaga and Iturralde (2014)
C1.3 Leadership practices, communication and decision making	Capability	Nilsson and Ritzén (2014), Saunila and Ukko (2013), Saunila (2016), Iddris (2016), Chang et al. (2012), Saunila et al. (2014), Haldma et al. (2012), Vicente et al. (2015), Rahman et al. (2015), Direction (2019), Purwanggono and Amalia (2019), Weissenberger-Eibl and Schwenk (2009), Saunila (2017b), Saunila (2017a)

There are three innovation capability dimensions on the organisational level which are influenced by the organisational culture and leadership which themselves influence the ability to host the innovation process itself. One of these is C2 'entrepreneurship and strategy'. For example, Sicotte et al. (2014) and Kauf and Kniess (2014) state a positive correlation between continuous strategic renewal and innovation capability. This correlation is intensified if supported by organisational flexibility and agility (Saunila et al., 2012, Kamaruddeen et al., 2009).

Additionally, a highly entrepreneurial mindset of a company's leadership has a similar effect (Saunila, 2019). A high diversity of products and broad customer base also have a supporting effect on innovation capability (Detarsio et al., 2016, Sicotte et al., 2014). Kauf and Kniess (2014) state that supply chain resilience and a broad supplier base influence innovation capability positively as well. These subdimensions, including if they are capabilities or impact factors supporting capability building can be found in Table 4-6. C2.1 to C2.5 are considered capabilities as they describe activities which the firm is responsible for. C2.4 refers to the capability to building supply chain resilience and not the supply chain resilience as a status quo. C2.6 is considered an impact factor, as the existing diversity of products, services, and customers impacts innovation capability in the present. The capability of developing new products, services, markets for the future, is represented by C2.3 already.

Table 4-6: Subdimensions of ICD C2 - Entrepreneurship and strategy

Subdimensions	Capability or IF	Source
C2.1 Strategic renewal and flexibility (Change management)	Capability	Sicotte et al. (2014), Lee et al. (2014), Durst and Ferenhof (2016), Detarsio et al. (2016), Kauf and Kniess (2014)
C2.2 Organisational flexibility and agility	Capability	Janssen et al. (2016), Saunila et al. (2014), Haldma et al. (2012), Kamaruddeen et al. (2009), Weissenberger-Eibl and Schwenk (2009), Sankowska and Paliszkiewicz (2016), Saunila (2017b), Durst and Ferenhof (2016), Friedrich and Hiba (2016), Detarsio et al. (2016), Kauf and Kniess (2014)
C2.3 Entrepreneurial capability	Capability	Detarsio et al. (2016), Kauf and Kniess (2014)
C2.4 Supply chain resilience	Capability	Sicotte et al. (2014), Kauf and Kniess (2014), Kurtz and Varvakis (2016)
C2.5 Accessing of innovation support and funding	Capability	Iddris (2016), Chang et al. (2012), Saunila (2019)
C2.6 Diversity of products / services and diversity of customers	IF	Detarsio et al. (2016), Kauf and Kniess (2014)

The next ICSM is C3 'Knowledge management and technology adoption'. Saunila (2017b) and Sicotte et al. (2014) highlight the importance of active knowledge and idea management for innovation capability. Especially, the contribution to knowledge and the access of knowledge are important. Further, in technology-oriented companies this also refers to building knowledge about technology in terms of the adoption of new technology. Especially, technology adoption strategies and standardised processes show a positive impact on innovation capability (Kamaruddeen et al., 2009, Vicente et al., 2015). These subdimensions, including if they are capabilities or impact factors supporting capability building can be found in Table 4-7. Managing knowledge and ideas, as well as adopting new technology are both considered capabilities.

Table 4-7: Subdimensions of ICD C3 - Knowledge management and technology adoption

Subdimensions	Capability or IF	Source
C3.1 Knowledge management, idea management, and knowledge sharing	Capability	Saunila and Ukko (2013), Saunila (2016), Belkahla and Triki (2011), Iddris (2016), Chang et al. (2012), Saunila et al. (2014), Haldma et al. (2012), Sicotte et al. (2014), Rahman et al. (2015), Kamaruddeen et al. (2009), Lee et al. (2014), Danks et al. (2017a), Saunila (2017b), Danks et al. (2017b), Saunila (2019)
C3.2 Technology adoption strategy and processes	Capability	Chang et al. (2012), Vicente et al. (2015), Direction (2019), Fell et al. (2003), Kamaruddeen et al. (2009), Detarsio et al. (2016), Arzubiaga and Iturralde (2014)

The innovation capability dimension C4 'Innovation strategy, communication, and open innovation' refers to the positive impacts of innovation strategies including open innovation on innovation capability building (Vicente et al., 2015, Rahman et al., 2015, Nilsson and Ritzén, 2014). Purwanggono and Amalia (2019) and Belkahla and Triki (2011) explicitly state that open innovation practices, collaboration and active data sharing enhance innovation capability. However, Iddris (2016) specifies that an innovation strategy needs to be in line with the competitive strategy and needs to be supported with sufficient funds to raise innovation capability. Besides an appropriate innovation strategy, Saunila (2016) finds that appropriate measures for innovation success are needed. These subdimensions, including if they are capabilities or impact factors supporting capability building can be found in Table 4-8. C4.1 and C4.2 are both considered capabilities in themselves.

Table 4-8: Subdimensions of ICD C4 - Innovation strategy, communication, and open innovation

Subdimensions	Capability or IF	Source
C4.1 Clear innovation strategy aligned with company strategy and innovation measurement and adequate recourse allocation	Capability	Saunila and Ukko (2013), Nilsson and Ritzén (2014), Saunila (2016), Iddris (2016), Chang et al. (2012), Saunila et al. (2014), Vicente et al. (2015), Raghuvanshi et al. (2019), Rahman et al. (2015), Purwanggono and Amalia (2019), Danks et al. (2017a), Saunila (2017b), Danks et al. (2017b), Saunila (2019)
C4.2 Cooperation with suppliers, customers, public institutions, and openness to share information and to adopt new outside knowledge	Capability	Janssen et al. (2016) Saunila and Ukko (2013), Belkahla and Triki (2011), Iddris (2016), Chang et al. (2012), Saunila et al. (2014), Raghuvanshi et al. (2019), Rahman et al. (2015), Purwanggono and Amalia (2019), Weissenberger-Eibl and Schwenk (2009), Lopes and Farinha (2018), Danks et al. (2017a), Saunila (2017b), Aloini et al. (2015), Danks et al. (2017b), Saunila (2019), Biazzo and Filippini (2021)

The next dimension C5 is called 'Organisational learning and absorptive capacity'. This dimension refers to the innovation process itself and the capability of hosting it, which is influenced by the before mentioned organisational innovation capability dimensions and the following individual innovation capability dimension C6. For this study the concept of absorptive capacity has been adopted as a well-recognised abstraction of any organisational learning process and innovation process as already shown in chapter 2.3.2. In detail, the concept developed by Zahra and George (2002) is used as the predominant concept in literature. Besides Zahra and George (2002) also Machikita and Ueki (2015) and Belkahla and Triki (2011) highlight correlations between innovation capability and absorptive capacity as well as the capability to host the innovation process. These subdimensions, including if they are capabilities or impact factors supporting capability building can be found in Table 4-9. All subdimensions are explicitly considered capabilities as the subdimensions C5.1 to C5.4 represent the innovation and organisational learning process itself.

Table 4-9: Subdimensions of ICD C5 - Organisational learning and absorptive capacity (innovation process)

Subdimensions	Capability or IF	Source
C5.1 New knowledge and skills identification and acquisition (acquisition)	Capability	Belkahla and Triki (2011), Machikita and Ueki (2015), Zahra and George (2002)
C5.2 New knowledge and skills integration (assimilation)	Capability	Belkahla and Triki (2011), Machikita and Ueki (2015), Zahra and George (2002)
C5.3 Application of knowledge and skills (transformation)	Capability	Belkahla and Triki (2011), Machikita and Ueki (2015), Zahra and George (2002)
C5.4 Application of knowledge and skills (transformation)	Capability	Belkahla and Triki (2011), Machikita and Ueki (2015), Zahra and George (2002)

The sixth innovation capability dimension of the company scoring model is C6 'individual creativity, skills and learning'. It refers to skills which employees hold on an individual level, and which the company can use. The levels of individual skills and expertise, just like organisational factors, influence the ability to host the innovation process. In-depth technical skills in a special field of knowledge are significant to develop innovation in this field (Saunila, 2016, Kamaruddeen et al., 2009). For innovation capability in-depth knowledge and skills about innovation are as important (Purwanggono and Amalia, 2019, Saunila et al., 2012). Besides organisational learning, individual learning has a positive impact on innovation capabilities. This is necessary to adjust to changes of the environment on a personal level. However, companies should facilitate the individual learning process (Sicotte et al., 2014, Saunila, 2016). These subdimensions, including if they are capabilities or impact factors supporting capability building can be found in Table 4-10. C6.1 and C6.2 are considered impact factors and not capabilities, as the present state of skills is referred to. C6.4 is as well considered an impact factor as it solely refers to the availability of options for learning. C6.3 continuous individual will for learning is the capability developing C6.1 and C6.2 for the future based on C6.4.

Table 4-10: Subdimensions of ICD C6 - Individual skills and learning

Subdimensions	Capability or IF	Source
C6.1 Individual skills in one's field of knowledge	IF	Janssen et al. (2016) Saunila and Ukko (2013), Iddris (2016), Chang et al. (2012), Kamaruddeen et al. (2009), Saunila (2017b), Saunila (2017a)
C6.2 Individual knowledge and skills about innovation	IF	Iddris (2016), Purwanggono and Amalia (2019), Saunila (2017a)
C6.3 Individual continuous will for learning	Capability	Janssen et al. (2016), Saunila and Ukko (2013), Saunila (2016), Iddris (2016), Chang et al. (2012), Haldma et al. (2012), Sicotte et al. (2014), Sankowska and Paliszkiewicz (2016), Saunila (2019), Saunila (2017a)
C6.4 Availability of options for individual learning	IF	Saunila and Ukko (2013), Saunila (2016), Chang et al. (2012), Saunila et al. (2014), Sicotte et al. (2014)

4.2.2 The supply chain and industry score model

The supply chain and industry level of MaSCICMAF comprises the innovation capability dimensions 'supply chain structure and governance', 'supply base', and 'public supply chain support'.

SC1 'Supply chain structure and governance' essentially relates to how the supply chain is organised as a system. This is different for each supply chain. Lopes and Farinha (2018) highlight the positive influence of fair treatment of all organisations along the supply chain and responsibility taking have on the innovation capability of the supply chain. Weissenberger-Eibl and Schwenk (2009) add the importance of mutual trust and reliability. Essential for both is no misuse of power by large OEMs or TIER 1 suppliers. Good communication and openness towards data sharing along the supply chain have positive impacts on the supply chain's innovation capability. A committee which represents all members of the supply chain equally can help set standards for collaboration and data sharing (Zimmermann et al., 2016). Enkel et al. (2011) add that joint development activities between companies along the supply chain and public support organisations as well as joint value capturing mechanisms improve innovation capability of the supply chain. Whereas the mentioned factors have positive impacts, the following factors can have negative impacts on a supply chain's innovation capability. The length and the complexity of supply chains have negative impacts

(Zimmermann et al., 2016). Further, the more a supply chain is regulated legally, the less capable of innovating it is (D'Este et al., 2012, Gupta et al., 2020). Regulation however must not be mistaken for collaboration standards which have a positive effect (Enkel et al., 2011). A negative effect has also a general aversion of change and risk as Saunila (2017a) and Durst and Ferenhof (2016) find. These subdimensions, including if they are capabilities or impact factors supporting capability building can be found in Table 4-11. SC1.3, SC1.4, SC1.6, and SC1.7 are considered impact factors as they are of structural nature and not an activity as such. The other subdimensions are considered capabilities.

Table 4-11: Subdimensions of ICD SC1 - Supply chain structure and governance

Subdimensions	**Capability or IF**	**Source**
SC1.1 Nature of collaboration, fairness, use of power, and responsibility	Capability	Saunila and Ukko (2013), Belkahla and Triki (2011), Iddris (2016), Chang et al. (2012), Haldma et al. (2012), Weissenberger-Eibl and Schwenk (2009), Lopes and Farinha (2018), Saunila (2017b), , Saunila (2019), Saunila (2017a)
SC1.2 Communication	Capability	Janssen et al. (2016) Saunila and Ukko (2013), Belkahla and Triki (2011), Iddris (2016), Chang et al. (2012), Saunila et al. (2014), Raghuvanshi et al. (2019), Rahman et al. (2015), Purwanggono and Amalia (2019), Weissenberger-Eibl and Schwenk (2009), Lopes and Farinha (2018), Danks et al. (2017a), , Saunila (2017b), Saunila (2019)
SC1.3 Reliability and trust	IF	Janssen et al. (2016) Saunila and Ukko (2013), Belkahla and Triki (2011), Iddris (2016), Chang et al. (2012), Saunila et al. (2014), Raghuvanshi et al. (2019), Rahman et al. (2015), Purwanggono and Amalia (2019), Weissenberger-Eibl and Schwenk (2009), Lopes and Farinha (2018), Danks et al. (2017a), , Saunila (2017b), Saunila (2019)
SC1.4 Regulation	IF	Zimmermann et al. (2016), Gupta et al. (2020), D'Este et al. (2012), Zhu et al. (2012)
SC1.5 Change and risk attitude	Capability	Janssen et al. (2016), Saunila (2016), Iddris (2016), Chang et al. (2012), Saunila et al. (2014), Haldma et al. (2012), Sicotte et al. (2014), Rahman et al. (2015), Raghuvanshi et al. (2019), Rahman et al. (2015),

		Direction (2019), Fell et al. (2003), Sankowska and Paliszkiewicz (2016), Lee et al. (2014), Saunila (2017a), Durst and Ferenhof (2016), Friedrich and Hiba (2016), Arzubiaga and Iturralde (2014)
SC1.6 Supply chain structure	IF	Zimmermann et al. (2016)
SC1.7 Supply chain visibility	IF	Wei and Wang (2010)
SC1.8 Joint value capturing with supply chain members and public support organisations	Capability	Saunila and Ukko (2013), Belkahla and Triki (2011), Iddris (2016), Chang et al. (2012), Haldma et al. (2012), Weissenberger-Eibl and Schwenk (2009), Lopes and Farinha (2018), Saunila (2017b), , Saunila (2019), Saunila (2017a)

The innovation capability dimensions SC2 'Supply base' and SC3 'public supply chain support' can be considered factors which apply to all supply chains within the same industry. In terms of systems design, these dimensions are system inputs influencing the system supply chain.

The innovation capability dimension SC2 'Supply base' comprises all companies operating in an industry whether they belong to a certain supply chain or not. If the supply base is narrow, it is more difficult to substitute existing suppliers which affects resilience (Sicotte et al., 2014, Kauf and Kniess, 2014). In general, more competition leads to more innovation and i.a. Kamaruddeen et al. (2009) and Vicente et al. (2015) find a positive correlation between innovation capability and generally high adaptation capability of new technology throughout the whole supply base. These subdimensions, including if they are capabilities or impact factors supporting capability building can be found in Table 4-12. SC2.2 can be considered a capability on supply chain level. SC2.1 is also be considered a capability like C2.4 supply chain resilience of a single company, just with the focus on the whole of the supply base.

Table 4-12: Subdimensions of ICD SC2 - Supply base

Subdimensions	**Capability or IF**	**Source**
SC2.1 Supply base resilience	Capability	Sicotte et al. (2014), Kauf and Kniess (2014), Kurtz and Varvakis (2016)
SC2.2 Technology adoption capability	Capability	Chang et al. (2012), Vicente et al. (2015), Direction (2019), Fell et al. (2003), Kamaruddeen et al. (2009), Detarsio et al. (2016), Arzubiaga and Iturralde (2014)

The dimension SC3 'public supply chain support' refers to the positive impact of the availability of public funding and skills and knowledge support for innovation capabilities, especially of SMEs. Fundamentally is, however, that the funding is easily accessible (Saunila, 2019, Iddris, 2016). Besides funding issues, especially SMEs, lack skills and expertise needed for innovation initiatives. Therefore, public industry support offering specialised skills in different engineering disciplines, in operations management, and innovation management have a positive impact on innovation capability of a whole supply chain. This support needs to be public to effectively strengthen financially limited SMEs as they cannot afford private offerings to ensure more equality and fairness along the supply chains. These subdimensions, including if they are capabilities or impact factors supporting capability building can be found in Table 4-13. SC3.1 and SC3.2 are both considered impact factors and not capabilities are they purely aim at availability of public support, as public support cannot be changed directly by the supply chain organisation.

Table 4-13: Subdimensions of ICD SC3 - Public supply chain support

Subdimensions	Capability or IF	Source
SC3.1 Availability of public funding for supply chain and supply base development	IF	Iddris (2016), Chang et al. (2012), Saunila (2019)
SC3.2 Availability of public support organisations for supply chain and supply base development	IF	Chang et al. (2012)

4.3 Summary and next steps

In this chapter the framework MaSCICMAF was created. It is a literature-based framework that describes the innovation capability of supply chains. For this purpose, a systems approach is used in connection with a basis in the SCOR model. The systems perspective is related in the company scoring model and the supply chain scoring model, whereas the former aims at describing innovation capability of a single company within a supply chain and the later aims at analysing the interconnection of single companies within the supply chain they operate in. MaSCICMAF with its three maturity stages also allows to classify if supply chains have a more mature innovation capability or less mature one. This chapter solely presents the creation of MaSCICMAF up to a first testing with experts. This means that De Bruin et al. (2005)'s methodology is followed up to stage 4 of Figure 3-2. A field test and the deployment of the framework are yet to be executed. These steps are carried out as a case study with one supply chain. In chapter 6 the framework is applied and validated as audit tool of the status quo of innovation capability of a selected supply chain and in chapter 8 the framework is applied and validated as strategy making tool for improvement of innovation capability tool. Which supply chain in which industry is used as a case study is the result of the following chapter 5. The framework undergoes smaller changes as results of the field application in the case study. The framework presented in this chapter is the final version.

CHAPTER 5

PERCEPTION OF INNOVATION DURING COVID-19

And then the Covid-19 pandemic hit the world, the UK, and Scotland….

As briefly discussed in the introduction to this research, this thesis is a thesis which was created before and during the Covid-19 pandemic. The original idea behind MaSCICMAF was to apply it to any suitable Scottish supply chain for field validation of the research. It was also intended to derive strategies for improvement of innovation capability for that supply chain and provide recommendations for policy makers.

And then the Covid-19 pandemic hit the UK. MaSCICMAF still needs a field validation and the creation of improvement strategies for innovation capability of a supply chain and policy recommendations were still on the table, but suddenly it made a very practical difference which sector to choose for a supply chain to analyse. So, their became a question of very practical relevance to this research. But in which sector would the application of MaSCICMAF and its field validation provide the most impact? This chapter has an intermediate role to answer this question and to define the industry that will be focussed on for the rest of the thesis.

All industries were affected in some way, including all manufacturing sectors. Within the early stages of the pandemic the decision was made to investigate manufacturing sectors further in Scotland alone. This decision was made based on the fact that the University of Strathclyde and the National Manufacturing Institute of Scotland where this research was conducted, are located in Scotland and could provide significant connections and insight into Scottish manufacturing. As economic policies are mainly developed on the level of the devolved nations within the UK, it was thought that the research would generate the biggest impact on a Scottish level, for Scottish policy making alone. Even with these pre-decisions limiting the scope, a lack of understanding of how the Covid-19 pandemic has impacted Scottish manufacturing and its subsectors had to be faced. Whereas some public information was available on the general commercial impact on different sectors, precise insights into the innovation behaviour remains under researched. Therefore, this chapter aims at developing a better understanding of this research gap and answer research question

RQ-P1: How did the Covid-19 pandemic change the view on innovation in Scottish advanced manufacturing supply chains and which sectors especially need innovation capability support?

To answer this question manufacturing in Scotland is observed during the Covid-19 pandemic for one and a half years between February 2021 and July 2022 with a special focus on the importance of innovation behaviour, innovation barriers, and their changes over time. For this purpose, two interview series are carried out. Interview series one takes place between February and April 2021 capturing the Covid-19 impact of the early stages of the pandemic. Interview series two takes place between April and July 2022 capturing the second half of the pandemic and the industry's view of the future beyond the pandemic. Both series are divided into two parts. Part one, aims at identifying the Covid-19 impact on the manufacturing sector in Scotland in general. For this purpose, industry support organisations are interviewed. This meta-approach is considered a suitable way of collecting the desired data, as these organisations have good insights into the sector through the companies they work with while they can put insights of single companies into perspective of the wider manufacturing sector. Part two, aims at analysing innovation behaviour and barriers over time in the aerospace, the food and drink, and the chemistry and pharmacy sector in particular. These three sectors have been chosen as sectors of special interest following the initial findings in chapter 1.1. The aerospace sector and the food and drink sector both had imminent substantial commercial consequences to suffer when international travel was halted and when hospitality was shut down. On the other hand, the chemistry and pharmacy sector have seen opportunities arise through the pandemic. Three companies of each of these sectors are interviewed to obtain first-hand insights into their innovation behaviour and their particular challenges as sample companies from the sector in addition to the results from the general interviews in part one. For clarification Figure 5-1 shows the organisation of the interviews.

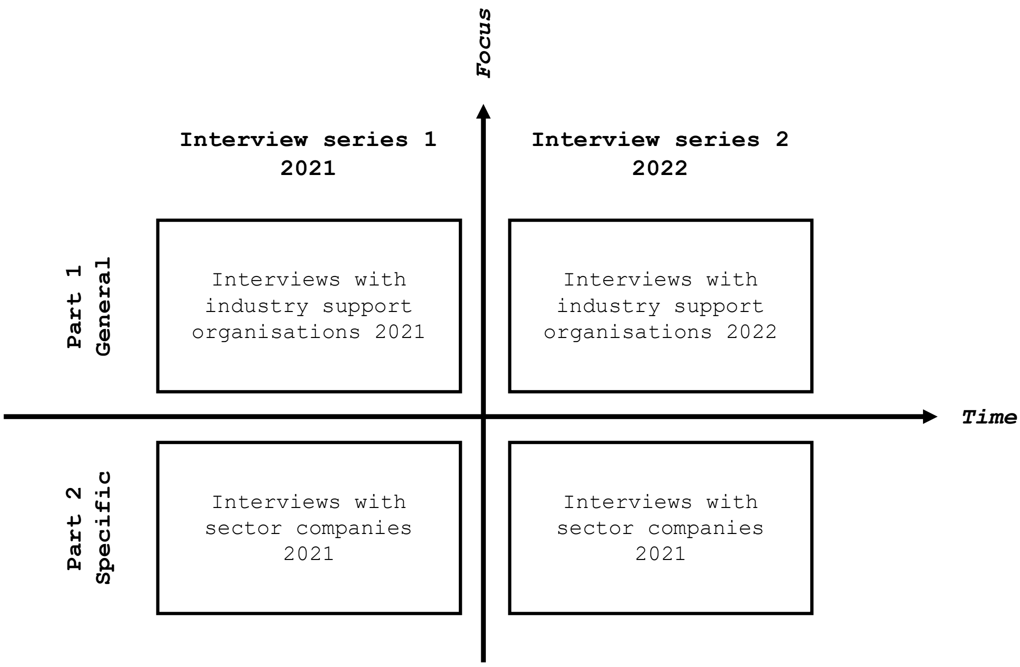


Figure 5-1: Interview organisation divided into time and focus

This chapter first summarizes the methodological approach and the applied process of conducting the interviews as described in chapter 3.4, Then findings are presented and discussed. At the end, research question RQ-R1 is formally answered, and it is explained what the implications of this answer are and how later chapters of this thesis relate to them.

5.1 Review of expert interview method

Expert interviews are frequently used to investigate general topics of interest in exploratory studies (Saunders et al., 2016, Goffin et al., 2006). Expert interviews offer an informal way of interacting with relevant knowledge holders. Important roles hold both the interviewer and the interviewee. The researcher who acts as interviewer is considered an expert of theoretical knowledge in the field of investigation. The interviewee is considered the holder of practical knowledge. Conclusions are drawn based on both perspectives (Saunders et al., 2016).

In-depth interviews aim at exploring an individual's specific perception of a topic of interest. Usually, a small number of in-depth interviews is carried, expecting each interview to have a different focus of interest based on different backgrounds (Saunders et al., 2016). The interviews with industry support organisations (interviews part 1, Figure 5-1) are conducted as in-depth interviews because it is a broad approach to exploring the Covid-19 impact. For such a broad approach Saunders et al. (2016) recommends this method. Usually, the interview is started with an initial question and developed from there.

The semi-structured nature of the sector specific interviews (interviews part 2, Figure 5-1) provides the option to leave pre-set questions and enter an open conversation. However, the semi-structuring ensures that key topics are covered (Bell et al., 2022). This way a phenomenon can be investigated in detail depending on the interviewee's standpoint. Thus, data can be maximised, and detailed descriptions can be deducted (Saunders et al., 2016). Consequently, collected data varies from interview to interview depending on the interviewee's background and the context of the interview (Srivastava and Thomson, 2009). However, the semi-structured nature also provides comparability to a certain extent. The freedom of going of script while keeping comparability is an effective method to investigate a qualitative exploratory topic after the first point of contact (Saunders et al., 2016).

The in-depth interviews start with an initial question as conversation starter, as Saunders et al. (2016) suggest. For this research this is:

> *How have the companies you support experienced the Covid-19 pandemic, how have they been impacted and how have they reacted?*

To select interviewees a non-probability sampling approach is used. Thus, the researcher can choose the most relevant interviewees based on theoretical pre-set parameters. For the present research these parameters relate to broad knowledge about the manufacturing industry in Scotland and the level of engaging with companies operating in the industry. Further, the suitable interviewee has detailed insights in how the Covid-19 pandemic affected the industry and how different sectors reacted. This includes the innovation behaviour. Suitable experts are identified as senior managers at Scottish industry support organisations as they hold the general overview that is required. The list of participants and their roles are shown in Table 5-1. The interviews are carried out as video chats using Microsoft Teams software between February and April 2021 for the first round of interviews and between April and July 2022 for the second round of interviews. The interviews typically last about one hour. Provided the interviewee's consent the interviews are recorded for transcription and analysis.

Table 5-1: Participants of first interview series

Interviewee No	Organisation Type	Interviewee Role
1	Public industry support (Engineering)	CEO
2	Public industry support (Manufacturing)	CEO

To analyse the processed data a thematic analysis approach is used. Coding takes place in a four-step process adopted from Williams and Moser (2019) which is shown in Figure 5-2. Their first step is the preparation of data which means preparing transcripts and cleaning them up. Step two and three is the development of codes in two orders.

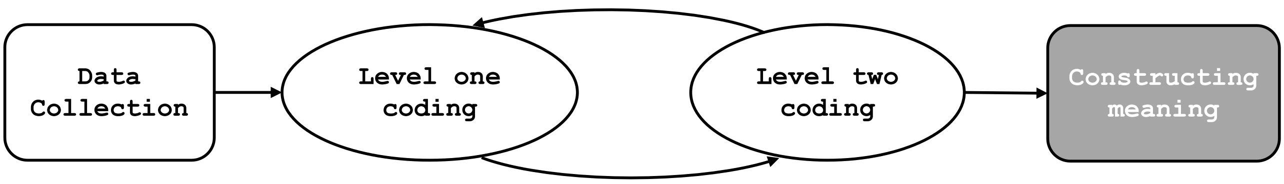


Figure 5-2: Coding process (adapted from Williams and Moser (2019))

Order one coding refers to analysing the row data and labelling it with initial codes. Order two coding refers to labelling codes with codes or grouping order one codes. They are also referred to as themes. The development of codes is a non-linear cyclic process enabling the evolution of codes through constant data comparison. Once a final set of codes is generated, step four aims at deriving meaning from the data and reporting it. This meaning is presented in the findings and discussion section of this chapter. The final set of codes is shown in Table 5-2.

Table 5-2: Coding framework

Interview series	Order 1 Codes	Order 2 Codes - Themes
Series 1	Commercial sector impact	Remote working
	Operational sector impact	Manufacturing operations adaptation
	Instant reaction	Differentiating impact of Brexit and Covid-19
	Planned longer term innovation	Skills gap
	Opportunities	Government support
	Challenges	
	Public industry support perception	
Series 2	Commercial sector impact	The Shift to NetZero
	Operational sector impact	Diversification
	Innovation and change	Energy and trade issues
	Future development	Skills gap
	Public industry support perception	

The conduction of the semi-structured interviews in this research is divided into the three parts: questionnaire development, interviewee recruitment and interview conduction, and data analysis. There are two questionnaires, one for the first series of interviews and one for the second series of interviews. The questions themselves are based on research question RQ-R1. Both questionnaires can be found in the appendices A.C5.1 and A.C5.2. To select interviewees a non-probability sampling approach is used again to choose the most relevant interviewees. The selection criteria for part 2 interviews (see Figure 5-1) relate to having detailed knowledge about either the aerospace, the food and drink, or the chemical and pharmaceutical sector. This includes knowledge about the economic situation of the company they represent as well as the sector as a whole, knowledge about supply chain structures and operations, and innovation behaviour. Following this, suitable experts are people working either in senior supply chain or operations management positions or innovation management positions in private companies in the respective sectors. Interviewees, their roles within their organisations, and their supply chain position are shown in Table 5-3. The interviews are again carried out as video chats using Microsoft Teams software between February and April 2021 for the first interview series as well as between April and July 2022 for the second interview series. The interviews also typically last about one hour and provided the interviewee's consent the interviews are recorded for transcription and analysis.

Table 5-3: Participants of second interview series

Interviewee No	Sector	Organisation Type	Interviewee Role
3	Aerospace	TIER 1	Operations manager
4	Aerospace	TIER 2	Innovation manager
5	Aerospace	TIER 1	Operations manager
6	Food and Drink	OEM	CEO
7	Food and Drink	OEM	CEO
8	Food and Drink	OEM	CEO
9	Chemistry / Pharmacy	TIER 1	CEO
10	Chemistry / Pharmacy	TIER 1	CEO
11	Chemistry / Pharmacy	TIER 1	CEO

For data analysis the same approach as for the first interview series is used as well as it is described above. This approach is followed as the reasons for choosing this approach are valid for the second interview series as well. The type of coding does not depend on the type of interview (Saunders et al., 2016). Further, the aim of the research remains the same, just the unit of analysis is different.

5.2 Findings

The findings presented in this section are divided into two parts following the differentiation in Figure 5-1. The first part presents the meta perspective of the industry support organisations and findings that are valid across the different manufacturing industry sectors. The second part highlights the primary views from aerospace, food and drink, and the chemical and pharmaceutical sectors and findings that are special to these sectors. Both sections are divided into findings from the first interview session in 2021 and the second interview session in 2022.

5.2.1 The perspective of industry support organisations and general findings across sectors

General findings are presented divided into findings from the first interview session in 2021 and findings from the second interview session in 2022, highlighting developments over time.

5.2.1.1 Interview series 1: During the pandemic

The pandemic meant a disruption for the entire economy and therefore also for all manufacturing related sectors. Insights provided by interviewees (1) and (2) show impacts that have been fairly similar across manufacturing in Scotland and sector specific impacts. How companies reacted to these impacts or what innovative solutions they developed to go forward in the short term and in the longer-term depends highly on the company itself. (1) and (2)'s general impression is that manufacturing in Scotland was steadily growing and prospects looked promising for the future before Covid-19 hit. But then Covid-19 arrived in Europe and the first lockdown was put in place. The Covid-19 restrictions caused recession is different compared to other recessions as (1) says. During previous recessions such as the financial crash in 2008 it took about nine to twelve months until the UK went into technical recession. The Covid-19 recession was immediate. (1) says:

> *"March hit everyone in the face like a frying pan"*

The impacts Covid-19 had, were diverse. There was the sudden closure of shops and hospitality, the stop in international travel. There were impacts on productivity caused by social distancing rules in factories and temporary closures if a business was not considered essential. There were shortages of supply. In general, the two interviewees divide the impacts into two categories, commercial and operational. Each company individually, the industry support organisations, and the government as policy makers had to develop innovative solutions to handle these impacts. In general, operational impacts were met with process innovations, whereas commercial impacts were met with a variety of innovation types. However, both interviewees point out that most business were able to develop innovative reactions very quickly. In the following the operational impact and common process innovations are explained before the interviewees' evaluation of the commercial impact on different sectors is presented.

The common themes across manufacturing sectors emerging from the first series of interviews are remote working, manufacturing operations adaptation, government support, and Brexit as it also had an effect.

5.2.1.1.1 *Remote Working*

Due to Covid-19 restrictions most manufacturing companies had to adapt to remote working models as both interviewees state. How the transition went and how the concept of remote working is considered depends to the openness of the senior management. The rapid transition from an office-based setting to remote working did not go smoothly. Whereas after a year into the pandemic all companies have adopted video chatting technology and some form of data sharing in some cases there was not the necessary commitment, and the transition was bumpy. Companies which had invested in technology before the pandemic were generally better prepared for the transition. Proactive supply chains embraced the situation and fostered more virtual collaboration and data sharing whereas conservative supply chains struggled with collaboration.

In general, the attitude towards remote working is changing as both interviewees say. More and more companies say they will adopt a blended model of office and remote work where possible going forward after the pandemic. Complete remote working as required during the lockdown is not likely to be extended. Employers fear good performance and appreciate face to face contact not only for control reasons. It is extremely difficult to integrate new staff into teams if they never physically meet. The personal connection cannot be established and informal chat normally happening during coffee breaks generating good ideas cannot happen. Further, loyalty and dedication is feared to be at a lower level if staff does not have a physical connection with their work space. The interviewees stress that some employers emphasize the need for teams to collaborate in person, especially for creative tasks. However, many employers want to offer more flexibility and offer their staff blended models. As interviewee 1 points out it is a matter of generation. Younger people wish for the freedom to work from home at least partially. They want to safe travel time and feel more productive in that setting. Older people tent to want to go back to the office fulltime as they say they are more productive there.

5.2.1.1.2 *Manufacturing Operations Adaptation*

Many manufacturing businesses worked throughout the Covid-19 lockdowns. However, most had to close initially, and everyone had to adopt social distancing measures. Social distancing meant less people allowed factories. Interviewee (1) states:

"Many SMEs rely on manual labour. If they suddenly have to space out people but don't have more space available this simply means less productivity."

This meant less productivity for those companies with low automation levels. In return both interviewees state a significantly higher interest in digitalisation and automation support. However, social distancing also meant that access to sites was limited for visitors. This in return had an effect on innovation in some cases. For example, it influenced installation and maintenance of equipment. Further, there were shortages of supply which companies had to react to. In some cases, simple stockpiling was effective to equalise volatility. Even though global shortages of for example semi-conductors seem to significantly impact many sectors. In other cases, new suppliers had to be identified. One mayor topic in this context is as both interviewees state is the reshoring of manufacturing capabilities and capacities. Especially SMEs are looking to re-shore capabilities or to buy from re-shored businesses in an attempted to reduce risks of international supply chains. However, both interviewees say that those companies which were involved highly in innovation development found it easier to adapt to the changes and find innovative solutions compared to those who did not.

5.2.1.1.3 The importance of government support

The most prominent government support has been the furlough scheme. Both interviewees state that most companies they are in contact with have used furlough for a period of time. It has been a "life saver" for most manufacturing sectors as it allowed companies to retain jobs and cut their costs at the same time. However, there are concerns that the furlough scheme just postponed economic developments and that there might be higher numbers of bankruptcies in the long run after the scheme ends.

The interviewees report frustration from industry side regarding the organisation of other available industry support. The Scottish industry support landscape is complicated and especially for SMEs not easy to navigate. Many SMEs do not know whom to approach for which type of support in the first place and do not access available support and funding as a consequence. This issue is known to both interviewees and both organisations work on a better collaboration and more straightforward organisation of support. In this context NMIS should be establish as the centralised point of contact who directs the different inquires to the suitable organisation.

That the Scottish innovation and industry support can be a success story shows the creation of a national supply chain for PPE and ventilators when there were global shortages. However, it also shows that there need to be long term government investments and public procurement contracts, to create national supply chains in other sectors.

5.2.1.1.4 The issue of differentiating between Covid-19 and Brexit impacts

The Covid-19 impacts on movements of goods and shortages of supply have been intensified by Brexit implications. Both interviewees stress that Covid-19 and Brexit impacts multiply each other. They also state that it is impossible to differentiate in detail the commercial impacts Brexit and Covid have.

5.2.1.1.5 Skills - The big challenge for the future

The real issue moving forward will be skills. It was already an issue before the pandemic, but the pandemic and the economic downturn has led to more skilled people leaving companies voluntarily by e.g., taking early retirement intensifying the problem as a result. At the same time apprenticeship numbers are just at 50% of where they should be, and the pipeline of university graduates is not as filled as it was hoped for. But if manufacturing and engineering graduates do not get jobs quickly, they will move to different industries where they find jobs and once, they are gone, they will not return anymore.

NMIS itself is affected by the skills issue as well. It is the biggest challenge for NMIS's growth and its ability to support companies to hire enough personnel in specialised and general business and engineering areas.

5.2.1.1.6 The public industry support on the commercial impact on different manufacturing sectors

Both interviewees state that different sectors are affected differently by Covid-19 implications. Overnight shutting down all hospitality has affected the food and drink sector significantly. This impact is believed to be a short-term impact and should recover quickly after restrictions are eased. On the other hand, there is the aerospace sector which will be longer-term impacted as travel behaviour change and therefor airlines cancel orders. Additionally, the aerospace sector is a very slowly moving sector which life cycles measured in decades. Other sectors like automotive also had short term impacts as orders disappeared over night.

However, Covid is considered an operational issue, and the sector expects to bounce back quickly. In these sectors quick entrepreneurial decisions were needed and there are high numbers of stories about the development of new business models, of diversification where possible, of new marketing and distribution strategies and many more. However, these are also the sectors where most job losses are expected. Nevertheless, many companies see Covid-19 as a chance for the opportunity to “reset” and use the “breathing space” or “fire break” to restructure their businesses and hopefully emerge stronger.

In contrast to this development there is an extremely good development in the chemical and pharmaceutical industry and their supply base. Not just because of the construction of vaccine production facilities, the sector has seen significant increases in orders for equipment renewal and automation. This sector created jobs during the pandemic.

The interviewees predict that the manufacturing sectors that involved with green recovery, NetZero, etc will bounce back and emerge stronger than they were. The reason for this is the governmental support for these topics in e.g., the recovery plan for Sottish manufacturing (Scottish Government 2020).

5.2.1.2 Interview series 2: At the end of the pandemic

The second round of interviews with public industry support organisations at the end of the Covid-19 pandemic in 2022, one and a half years after the first round, reveals that a shift of focus has taken place across the different manufacturing sectors. The main driver for the future identified by interviewees (1) and (2) is NetZero whereas new everyday challenges besides Covid-19 have arisen in connection with energy prices and free trade whereas availability of skilled workforce is still considered the biggest long-term challenge. These shifts in interest, their opportunities and challenges are explained in more detail in the following.

5.2.1.2.1 The shift towards NetZero

After the impact of Covid-19 on companies’ operations and business has eased, a paradigm shift can be noticed across manufacturing in Scotland. Moving away from mitigating the impact of the pandemic, the next main driver of change in the industry is NetZero. Especially SMEs across sectors aim at reducing their carbon footprint and contributing to a greener, more sustainable society. As a technology, hydrogen is of special interest. However, (1) and

(2) both report shortcomings in innovation capability within most SMEs in relation to NetZero. Interviewee (2) states:

> *"Smaller companies struggle especially with technology strategy making capabilities. Many don't know how to effectively use technology forecasting or technology road mapping."*

(1) and (2) are ramping up their capacities in the field for efficient support, overall availability of support is insufficient for SMEs at present seriously limiting the move towards NetZero.

5.2.1.2.2 More diversification

During the pandemic interviewees (1) and (2) both see a trend to diversification, from small to larger companies. The pandemic in many cases has been used to create new business models around new products or services. New markets have been developed as well. Afterall, this trend has made the sector and its businesses more resilient than before the pandemic. However, it is not clear if this is a lasting trend or solely a one-time consequence of the pandemic.

5.2.1.2.3 The energy and the trade issue

Whereas new trends have emerged resulting in refocussing of the industry, there are two main commercial challenges which have come along with them. One is the continuous disruption of international supply chains. Shortage of microchips caused by the pandemic is still not under control and affects almost everyone who wants to develop or buy new machinery. Lead times are high and remain unpredictable. The strict lockdown enforcements of the Chinese government on areas with new Covid-19 cases has an additional negative effect on the situation. On top, Brexit and continuous disagreement about regulation with the EU continue to cause friction for import and export, and cause uncertainty. By far, the biggest challenge for manufacturing businesses, however, is the immense raise in energy prices. Especially SMEs are endangered. Afterall, the rise in energy prices is solely the tip of the iceberg and the general increase of inflation affects every business substantially in the industry.

5.2.1.2.4 The skill issue and what the impact of work-life balance

The skill issue has not significantly changed compared to during the pandemic. There is still a significant shortage of skills. However, what has changed is that as the focus of the sector shifts towards NetZero, there are significant shortages in NetZero related technologies and in general in technology management. Interviewee (2) says:

> "The skills shortage is the most significant problem to solve if we actually want to make Scottish manufacturing ready for the future."

The skills issue manifests in companies not being able to find suitable candidates for open positions. Whereas this is not a new situation, the reasons for not being able to attract qualified personnel have changed. A major factor now is work-life balance and the availability of remote working. Many companies follow a hybrid-model after the pandemic where staff comes into the office a few days per week pointing out that personal contact with colleagues is important for teambuilding and for ideation and problem solving. Nevertheless, they offer flexibility for staff. Other companies stress that they get greater access to potential staff if they offer a complete remote working model which offers flexibility as well. The few companies who demand their staff working from the office with no significant flexibility, however, struggle the most in recruiting new staff. Well qualified people know their value and simply demand more staff focussed and less control focused management.

5.2.2 The perspective of special manufacturing sectors and specific sector findings

In this section, findings from the interviews with the company representatives of the aerospace, food and drink, and chemistry and pharmacy sectors are presented. These findings are specific to these industries (see part 2, Figure 5-1). Findings are again separated into findings from the first interview session and findings from the second interview session (see Figure 5-1) and changes over time. The general findings from section 5.2.1 are valid for these sectors as well.

5.2.2.1 Aerospace

Interviewees (3), (4), and (5) paint a similar picture of the Covid-19 impact on their businesses and the sector as a whole during the early stages of the pandemic. They all state that the sector was in good commercial conditions and the outlook was considered positive. There were huge backlogs of orders. However, interviewees (3) and (5) also stated that their companies were in financial struggles before Covid already. The interviewed companies are all international large TIER 1 or medium-sized TIER 2 suppliers. Due to the internationality of the aerospace sector the interviewees state that their businesses have been hit differently in different countries. Even though in countries like the UK furlough was available, nothing similar was available in many other countries. Consequently, interviewees (3) and (5) talk of large numbers of redundancies around the world and also in Scotland to stabilise their cashflow problems. Interviewees (3) and (5) both state that their businesses tried to diversify their business models where possible and went to a more service and maintenance-based model since orders for new equipment almost disappeared and they do not believe that new large numbers of orders will come in soon. They also tried to diversify into other markets. The aerospace industry being highly specialised as it just left them the option to diversify the customer base. Both said they used defence contracts to keep them afloat. Interviewee (4) also reports financial problems; however, the business was already serving different industries before the pandemic, and they manage to successfully develop new markets for themselves during the pandemic, moderating the financial tension.

Interviewees (3), (4), and (5) all say that they handed shortages in orders down the supply chain and that large parts of the supply chain struggle as well. Even though they did not experience major supply shortages or bankruptcies within their supply chains, all three state that their supply chains are noticeably fragile. Interviewee (5) explicitly says:

> *"Our own business is in a very fragile situation, so we had to pass on our own order shortages to our suppliers and they had it further. Right now, it feels that we drag everyone along, but it seems more like a zombie supply chain – dead but still moving."*

and that they are "dragged along" (Interviewee 5). They all expect bankruptcies to happen after the furlough scheme ends. Whereas the interviewees have not experienced supply chain disruption, they have seen customers struggling seriously. Hence, all of them ran risk assessments to decide which orders to fulfil and which better not to but more cost into. Especially interview (4) was concerned about some of their customers not being able to pay their bills.

The major issue for all three interviewees moving forward are skills. Especially interviewee (4) and (5) talk about losses of many highly skilled employees because of redundancies and early retirement schemes. In both cases the companies seemed to be more concerned about cutting costs than strategically think about which skills are needed in the future. This development is increased by the general shortages of specialised skilled workforce in Scotland in general, as mentioned before. Other issues for innovation in the future are very high upfront cost in very turbulent times and in an industry where everything depends on the OEMs willingness to certify innovations.

During the second interview phase the skills shortage and its impact on operations is the most prevalent. All three interviewees state that especially innovation activities are limited because no suitable staff is available either inhouse or on the job market. Interviewees (3) and (5) especially state that it is impossible to hire the amount of skilled people they let go within the early stages of the pandemic within a short period of time. Further, interviewee (5) states:

> *"I have noticed changes in people's attitude. Skilled people are more and more aware of their significance for the sector and of their own work life balance. People tend to jump more from industry to industry if they can get a better deal somewhere else."*

Hence, the aerospace sector needs to make itself for attractive to skilled workforce. Especially interviewee (5) tells of significant downtimes of aircrafts this time caused by staff shortages of airlines and airports reporting in cashflow issues for aircraft manufacturers as they own most of airline planes and simply rent them out. The few innovation activities happening in all three companies are mostly related to sustainability and carbon emission reduction as the sector has embraced the topic as big new trend just like other sectors. However, the resistance to change and regulation in the sector are significant as all three interviewees state. Interviewee (4) states that their focus of future development will be to continue creating and developing other markets moving the business away from aerospace.

5.2.2.2 Food and Drink

During the first round of interviews, interviewees (6), (7), and (8) all have different stories to tell reflecting different Covid-19 experiences across the food and drink sector. (7) and (8), both food and drink producers, state that companies mainly supplying the hospitality sector lost that business over night with little planning options for when the sector would be allowed to open again. In contrast those companies who supply supermarkets saw a stable time with a peak at the beginning of the first lockdown and panic buying as interviewee (7) states. Panic buying in early stages of the first lockdown in 2020 led to supply issues. This trend got especially clear in the case of interviewee (7). Working in the brewery sector they supply pub chains, restaurants, and hotels on the one side but also supply supermarkets as a smaller part of their business. Whereas the big part of the business went to zero, the retail part was massively grown. That in return led to other issues. Interviewee (7) states:

> *"There was suddenly no bottling capacity to get anymore, anywhere. As if that wasn't challenging enough, packaging material, especially cardboard was hard to come by as well, and I am not even talking about the increase in price."*

Interviewee (7) mentions that many players in the sector including themselves either tried to build up new bottling capacities or changed their bottles for cans or kegs. Many players also started online shops in an attempted to directly sell to the end consumer. Interviewee (7) also says that the players who already had an online presence before Covid-19 had a real advantage. The other big topic interviewee (7) talks about is the introduction of a deposit system for bottles in relation to Netzero. However, they ask for more commitment from government side as they say that the sector itself is very fragmented. Further, interviewees (7) and (8) state that the food and drink sector lacks communication and collaboration along the supply chain and between competitors. Interviewee (6), producer of specialised food manufacturing machinery, speaks of a commercially positive situation until the first interview takes place. Their main impact has been on operational level where like all other companies they had to make adjustments to facilitate hygiene and Covid-19 rules set out by the government. Their most significant challenge as interviewee (6) state, was to find a way to install their equipment at customer's sites. They introduced an augmented reality technology to allow customers to set up the machinery themselves with live instructions form company (6). This challenge overcome, interviewee (6) states that they are prepared to deal with the Covid-19 impact until the pandemic and its influence is over.

During the second interview phase all three interviewees state a positive development of their business since the first round of interviews. For all three the direct Covid-19 impact has been overcome. (6), (7), and (8) all continue changes they have made to their business during the pandemic. (7) and (8) keep evaluating their product portfolio and re-positioning themselves in different geographical markets. Especially, interview (7) speaks of focussing on the Scottish market and gaining more market share domestically. (7) and (8) both also aim at developing their overseas markets further. However, both explicitly do not want to grow their EU markets as a consequence of the Brexit uncertainty and complexity of import and export rules. Interviewee (7) says:

> *"During the first lockdown we simply wanted to serve new markets to keep us afloat, we have reevaluated the situation and think that now at the end of the pandemic it is more reasonable to focus on developing our presence in Scotland. […] Other countries will be reevaluated but trading with the EU has become very complex after Brexit."*

Brexit still has a significant impact on all three businesses as they all use European suppliers. (6) and (8) state to continue using their artificial intelligence technology for installation and control of machinery either as supplier or user of machinery. All three interviewees name the rise in energy prices the main challenge for the nearer future, interviewee (8) stating that profitability has been pushed to levels where the business might get into financial trouble. Nevertheless, (8) also states that their order books are seeing significant increases in orders. After all, all three interviewees are looking positively into the future.

5.2.2.3 Chemistry and Pharmacy

The chemistry and pharmacy interviewees (9), (10), and (11) confirm the impressions industry support organisations have during the pandemic. They all operate directly or indirectly in equipment manufacturing for pharmaceutical and chemical use or for hospital supply. They all state a significant increase in business from the beginning of the pandemic. Interviewees (9) and (10) mention the creation of a significant number of jobs. Interview (9) stated explicitly:

> *"Suddenly we had so many more orders that we had to do extra shifts. We decided to hire new staff because we simply could not handle the orders over a longer period."*

The positive situation in the sector during the pandemic is based on two trends as these interviewees state. Vaccine production and the demand for other medical equipment has created significant business. Additionally, pharmacy and chemical companies have taken Covid-19 as a chance to modernise equipment. However, they all doubt that this development is long lasting. They also state that in order to make it last longer and to make Scotland competitive in the sector, there must be more government commitment and permanent changes in public procurement.

During the second interview phase interviewees (9), (10), and (11) all continue to state full order books for the foreseeable future. Whereas this might seem contradictory to their stated fears during the first interview phase, all three clearly state that this positive order situation has lasted longer than originally anticipated but that they do not expect it to continue to last. Most concerned are all three interviewees about the supply chain issues in 2022. Especially shortages of electronics supply triggers massive delays in their own manufacturing processes and therefore payments are delayed. This causes significant cashflow tension. Hence, interviewees (9) and (10) explore diversification options into different markets. Interviewee (10) states he still expects supply chain casualties as late impact of Covid-19. Nevertheless, interviewees (9) and (10) actively used the Covid-19 pandemic to innovate inhouse. Interviewee (9) speaks of digitalising their manufacturing processes on an operations level and of introducing a four-day work week without salary cuts to boost productivity and motivation on a people level. Interviewee (10) speaks of developments of its own innovation centre. Afterall, all three interviewees look positively into the future.

5.3 Answer to research question RQ-R1

The findings of the two-interview series show clear trends over the course of the Covid-19 pandemic as well as challenges for the future for manufacturing in Scotland in general and in the specific sectors in particular. Regarding answering the first part of research question RQ 1, how did Covid-19 pandemic change the innovation behaviour in Scottish advanced manufacturing supply chains, the answer is that innovation has become an imperative across manufacturing sectors and has worked as an accelerator for innovation. Nearly every business had to make changes to some aspects of their business and innovate as a direct or indirect effect of the Covid-19 implications. What exactly these changes and innovations are depends on the individual businesses, but a large variety of innovation types as has been reported. May it be changes in operations to be leaner or to update equipment for productivity purposes, development of new products or services, exploration of business models and new markets, new partnerships, or complete change in strategic direction. Innovation will be a more present and a more important topic moving forward after the pandemic across manufacturing sectors in Scotland.

A clear trend within the innovation imperative theme is the acceleration of introduction of digitalisation. The meta view from industry support just like the direct insights from the sectors show a much higher interest in the topic and how to introduce the digital technologies in various fields of operations. In general, it can be said that those companies who already introduced digital technologies had an easier transition to remote working and social distancing in factories as communication tools and automated machinery were in place.

Another trend within the innovation imperative theme is changing the way people and companies work. Companies across sectors had to introduce ways for their employees to work from home. Whereas most companies do not want to follow a full remote working approach after the pandemic, a major part talks about adopting a blended model to use the advantages of remote working and office-based working alike. After all the wishes and needs of employees are considered much more flexibility is sought to be granted where possible. In this regard there has been much more emphasis on building strong relationships between employees and ensuring that health and well-being is looked after. The trigger here was issues that came along with isolation and complete remote working. However, a more employee centred approach will remain moving forward after the pandemic.

The biggest driver of change in manufacturing after the pandemic is thought to be climate change and the drive to manufacture more sustainably. With society becoming more and more aware of the issue and raised customer interest in sustainable products and services, manufacturers will put more emphasis on their carbon footprint. This trend has the potential to be a new enabler and driver of innovation as the route to NetZero for many companies and supply chains means significant technological changes.

However, there are short-term challenges for innovation arising at the end of the pandemic. The war in Ukraine has caused significant raises in energy prices and inflation, making day to day operations of businesses more expensive which might lead to cuts on innovation activities in the short term. There are also still significant supply chain issues between the UK and the rest of the world, especially the EU. The Brexit implications become clearer after the end of the pandemic. Supply shortages within the electronics sector are caused mainly by local lockdowns in China where Covid-19 politics are much more restrictive even at the end of the pandemic. Afterall, energy, inflation, and supply chain disruption can be called the short-term innovation barriers of after the pandemic.

The biggest long-term challenge moving forward after the pandemic will be skills. The availability of specialised skills, talents, and people was an issue already before the pandemic. The pandemic has increased the level of the issue across manufacturing sectors. Especially, workforce over 50 with significant experience have left the industry for example by taking early retirement. At the same time the apprentice numbers are considerably lower. The companies which already started their digital journey need employees with digital skills beyond traditional manufacturing, which are equally challenging to attract. The skills challenge is expected to be a long-term challenge with no simple solution and could be named the biggest innovation barrier in Scotland.

In regard to the second part of research question RQ 1, which sectors especially need innovation capability support, there is a clear answer. Table 5-4 provides a comprehensive comparison of the findings across the three analysed sectors.

Table 5-4: Comparisons of findings across analysed three sectors

	Aerospace	**Food and Drink**	**Chemistry/Pharmacy**
Impact	Immediate loss of business Laying off large numbers of staff without skill retaining strategy not using furlough schemes in the beginning Long innovation cycles Serious issues of recruiting skills back with an estimated long-term impact	Immediate loss of business Furloughing large numbers of staff in hospitality Short innovation cycles Food and drink producers quickly established new distribution channels Sector bounced back very quickly after lockdowns were lifted	Increased orders from start of pandemic with positive lookout for nearer future Sector adapted quickly with new business models and upscaling in production Significant number of jobs created but issues finding candidates

The worst hit sector in Scotland is undoubtedly the aerospace sector. This is based on the immediate loss of business and the predicted long-term impact of Covid-19 on travel. It is believed that the sector has to change fundamentally quickly and explore new business models. At the same time the industry is characterised by high regulation levels and long innovation cycle and life cycle times. The skills challenge is the most evident in aerospace. Many skilled people were made redundant without a strategic plan of retaining crucial skills, impacting innovation capability even more. The impact of energy prices, the shortages of electronics, and inflation all additionally hit the aerospace sector hard.

The other two sectors of interest after the initial investigation at the beginning of this research, the interviewed companies form the food and drink sector and the pharmacy and chemistry sector, have been proven that they are equipped to handle the implications of the Covid-19 pandemic and seize arising opportunities. The food and drink sector seems to have bounced back after lifting the restrictions while exploring and realising innovation opportunities moving forward. Nevertheless, the sector faces challenges for innovation especially around supply chains and collaboration in the sector.

Consequently, it is the aerospace sector and its supply chains that are in most need of additional innovation capability building. Supporting the development of innovation capability could help and accelerate the recovery in the sector and thereby, stabilise and even create new jobs in this important sector for the Scottish economy. How this could be realised is discussed in the following chapters.

CHAPTER 6

INNOVATION CAPABILITY MATURITY ASSESSMENT

THE FRAMEWORK'S FIELD VALIDATION AS AUDIT TOOL

After the development of MaSCICMAF in chapter 4, this chapter is about the application of the framework. The main reason of the application is the field validation of MaSCICMAF as a diagnostics or audit tool as additional testing of the framework. Additionally, the application of MaSCICMAF aims at answering research question

RQ-P2: What is the status quo of innovation capability in a by Covid-19 hard-hit supply chain?

The hard-hit supply chain in the case of this research is a supply chain from the aerospace sector in Scotland. Following the results of chapter 5, the aerospace sector has been hit hardest in Scotland and requires structural development of innovation capability. Consequently, this chapter aims at analysing the innovation capability of an aerospace supply chain and identify strengths and weaknesses of innovation capability. MaSCICMAF is applied during audit workshops. These workshops are based on semi-structured focus group interviews as data collection method.

The supply chain that is being analysed is a supply chain with four TIER levels which is entirely based in Scotland. Originally planned with four companies representing all four TIER levels, because of economic uptake after the initial Covid-19 lockdowns, only two companies were analysed in the end. The participating companies are the TIER 1 and TIER 2 companies. This is highlighted in Figure 6-1.

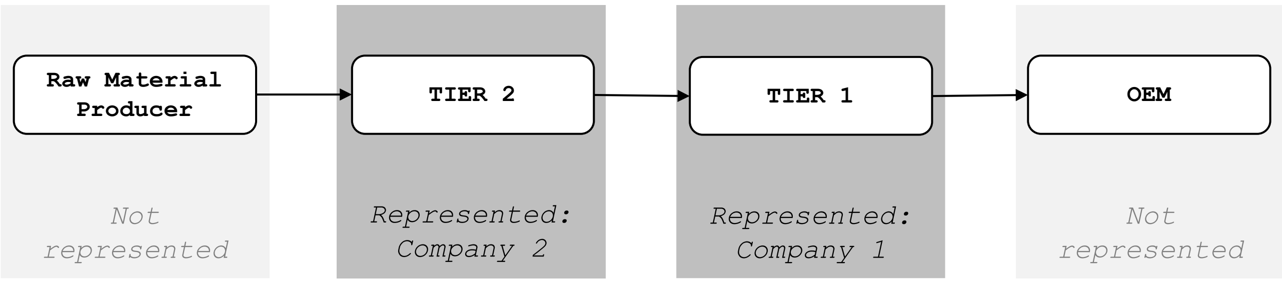


Figure 6-1: Analysed Scottish aerospace supply chain with represented companies

The chapter begins with a review of the research methods applied in this chapter as a reminder of chapter 3. Findings are outlined before they are put into perspective in the following subchapter where research question RQ-P2 is formally answered. The chapter finishes with a reflection of the application of MaSCICMAF and the field validation through the pilot case study.

6.1 Review of the focus group method

The innovation capability measurement is conducted as semi-structured focus group interviews. Focus group interviews have been chosen to reflect different perceptions of different participants of the same situation and help minimize bias (Saunders et al., 2016). These interviews are semi structured to allow a conversation to happen (Bell et al., 2022). The interview is led by an innovation capability expert who asks participants to choose from a set of statements which they believe apply to their organisation or supply chain. The statements are meant to provoke a discussion between the interviewer and the interviewees about each innovation capability dimension to understand the situation in either the company or the supply chain. After this discussion a maturity level of MaSCICMAF is chosen. The set of statements is called questionnaire in this research. The questionnaires for the supply chain and the company scoring model can be found in the appendices A.C6.1 and A.C6.2. The statements are derived from the maturity stages for each innovation capability dimension of MaSCICMAF.

The focus groups are structured in six parts. After an introduction, a first discussion about what participants consider important aspects of innovation capability is hosted. Steps two to four are before mentioned selection of maturity levels including a discussion. Step fife is a final discussion serving as conclusion of the workshop. Step 6 is a formal feedback step.

Innovation capability audit focus group type 1 aims at analysing the innovation capability at company level. A non-probability sampling approach is pursued, ending in the identification of two companies which operate in the same aerospace supply chain in Scotland. They vary in size and position in the supply chain. Company 1 is a large international TIER 1 supplier. Company 2 is a SME operating in a TIER 2 position supplying company 1. For each company a separate workshop is carried out to ensure that the interviewees share the necessary information with the researcher and that there are no concerns about sharing company interna with another company. For the workshops the companies send three to four interviewees. Following a non-probability sampling approach again, these are senior managers with supply chain, research and development, operations, or general management backgrounds as these can provide the necessary information needed for the innovation capability assessment. Details about the participants from both companies can be found in Table 6-2.

Table 6-1 Focus group participants on company level

Company	**Size**	**Tier stage**	**Participant occupation**
Company 1	Large multinational	TIER 1	Operations manager Operations manager Research and development manager Supply chain manager
Company 2	National SME	TIER 2	Managing director Research and development manager Research and development manager

For the supply chain scoring model of MaSCICMAF a single workshop is carried out. The sampling is non-probabilistic here as well. A total of nine experts participates. These experts represent two different public industry support organisations, one private industry support organisation, and three different companies operating in or with the same supply chain as the companies analysed on the company level. The variety of backgrounds ensures maximisation of data from all relevant perspectives. More details about the background of these experts can be found in Table 6-2.

Table 6-2 Focus group participants on supply chain level

Participant	**Role**	**Organisation type**
Participant 1	Aerospace supply chain specialist	Public industry support organisation 1
Participant 2	Manufacturing supply chain specialist	Public industry support organisation 1
Participant 3	Aerospace supply chain specialist	Public industry support organisation 2
Participant 4	Aerospace supply chain specialist	Public industry support organisation 2
Participant 5	Aerospace industry engagement officer	Public industry support organisation 2
Participant 6	Aerospace supply chain lead	Private industry support organisation
Participant 7	CEO	Private company 1
Participant 8	CEO	Private company 2
Participant 9	Managing director	Private company 3

All focus groups are carried out as virtual workshops using Microsoft teams as communication tool and Miro as virtual note board. The decision for virtual focus groups is based on the number of different interviewees' locations, time and cost implications. All focus groups take place between December 2021 and March 2022 and last between two and three hours.

The researcher acts as host and innovation capability expert. For field validation, observation as research method is used. In detail, the participant as observer method is used. This is a suitable method for validation as the researcher can observe first-hand how the application of MaSCICMAF is conducted (Saunders et al., 2016).

Proof of all focus groups as screenshots of Miro-boards can be found in appendix chapter 6.

6.2 Findings

The findings presented in this section adhere to the structure of MaSCICMAF. Therefore, findings are divided into findings derived from the company scoring model and findings from the supply chain scoring model. Full scores of all companies of the company scoring model and the supply chain scoring model can be found in the appendices A.C6.4, A.C6.6, and A.C6.8.

6.2.1 The company scoring model

It is important to recognise that the two companies which are analysed, differ in many aspects. They have a different size, they operate in different supply chain positions, and they follow different competitive strategies. Therefore, a direct comparison of both companies does not make sense. Nevertheless, the findings are presented by innovation capability dimension and subdimensions as outlined in MaSCICMAF. Findings are presented as scoring on the maturity scale of MaSCICMAF along with a justification for the scoring.

6.2.1.1 Organisational culture and leadership

For risk management and attitude both companies are at an adaptive level. Even though both companies use risk management practices, there is little appreciation of risk taking and little acceptance of failure. Ambition, openness to change and promotion of innovation is characterised by high resistance to change in both companies. In both companies the importance of innovation for economic success appears not to be clear throughout the organisations. Hence, this dimension has to be labelled as reactive. Leadership and decision making in both organisations is characterised by highly hierarchical structures and timely decision-making processes. Company 2's leadership is described as participatory whereas company 1's leadership is characterised as autocratic. Consequently, company 1 is labelled as reactive and company 2 as adaptive in this subdimension.

6.2.1.2 Entrepreneurship and strategy

The first subdimension of entrepreneurship and strategy, strategic renewal, appears to be at an adaptive level in company 1. External changes are monitored, and the competitive strategy is adapted accordingly. They use formal change management including defined change processes. Company 2 in comparison is largely not aware of external changes. Both companies additionally state that they do not learn from past mistakes. Given both aspects, company 2 is at a reactive level. Both companies apply lean strategies for their operations. Both do not actively create or manage flexibility. Company 1 even tells of constant firefighting situations because of a lack of flexibility. Consequently, both companies are at a reactive maturity level. Both companies are at an adaptive level for entrepreneurial capability. Both consider new markets, business models and partnerships solely infrequently. Both companies are built on a broad diversity of products, services, and customers which has even increased during the Covid-19 pandemic. Therefore, both companies can be labelled proactive. Supply chain resilience is at an adaptive maturity level for both companies. Both companies use defined processes to select suppliers, but there is no frequent scanning of the supply base. Real-time data from suppliers are not used in both cases. Company 1 uses supplier retention and development programmes for close collaborations. They use defined processes and resources to monitor public funding and the availability of non-financial support from industry support organisations. They also use defined processes for funding applications and access to industry support. Both are accessed frequently. Consequently, company 1 is at a proactive level. Company 2 scans innovation support and funding frequently but there are not enough resources available in house to access these frequently. Hence, they are an adaptive level.

6.2.1.3 Knowledge management and technology adoption

The subdimension knowledge and idea management is on a reactive level in both companies. In both companies, ideas are shared informally but they are not recorded. Both do not assign a special budget for idea management and in both companies, knowledge is bound to the knowledge holder. Technology adoption is on an adaptive level for both companies. Company 1 relies on individuals to stay aware of technological developments whereas the company itself is described as largely unaware of those developments. clear technology search and development strategies are not used in either company. Company 2 creates a good understanding of a technology before its introduction, whereas company 1 introduces new technology without developing a thorough understanding before its introduction. Company 1 on the other hand includes up and down stream supply chain members into the technology adoption process to maximise its value. Company 2 does not consider this.

6.2.1.4 Innovation strategy, communication, and open innovation

Company 1 uses a formal innovation strategy whereas Company 2 does not consider this import. However, both companies report that there are significant resource shortages for innovation activities. Company 1 is consequently at an adaptive level whereas company 2 scores reactive. Open innovation is well adopted within both companies leading to an adaptive level of innovation capability maturity. Innovation collaborations are usually based on individual initiatives in company 2. Nevertheless, they explore new collaborations frequently. These collaborations are reported to not be focussed on longevity. Company 1 in contrast, aims at long lasting collaboration and the development of trusted partners. Exploration of new collaborations are rare.

6.2.1.5 Organisational learning and absorptive capacity (innovation process)

For organisational learning, absorptive capacity and the ability to host innovation processes new potentially useful information and skills are identified across different industry sectors in both companies. However, in company 2 searches are based on individual initiatives. Company 1 reports challenges with handling too much data generated by not using a clear search strategy. Therefore, both companies are at an adaptive level. In company 1 new potentially useful information and skills are shared across the organisation once they are acquired leading to extensive cross departmental problem solving. Company 1 consequently scores proactive. Company 2 encourages cross departmental problem solving as well; however, new knowledge and skills usually remain in the departments that acquire them. Hence, company 2 is at an adaptive maturity level. In both companies, new knowledge and skills are barely integrated into daily operations meaning that the ability to run innovation processes are reactive. The main reason brought forward by both companies is the tight regulation and certification of processes in the aerospace industry which make fast changes impossible. New products and services are explored frequently as exploitation of knowledge. Its realisation is rare in both cases as large financial and time commitments are required needed. Hence, both companies are at an adaptive state.

6.2.1.6 Individual skills and learning

In the first subdimension of individual skills and learning, company 1 is labelled as adaptive whereas company 2 is at a proactive level. Company 1 characterises a medium level of staff as holding deep knowledge in their field of expertise. These function as lead employees. Company 2 states that most employees hold deep expert knowledge in their field of responsibility. Both companies consider it challenging to find suitably skilled staff. Company 1 uses its own apprenticeship scheme, company 2 is planning on developing an apprenticeship scheme. Innovation knowledge is held predominantly by the research and development department in company 1 and company 2 alike. These people lead innovation initiatives. Hence, both companies score adaptive. Both companies describe their staff as very open towards learning. Company 1 however reports little initiative taking whereas company 2 praises its employees for their high initiative taking. Hence, company 1 is at an adaptive maturity level and company 2 at a proactive level. Both companies offer their employees a wide range of learning options. Company 2 limits these activities to learning activities of which the company directly benefits. Company 1 in contrast encourages any type of learning even if it is not directly related to company benefit. Therefore, company 1 is at a proactive level while company 2 is at an adaptive maturity level.

6.2.2 The supply chain scoring model

The findings from the supply chain scoring model assessment refer to the particular supply chain the two analysed companies operate in. The wider Scottish aerospace industry functions as system input.

6.2.2.1 Supply chain structure and governance

Within the dimension supply chain structure and governance, the subdimension fairness and responsibility can be described as proactive. Most companies along the supply chain accept their responsibilities for the functioning of the whole supply chain. Collaboration standards ensure fair treatment of every company and larger corporations do not abuse their market power. The trust between supply chain members is at an adaptive maturity level. Supply chain members generally trust each other based on collaboration contracts and long-lasting partnerships. Changes in partnerships barely happen. There is active communication along parts of the supply chain. Especially communication with direct customers or suppliers in the upper part of the supply chain is actively pursued. SMEs of the lower TIER stages do not have the resources or contacts for frequent active communication with other parts of the supply chain beyond direct partners. Hence, the supply chain can be characterised as adaptive for this subdimension. The aerospace industry is highly regulated for safety reasons. For innovation capability this is a limiting factor as it leads to long innovation cycles, long certification times, and little flexibility and agility as an industry. Consequently, the innovation capability maturity level here is reactive. The supply chain's change and risk attitude scores reactive as well. Change cycles are long and there is significant resistance towards change within the supply chain. Change in the industry is usually associated with heavy investments which meet a highly risk averse attitude. Supply chain complexity of the full international supply chain beyond Scottish borders is high. The supply chain structure is characterised by many TIER layers. This includes companies serving different TIER levels. Hence, the supply chain is at a reactive level for this subdimension. A positive side effect of the high regulation in the aerospace sector is the high supply chain visibility as origins and manufacturing processes for every part are required to be transparent. The maturity level here is consequently proactive. Innovation collaborations happen along the supply chain between trusted partners with a history of collaboration but new collaborations are rare. Hence, the maturity is at an adaptive maturity level.

6.2.2.2 Supply base

The first subdimension of supply base, the supply base resilience subdimension is at a reactive level. This is the case because there is solely a relatively small number of aerospace companies based in Scotland. These are mostly SMEs operating in niches of the industry. As these companies are usually very specialized, they do not have the capabilities and flexibility to easily venture into other industries. High entry barriers to the aerospace industry make it difficult for new companies to enter the market. Capabilities for the introduction of new technology are widely existent, however technology uncertainty, high regulation, and high costs significantly limit the actual introduction of new technology. Hence, the maturity level of this subdimension can be described as adaptive.

6.2.2.3 Public supply chain support

For the first subdimension of public supply chain support, it is stated that public funding is available for many different purposes. However, purposes are usually very precise and therefor limited in purpose. Thus, they offer little flexibility for public funding organizations to support initiatives outside these boundaries. Especially within the SME community of the supply chain the awareness of public funding is limited. Application processes are described as too time and resource intense to be viable options for many SMEs. The broad availability of funding options however leads to an overall adaptive level. Industry support organisations offer relevant expertise in many areas which are relevant for the aerospace industry. However, the capacities are limited as industry support organisations suffer from the same skills shortage that individual companies suffer from. There are large skill development programmes in development already, a quick improvement of the situation is unlikely, however. The overall level can be described as adaptive.

6.3 Answer to research question RQ-P2: The status quo of innovation capability of an aerospace supply chain

To answer research question RQ-P2: What is the status quo of innovation capability in the aerospace supply chain in Scotland, in the following strengths and weaknesses in innovation capability of the supply chain are discussed based on before described findings.

Strengths and weaknesses are presented as the nature of the study is qualitative and no simple 'good' or 'bad' label can be used. It is also qualitative in nature because the research is a pilot case study for MaSCICMAF. This means that there is simply no reference point from other supply chains. Hence, it is also at this point in time not possible to say if this supply chain's innovation capability is better or worse than the innovation capability of other supply chains. This is a significant limitation of the relevance of the collected data but is normal for a pilot case study for maturity models (De Bruin et al., 2005). The application of MaSCICMAF in the future in other supply chains will generate this reference point and establish a benchmark.

6.3.1 Strengths

There are three main strengths evident in this supply chain. First of all, there is significant collaboration along the supply chain. Not all parts of the supply chain are necessarily connected but in parts there is collaboration that is based on longevity. These collaborations are characterised by mutual trust, reliability, and no market power abuse. The collaborations focus more on day-to-day operations and supply chain management than on joint open innovation activities. However, the partnerships are established and build a significant base for open innovation.

The next strength is the good supply chain visibility. As a side effect of the high regulation in the aerospace sector, the supply chain is completely transparent. Thus, every company and their capabilities can easily be identified. This is a good base for establishing new partnerships as finding the right partners is significantly easier than in other sectors. However, this just applies to companies already operating in the aerospace sector. If capabilities are needed which are only offered outside the sector visibility is not as high and complicates finding new partners.

The third strength is the supply chains attitude towards learning. Individuals are encouraged to learn and build new capabilities. This is a useful base for innovation on an organisational level. This learning attitude just needs to be transferred to the companies and the supply chain as an organisation as well.

6.3.2 Weaknesses

The main weakness in the supply chain as an organisation as well as in the individual companies is the high resistance to change. This affects all decision making along the supply chain and thus hinders change and therefore innovation from happening. Especially in times of industry 4 where connectivity of companies is key to success, collaboration, open innovation activities and joint change initiatives are required. Long innovation cycles in the industry support resistance to change as change does not have to be lived in the day-to-day business. Innovation as a topic does not seem to be important to the supply chain and its companies. Whereas they state it is, they do not live innovation, they do not actively create innovation strategies and do not allocate sufficient resources. Under the dominant lean cultures this is all considered unnecessary waste. This also leads to no active encouragement of raising ideas and of recording them.

The size of the aerospace industry in Scotland is another disadvantage for innovation capability. The existing industry solely covers certain parts of the whole aerospace value chain that is needed to produce whole aircrafts. This means that there are gaps in capabilities which make Scotland unattractive for international OEMs as they can get a better capability base elsewhere. The size of the industry in Scotland and the limited capabilities also impact the sector's resilience. Tightly connected to this is the skills shortage in workforce. Skilled workers for this sector as for others are hard to come by. This leads to more skills shortages as existing workforce retires and cannot be replaced. This is a challenge that the individual companies try to solve by providing apprenticeship schemes and training their own skilled workforce, also the NMIS skills academy has been opened to train more people. However, the issue remains significant.

Another disadvantage for innovation capability in the supply chain is the high regulation. High regulation ensures safety in this case and is necessary. However, as everything – new products, new process, etc – needs to be certified. The introduction of innovation is time and resource intensive. Certification is usually carried out by large OEMs for their suppliers, and they only invest time and money in certification processes if they are convinced of the innovation's benefit. Thus, many ideas, especially more future focussed without quick return on investment, might be lost. The regulation cannot and should not be changed, but the attitude towards certification can be changed.

Lastly, current public funding practices are a disadvantage for innovation capability of the supply chain. Public funding practices at present are complicated to understand especially for small businesses. They require time and resource investment while decision making process take a long time. Funding is largely provided for specific purposes or for specific funding calls. TO support innovation capability funding rules, decision making times, and especially funding constraints need to be eased.

6.4 Evaluation of innovation capability measurement with MaSCICMAF

Field validation of the MaSCICMAF has two aims. Validate the framework itself by practitioners and validate the application method. For this purpose, an intellectual arbitrage approach had been chosen with the workshop host or researcher being an observer to the research while the participants reflect on the framework and its application after the workshop through a feedback questionnaire. Said questionnaire can be found in the appendix A.C6.9. A total of twelve questionnaires were returned from participants of the company workshops and the supply chain workshop. This constitutes in a 70% return rate.

For content validity, the field validation largely confirms the expert validation of MaSCICMAF in chapter 4. Feedback confirms the validity of innovation capability dimensions and the maturity stage stating that there was no general request to add the dimensions or maturity stages within the company scoring model or the supply chain scoring model. However, as clarifying questions about terminology were encountered during the focus groups, food back has been taken into account and formulations have been adapted, leading to a revised framework after the focus groups. Relevance of innovation capability dimensions score a 4.2 and the maturity stage descriptions score a 4.3. Both were measured on a Likert scale of one to five. However, it was mentioned to include a total of five maturity stages as five stages are frequently used for maturity models and as five stages would provide more granularity than only three.

In terms of validating the application method of MaSCICMAF, the workshop design proved reasonable. Especially the warm-up exercise about innovation capability was a valuable preparation activity for the application of MaSCICMAF. During all workshops, some participants struggled with letting go of their day-to-day thinking, freeing their minds, and diving into innovation capability regardless of what it meant to them before. The exercise helped creating a common understanding of innovation capability. It also helped to reduce bias.

The questionnaires as audit tools also fulfil their purpose. The statements led to discussions around the different innovation capability subdimensions. However, not all statements are understood fully in every case and need additional explanation.

For accuracy of data reasons, the semi-structured focus group interview process is reasonable and as shown leads to a large amount of detailed data. However, this approach is limiting the attractiveness of MaSCICMAF to practitioners. The resources companies and supply chain representation have to invest in term of senior staff and their time is significant. This has been identified as the main reason why only two companies could be attracted to conduct the assessment, even though advantages and impact on potential companies would have been significant.

For easier innovation capability assessment of supply chains, it is recommended to adapt the application method. An approach should be picked where the company scoring model application can be done fully online without guidance and without an interviewer who can ask questions or clarify unclear statements. Once the supply chain scoring model assessment is conduct in the way it has been suggested in this research, the company scoring model assessment could be sent to companies in the supply chain for one senior staff member to fill in when it suits them. Thus, it is hoped to attract more companies, to make collected data more representable. A side effect of an automated online assessment would be the speed of data collection. A downside, however, would be the quality of data, as no interviewer would be available for clarification during the audit process. Another disadvantage would be, that company representatives might be biased in the interpretation of their own innovation capability and submit false information.

Hence, more research in other ways of applying MaSCICMAF are needed. Afterwards, in terms of De Bruin et al. (2005) methodology for the development of capability maturity models, MaSCICMAF needs to be deployed in many supply chains to establish it as a standard model, raise its relevance to practitioners.

CHAPTER 7

PROPOSING A METHODOLOGY: FUTURE SCENARIO STRATEGIZING

MaSCICMAF itself is a diagnostic tool which analyses the status quo of innovation capability of single organisations and supply chains. Whereas the diagnosis itself is helpful to understand the shortcomings in the present, it does not allow any thinking about what to do with these shortcomings. This chapter proposes a methodology to allow exactly that, to increase the value of MaSCICMAF for practitioners. Effectively, a strategizing approach is followed to systematically develop innovation capability based on the outcome of the application of MaSCICMAF.

Proposed is future scenario-based strategizing by Wright et al. (2013). This approach essentially allows the creation of internal strategies to react to potential external developments. These potential external developments are presented by a set of future scenarios. Once scenarios are developed, either strategizes of a company or strategizes of a supply chain decide which innovation capabilities they want to develop further for each scenario. Strategic objectives and actions are derived and planned for each scenario. Depending on which scenario is closest to real developments as time moves forward, planned actions can be implemented. If real developments change to being closer to another scenario over time, planned strategic actions for this scenario can be implemented. Figure 7-1 shows the proposed methodology graphically.

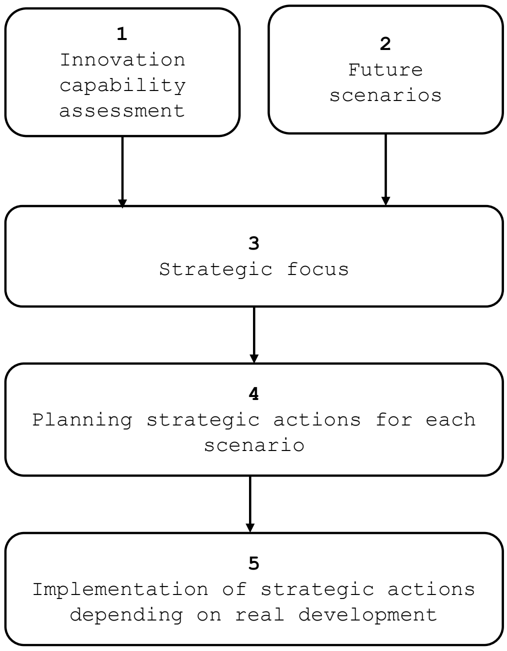


Figure 7-1: Methodology for innovation capability improvement strategy building

At the heart of this approach lay scenarios. What scenarios are in detail and why this approach is suitable for this research are explained in detail in chapter 3.4. A short summary of what scenario strategizing is and how it is applied in this research is provided at the beginning of this chapter. The result of this chapter is a set of four scenarios for possible and plausible developments of manufacturing in Scotland. These are necessary for developing strategies in the following chapter.

7.1 Review of the scenario development methodology

Future scenarios are a methodology that is frequently used to prepare organisations for potential futures and enhance their flexibility to react to these futures (Hiltunen, 2009). The methodology is frequently applied for strategy making in different domains ranging from business to military (Amer et al., 2013). Kahn and Wiener (1967) define future scenarios as:

"a set of hypothetical events set in the future constructed to clarify a possible chain of causal events as well as their decision points".

Future scenarios are a set of possible and plausible futures as reflecting an organisation's changing environment as a result of different trends and their combinations (Amer et al., 2013, Schoemaker, 1995, Fontela and Hingel, 1993). Scenarios aim at capturing all plausible future developments. The range of possible outcomes is a reflection of uncertainty of the future (Pillkahn, 2008). Reflecting all plausible futures, helps future strategizing in a holistic way (Jetter, 2003).

For this research the intuitive logics methodology proposed by Wright et al. (2013) is used to create a set of four scenarios. A set of four scenarios is considered the best cost vs accuracy of scenarios ratio (Pillkahn, 2008). Wright et al. (2013)'s methodology consists of seven steps to create scenarios which can be found in Figure 7-2.

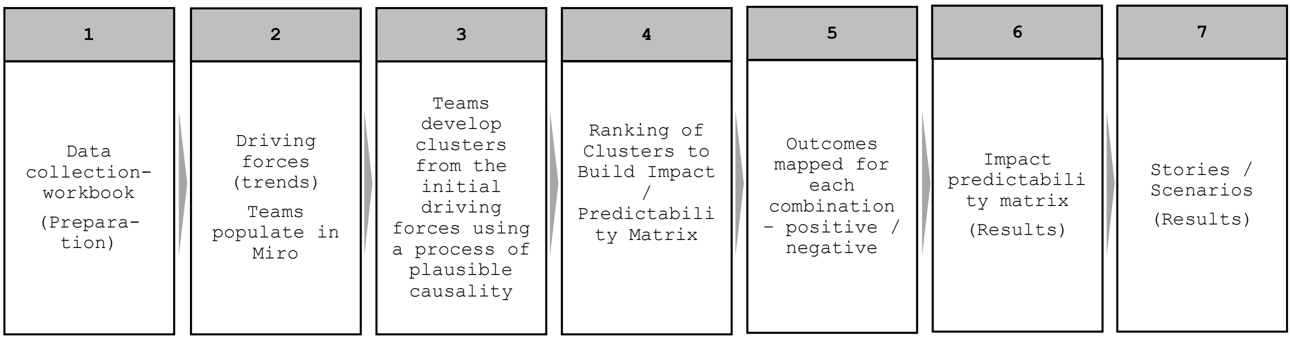


Figure 7-2: Scenario development methodology proposed by Wright et al. (2013)

Whereas the steps two to six are carried out by an expert team in scenario development workshops, step 1, data collection is carried out by the researcher as preparation, and step 7, creation of narratives is also carried out by the researcher with feedback from the workshop participants. The workshops themselves are hosted by an external scenario development specialist as process familiarity is required. The researcher acts here as participant as well. As the scenarios aim at describing the future of manufacturing in Scotland for use in an innovation capability context, experts represent the fields of supply chains management, innovation, strategy, as well as one scenario development specialist who leads the development of the scenarios. All participants are based in Scotland and work directly in manufacturing or have a strong connection to manufacturing. Table 7-1 shows the experts' backgrounds and professional roles in detail.

Table 7-1: Expert panel for developing scenarios for the future of Scottish manufacturing

Expert	Area of expertise	Role
1	Innovation and operations management	Academic
2	Innovation and operations management	Practitioner
3	Innovation ecosystems	Academic
4	Corporate strategy	Academic
5	Corporate strategy	Academic
6	Supply chain management	Practitioner
7	Supply chain management	Practitioner
8	Scenario development	Academic

Due to the Covid-19 pandemic the workshops are executed online using Microsoft teams for communication and Miro as a virtual note board. In total, three workshop sessions are carried out in June 2021, each lasting about two hours. Proof of these workshops can be found in form of screenshots of the Miro-boards used during the sessions in appendices A.C7.3 and A.C7.4.

7.2 Four scenarios for the aerospace industry in Scotland in 2036

As a result of the application of before described methodology, a total of four scenarios have been developed. These scenarios are set to describe the possible evolution developments of the Scottish manufacturing sector, covering all plausible developments. It has been decided to set the scenario horizon to fifteen years, ending them in the year 2036. A fifteen-year time horizon has been adopted for a number of reasons. First of all, fifteen years is an average time horizon for scenarios, which is frequently used for broad developments (Martelli, 2001). As the scenarios depict possible developments of a whole sector in a whole country this time horizon, consequently, seems reasonable. The other reason is that innovation capability as discussed before, is highly connected with company culture. Kotter (2012) state that changing company cultures is a timely endeavour and can easily take years in larger corporations. Therefore, it is reasonable to choose a longer time horizon from the perspective of building innovation capability built on these scenarios as well.

As basis of the scenario a workbook is developed, that contains literature highlighting key issues for the future. The main themes that emerge from the gathered data are:

1. Economic environment
2. Social environment
3. Political and legal environment
4. Technological and innovation environment
5. Ecological environment
6. Supply chain trends
7. Technology trends
8. Capabilities and workforce
9. Manufacturing industry
10. Brexit
11. Trends and drivers of the manufacturing industry after COVID-19

Based on these topics, different drivers are identified, which are clustered in a total of nine driving forces (DF). These driving forces can be found in Table 7-2. They are characterised in the following. A full detailed characterisation developed during the workshops can be found in the appendix A.C7.1.

Table 7-2: Driving forces for future scenarios for manufacturing in Scotland in 2036

Critical driving forces	**Non-critical driving forces**
DF1 Innovation and diffusion	DF3 Workforce and capabilities
DF2 International trade and relationships	DF4 Availability of finance
	DF5 Political environment
	DF6 Technological infrastructure
	DF7 Supply base
	DF8 Supply chain governance
	DF9 Sustainability and climate change

DF1 'Innovation and diffusion' refers to the level of development of innovation in Scotland and the diffusion of innovation throughout the manufacturing industry. This comprises research activity in the industry and academia and their collaboration. It comprises the ability to translate the research into the development of innovation and the ability to commercialise new developments. It also includes the ability to identify and adopt new technology nationally and internationally and implement the new technology.

DF2 'International trade and relationships' refers to Scottish manufacturing in an international context. It includes how international partnerships and trade agreements develop, especially between the EU and the UK. It involves the ability to import from outside the UK, it involves the cost of transport and the stability of international supply. It also comprises the impact of international competition on Scottish manufacturing and to what extent Scotland benefits from international supply chain governance and innovation ecosystem governance.

DF3 'Workforce and capabilities' refers to companies' ability of attracting new workforce. This includes the attractiveness of living and working in Scotland, immigration barriers for foreign talent, salary and cost of living levels. But it also includes the availability of relevant training programmes to develop skilled workforce domestically, and the perception of manufacturing in Scotland.

DF4 'Availability of finance' refers to the level of public and private funding available and accessible to the manufacturing sector in Scotland. This includes local, national, and international sources. It also includes volatility on the financial markets including inflation.

DF5 'Political environment' refers to the stability of politics in Scotland. This refers to a potential new independence referendum, but it also refers to levels of nationalism and socialism in Scottish politics. It also includes the political interest in manufacturing as a sector and in entrepreneurship initiatives.

DF6 'Technological infrastructure' comprises the use of technology across the manufacturing industry in Scotland. This includes the use of advanced manufacturing technology to offset high labour costs for example. It also includes the use of communication technology along the supply chain to connect whole supply chains on a technological level. As an enabler the development communication infrastructure like digital communication networks is included as well.

DF7 'Supply base' refers to the resilience of the whole of the manufacturing sector in Scotland and its capabilities. This includes the availability of capabilities needed for all levels of the supply chain. It also includes the technology infrastructure and the ease of good transport.

DF8 ‘Supply chain governance’ refers to how much Scottish manufacturing benefits from supply chain governance practices of international supply chains. This includes the nature of ownership of companies, the number of OEMs operating in Scotland who drive supply chain governance, the participation in the sharing economy, collaboration and data sharing.

DF9 ‘Sustainability and climate change’ refers to the perception of climate change and the importance of sustainability. This refers to the manufacturing industry’s perception as well as general public perception. It includes how customer and stakeholder wants and needs change. It also includes technological and management innovation in the field and how policy making supports their development and adoption.

The expert panel decides that the driving forces DF1 ‘innovation and diffusion’ and DF2 ‘international trade and relationships’ are the driving forces with the highest impact and uncertainty and are therefore considered the two critical driving forces. Voting outcomes can be found in the appendix A.C7.2. Based on this decision the impact-uncertainty matrix is created with DF1 ‘innovation and diffusion’ on the x-axis and DF2 ‘international trade and relationships’ on the y-axis. This leads to four quadrants representing four different combinations of positive and negative developments both critical driving forces. Figure 7-3 shows the impact-uncertainty matrix including where which scenario is located on the grid.

The four developed scenarios shown in Figure 7-3 are explained in the following. They cover the full spectrum of plausible futures for Scotland’s manufacturing in 2036. The full narratives can be found in the appendix A.C7.5.

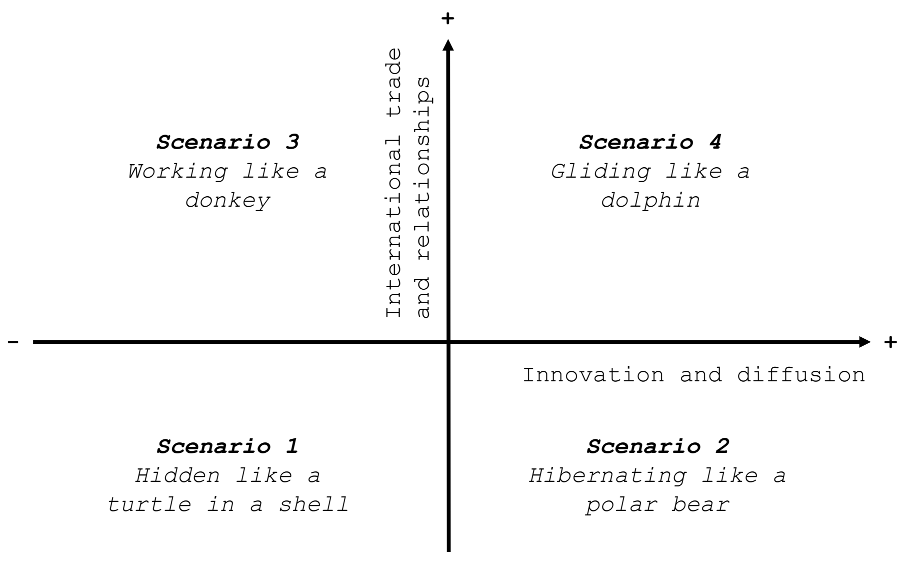


Figure 7-3: Overview over the developed future scenarios

7.2.1 Scenario 1: Hidden like a turtle in a shell

Scenario 1 – hidden like a turtle in a shell – is the most negative scenario out of the four. It refers to a world where international trade with Scotland is very limited and where good international relationships are a matter of the past. The UK and Scotland have closed themselves off. At the same time innovation activities and the diffusion of innovation are at low levels as well. This means Scotland's manufacturing does not actively renew itself. In a world of isolation and inactive innovation Scotland struggles to attract needed talent from other countries. Domestic talent frequently leaves for England or even abroad. Manufacturers suffer from old, unfit for purpose equipment. They struggle to attract foreign direct investment. Therefore, manufacturing supply chains in Scotland are not able to compete internationally. Scotland is like a turtle – hiding from the world in its shell. Figure 7-4 shows a more detailed version of the scenario.

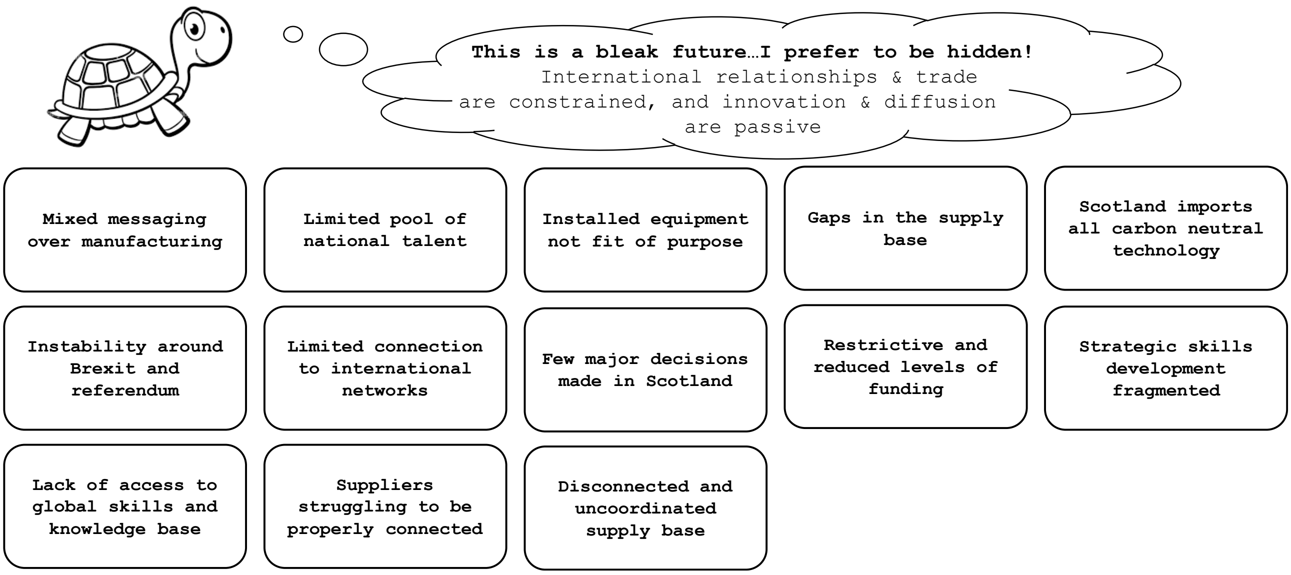


Figure 7-4: Hidden like a turtle in a shell scenario

7.2.2 Scenario 2: Hibernating like a polar bear

Scenario 2 – hibernating like a polar bear – refers to a world in which Scotland is as isolated internationally as in scenario 1. However, manufacturers in Scotland are very innovative. They develop new innovations themselves and they actively seek to spread innovation. It is still challenging to attract international talent to Scotland. But in this scenario, there are good education programmes in Scotland aiming at closing the skills gap. Manufacturing equipment is cutting edge. Public funding is extensively available for national development projects. Nevertheless, Scotland is cut off international markets making real capitalisation on the innovation impossible and Scottish manufacturing supply chains cannot compete internationally. Scotland is like a polar bear – strong but hibernating waiting to be awakened. Figure 7-5 shows a more detailed version of the scenario.

Figure 7-5: Hibernating like a polar bear scenario

7.2.3 Scenario 3: Working like a donkey

Scenario 3 – working like a donkey – describes a Scotland that is well connected in the world and where international trade flourishes. However, just like in scenario 1, innovation and the diffusion of innovation are at low levels, meaning Scottish manufacturers use unfit for purpose or innovations are imported from elsewhere. Largely, Scotland cannot compete on technology. International trade agreements undermine Scottish manufacturing, but Scotland can compete on labour cost. This leads to a race to the bottom culture. Good international relations allow talented but unqualified workforce to come Scotland. Funding is just available through direct foreign investments of large international corporations. Scottish government does not invest in manufacturing. Scotland is working like a donkey – hard but not smart. Figure 7-6 shows a more detailed version of the scenario.

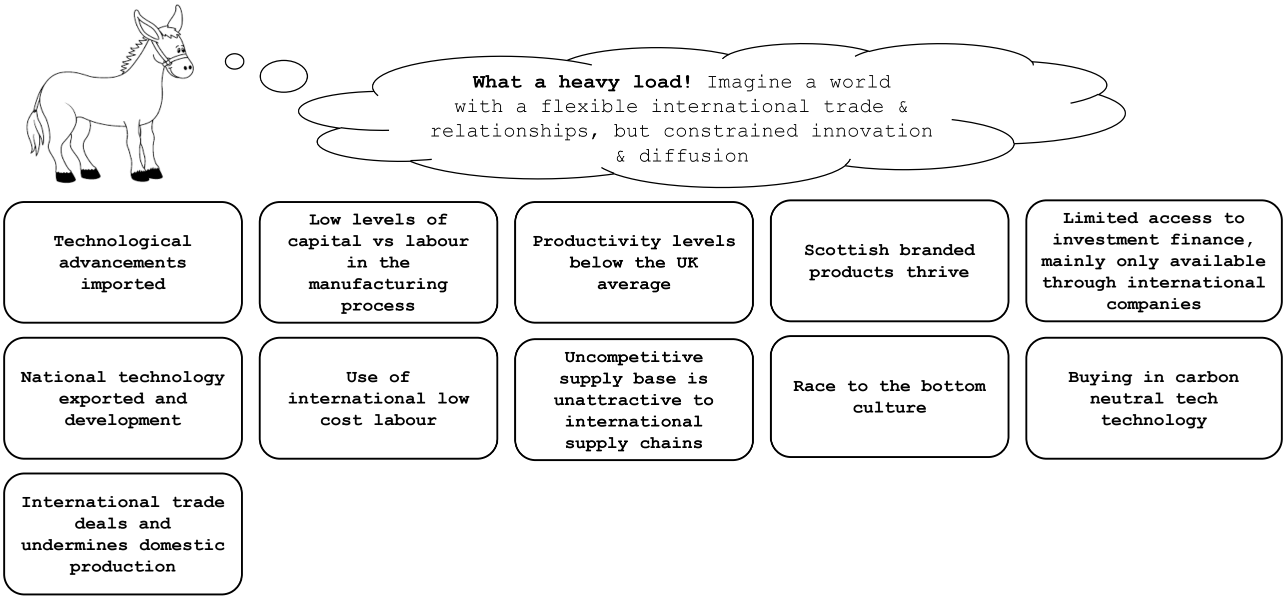


Figure 7-6: Working like a donkey scenario

7.2.4 Scenario 4: Gliding like a dolphin

Scenario 4 – gliding like a dolphin – describes a world where Scotland is well connected internationally and is part of international trade agreements. Scotland's manufacturing is also characterised by high levels of domestic development of innovation and active spread of innovation throughout the industry. In this scenario, there will be suitable training programmes to fill skills gap. As there are well-paid job opportunities for well-educated workers, Scotland easily attracts the needed workforce from national and international sources. The good international relations ease visa processes. Funding is available through large multi-national companies willing to invest in Scotland due to the high competitiveness of its manufacturing. The Scottish government also invests heavily in domestic innovation projects specifically supporting the development of supply chains. Manufacturing companies use mostly industry 4.0 equipment connecting whole supply chains beyond Scottish borders digitally. Scotland will be a recognised manufacturing country for its capabilities. Everything is going smoothly – like a dolphin gliding through the water. Figure 7-7 shows a more detailed version of the scenario.

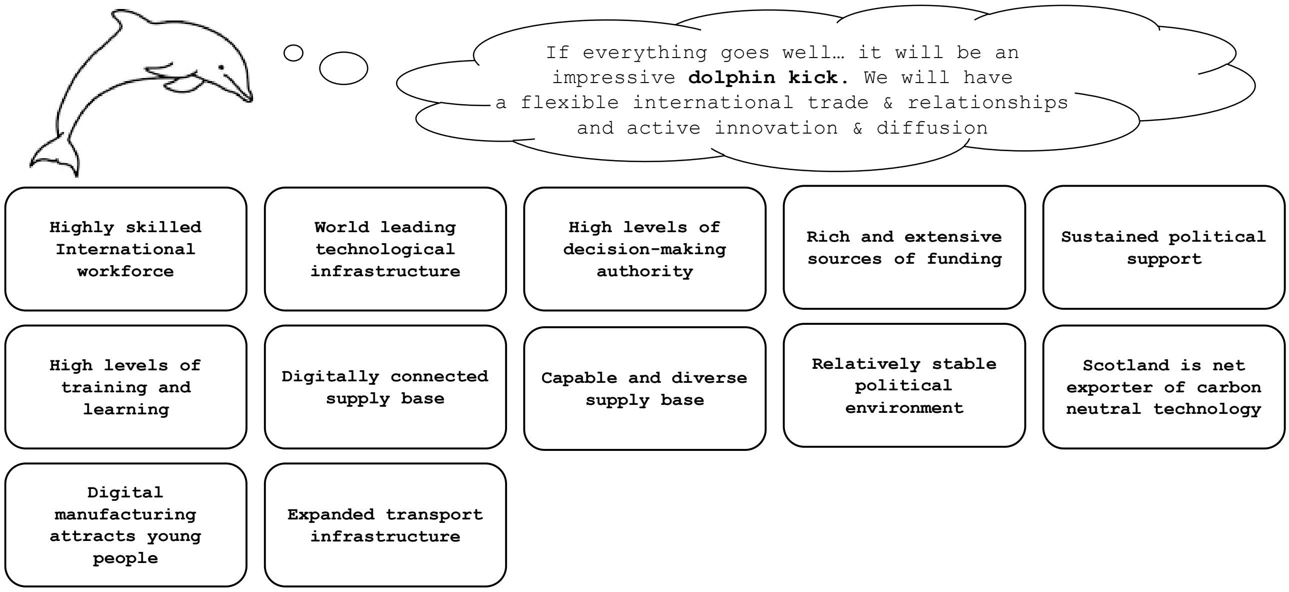


Figure 7-7: Gliding like a dolphin scenario

7.3 Conclusion

This chapter aims at extending the value of MaSCICMAF for practitioners by proposing a to integrate MaSCICMAF in a wider strategizing methodology. This methodology is based on the future scenarios approach. The approach allows strategic development of innovation capabilities in relation to potential future scenarios. For application of this methodology, scenarios had to be developed in preparation. This chapter proposes four scenarios for manufacturing in Scotland in the year 2036. As they are for general manufacturing they can be used for all subsectors. However, they might need small adjustments as not all general developments are important for all subsectors. Nevertheless, the developed scenarios and before developed MaSCICMAF allow now the application of the innovation capability assessment and the strategizing process on company and on supply chain level. This is the subject of the following chapter 6.

CHAPTER 8

STRATEGIZING FOR INNOVATION CAPABILITY IMPROVEMENT

THE FRAMEWORK'S FIELD VALIDATION AS STRATEGY TOOL

After the audit of innovation capability and the determination of its status quo in an aerospace supply chain in Scotland in chapter 6 and the development of four future scenarios for potential future developments of Scottish manufacturing until the 2036 in chapter 7, this chapter aims at developing strategies to improve said status quo in relation to the developed future scenarios. Effectively, in terms of a SWOT analysis, strategies are created which help improve internal strengths and weaknesses in innovation capability to react to external threats and seize external opportunities. Hence, this chapter aims at answering research question

RQ-P3: How can innovation capability be improved in this aerospace supply chain?

Scenario strategizing is the additional step in the methodology by Wright et al. (2013) for developing scenarios which is used to create the future scenarios for this research. The chapter starts with reviewing what the scenario strategizing approach is and how it is applied in this study as reminder of chapter 3. As creating improvement strategies is the next step after determining the status quo, research is carried out with the same audience in a similar setting as in chapter 6. Strategies for each scenario are presented to formally answer research question RQ-P3. These are then translated into advice for policy making to support the strategies in the best way possible, answering research question

RQ-P4: What can policy makers do to support innovation capability of this aerospace supply chain?

The strategizing workshops can also be considered a pilot study for the applicability of scenario strategizing for innovation capability building with MaSCICMAF. Therefore, at the end of the chapter it is reflected on its application and suggestions for improvements for future application are provided. Effectively, this chapter serves as field validation of MaSCICMAF as strategy tool as well as validation of the applicability of the scenario approach for innovation capability building.

It is important to state that this chapter has been published in parts in the following conference publication:

Reckordt, T. (2022). Future scenarios: An experiment to strategic innovation capability building. In *ISPIM Conference Proceedings* (pp. 1-11). The International Society for Professional Innovation Management (ISPIM).

8.1 Review of the scenario strategizing method

Scenario strategizing aims at creating strategies for different scenarios. In detail, each created strategy should be an organisation's internal reaction to the external impact that the developments stated in each scenario have on the organisation. Scenario strategizing is the extension to the future scenario development approach discussed in chapter 7.

Hence, here again, the approach by Wright et al. (2013) is followed. This approach suggests creating strategic actions for each scenario for each driving force development. As the present research aims at developing innovation capability strategically, based on the results of the innovation capability audit focus groups in chapter 6.

Strategizing is conducted as a strategizing workshop. As for the innovation capability audit focus groups, one strategizing workshop is conducted for each company for the company scoring model of MaSCICMAF and one strategizing workshop is conducted for the supply chain level.

The strategizing workshop is carried out in different steps. At first the scenario development and strategizing approach is explained. Participants are asked to set a focus in terms of which scenario they want to focus on mainly and which innovation capability dimension is most important to them. This serves as a starting point to derive strategic actions. One by one all scenarios are covered. A final discussion serves as summary of the actions and for planning next steps.
After the workshop participants are asked to provide feedback on how useful they find the workshop, the scenario strategizing method in the applied way, and where they think improvements could be made. This feedback is a structured questionnaire. It serves as base for validation of the framework as strategy tool and of the scenario strategizing methodology as useful methodology for strategizing for innovation capability building.

The participants of each strategizing workshop are the same as for the audit focus groups conducted for the innovation capability assessment. An overview of participants of both companies for the company scoring model can be found in Table 8-1.

Table 8-1: Workshop participants for strategizing for the company level

Company	Size	Tier stage	Participant occupation
Company 1	Large multinational	TIER 1	Operations manager
			Operations manager
			Research and development manager
			Supply chain manager
Company 2	National SME	TIER 2	Managing director
			Research and development manager
			Research and development manager

Participants of the supply chain group for the supply chain level, covering different public and private industry support organisations for the aerospace sector in Scotland and a total of three companies operating this supply chain, can be found in Table 8-2.

Table 8-2: Workshop participants for strategizing for the supply chain level

Participant	Role	Organisation type
Participant 1	Aerospace supply chain specialist	Public industry support organisation 1
Participant 2	Manufacturing supply chain specialist	Public industry support organisation 1
Participant 3	Aerospace supply chain specialist	Public industry support organisation 2
Participant 4	Aerospace supply chain specialist	Public industry support organisation 2
Participant 5	Aerospace industry engagement officer	Public industry support organisation 2
Participant 6	Aerospace supply chain lead	Private industry support organisation
Participant 7	CEO	Private company 1
Participant 8	CEO	Private company 2
Participant 9	Managing director	Private company 3

Workshops are conducted online using Microsoft Teams and Miro as virtual note board. Each workshop takes about 3 hours each. Proof is provided in from of screenshots of the Miro boards used during the workshops which can be found in appendices A.C8.1, A.C8.2, and A.C8.3.

Once strategies are developed for the different companies and the supply chain for improving innovation capability, recommendations for policy makers in Scotland are developed. They are derived from the strategic actions as well as from the outcome of the status quo of the innovation capability assessment in chapter 6 and the results of the interviews conducted in aerospace sector in chapter 5. As analysis method inductive thematic coding is used. Categories within the frame of coding and unit of analysis are developed. To create categories a thematic analysis approach is used, with the following codes:

- Open innovation
- Supply chain resilience
- Funding
- Skills shortage and education

For field validation of the scenario strategizing methodology for innovation capability development, observation as research method (Saunders et al., 2016) is used again in the same way it is used in chapter 6. To ensure reliability and validity of the collected data, the intellectual arbitrage approach is followed again (Van de Ven and Johnson, 2006). The participant as observer method leads to primary data and the qualitative feedback from other participants leads to secondary data.

8.2 Answer to research question RQ-P3: Strategies for innovation capability improvement

In this section the strategic actions in relation to each scenario are explained. These are explained for each company as well as for the supply chain level always referring to the innovation capability dimensions (ICD) outlined in chapter 4. However, during the workshops it became clear that certain innovation capability dimensions are wanted to be developed for all scenarios or in other words regardless the scenario.

It is important to state that the scenario strategizing methodology solely identifies strategic actions. In other words, the 'what' is identified. How these actions can be implemented in a business, or a supply chain is an operational question and is not part of this study.

8.2.1 Company 1

As a starting point to developing strategic actions for all scenarios, company 1 decides to develop a set of actions which they want to realise for all four scenarios alike. The scenario that they consider the closest to the present is scenario 3 'working like a donkey'. Hence, during the development of strategic actions, actions for all scenarios alike and scenario 3 have preference. However, the scenario that they believe requires the most intervention is scenario 1 'hidden like a turtle in a shell'. A total of twenty-one strategic actions is developed. The number of actions is used as indicator of how important a scenario is to the company as the impact of an action depends on implementation which is excluded from the study. Table 8-3 shows how many actions are related to which scenario.

Table 8-3: Number of strategic actions per scenario (actions can aim at more than one scenario)

Scenario	# strategic actions (Total 21)
For all scenarios	10
1 – Hidden like a turtle in a shell	8
2 – Hibernating like a polar bear	3
3 – Working like a donkey	6
4 – Gliding like a dolphin	2

Within the developed strategic actions, there is a clear focus on innovation capability dimension C4 ‘Innovation strategy, communication, and open innovation’ which accounts for 15 strategic actions, two of these also refer to ICD C2 ‘entrepreneurship and strategy’. Three strategic actions are related to ICD C3 ‘Knowledge management and technology adoption’. Table 8-4 shows how many actions are developed in relation to which ICD. Strategic actions can be used for more than one scenario and can address more than one ICD.

Table 8-4: Number of strategic actions in relation to ICDs (actions can aim at more than one ICD)

ICD	Subdimension	# strategic actions	Current IC maturity level
C2 Entrepreneurship and strategy	C2.5 Accessing of innovation support and funding	2	3 – proactive
C3 Knowledge management and technology adoption	C3.1 Knowledge management, idea management, and knowledge sharing	1	1 – reactive
	C3.2 Technology adoption strategy and processes	2	2 – adaptive
C4 Innovation strategy, communication, and open innovation	C4.1 Clear innovation strategy aligned with company strategy and innovation measurement and adequate recourse allocation	4	2 – adaptive
	C4.2 Cooperation with suppliers, customers, public institutions, and openness to share information and to adopt new outside knowledge	14	2 – adaptive
C6 Individual skills and learning	C6.1 Individual skills in one’s field of knowledge	1	2 – adaptive
	C6.4 Availability of options for individual learning	1	3 – proactive

In the following the strategic actions in relation to the different scenarios and the ICD they target are presented scenario by scenario. Strategic actions target ICDs of different innovation capability maturity levels regarding the assessment in chapter 6. A full list of strategic actions for company 1, for which scenario they are meant, and to which ICD they relate, can be found in Table 8-5, screenshots of the Miro board can be found in appendix A.C8.1.

The focus of strategic actions which should be realised regardless of the scenarios lays on developing a more refined innovation strategy referring to ICD C4.1 which currently is at an adaptive maturity level. This strategy seeks to strengthen their NetZero agenda, including technological changes as well as business practices. This also includes collaboration across industries to develop standards for sustainability practices for easier supplier selection referring to ICD C4.2 which currently is at an adaptive maturity level as well. On a skills level for all scenarios, company 1 wants to understand their current capabilities and expertise better and use the status quo to derive training programmes for staff for directed development of individual skills This aims at improving ICD C6.1 which is at an adaptive maturity level at present and ICD C6.4 which already is at a proactive level. They aim at repeating this exercise periodically. As important impact, changes in the political environment are meant to be communicated across the company. For all scenarios, company 1 also wants to increase their involvement with the Scottish government to raise awareness about the needs of the aerospace sector. They also want to develop more partnerships to be able to access more funding referring to ICD C2.5 which is at a proactive maturity level already.

In addition to this for scenario 4 ‘gliding like a dolphin’ company 1 aims at sharing best practices across their different sites relating to technology but also business practices. This refers to ICD C3.1 which is at a reactive maturity level and ICD C3.2 which is at an adaptive level. They also want to share best practices of good partnerships across the company network to increase positive collaboration. This refers to ICD C4.2. These actions are taken to boost the adoption of innovation even more which is already high in scenario 4.

Table 8-5: Strategic actions with targeted scenario and ICDs for company 1

	Strategic Action	All scenarios	Scenario 1	Scenario 2	Scenario 3	Scenario 4	ICD
1	Continue to be involved with ADS which is our ear on the ground for the political and economic environment	x					C4.2
2	Engage with local and national authorities - on funding needed to implement things on site to create high value jobs	x					C4.2, C2.5
3	Host periodic reviews with managers to understand the political environment	x					C4.2
4	We steer technical directions at a number of universities and research organisations and need to continue to do so		x	x			C4.2
5	Headcount is always a problem, and we tend to be under-resourced – push for government funded placements of experienced staff and not just early career starts	x					C4.1, C4.2
6	Headcount is always a problem, and we tend to be under-resourced – push for government funded placements of experienced staff and not just early career starts		x				C4.2
7	Access training academies to update knowledge		x		x		C6.1, C6.4
8	Invest in software and infrastructure that supports technology		x		x		C3.2
9	Create fast IT response and effective support team to support workforce		x		x		C3.2
10	Invite different government departments to work together and support the aerospace industry	x					C4.2
11	Lobby with the government to get investment in IT infrastructure and synchronise with the aerospace industry needs		x		x		C4.2
12	Generate agreement on standards - reporting scope 3 on sustainability is a nightmare today	x					C4.2

	Strategic Action	All scenarios	Scenario 1	Scenario 2	Scenario 3	Scenario 4	ICD
13	Make government aware that government needs to steer awareness and requirements campaign			x			C4.2
14	Share examples of rewards and celebration of good governing partnerships so excellent standards could be shared and built on			x		x	C4.2
15	Encouraging collaboration across the supply chain to gather solutions rather than products		x		x		C4.2
16	Encouraging government agents to increase collaboration between Scottish suppliers		x		x		C4.2
17	Developing cooperation to receive investment	x					C4.2, C2.5
18	Work on our green credentials now so we don't fall off the portfolios of investors already saying they will only support green companies	x					C4.1
19	Accurately assess and review global in-house capability and expertise	x					C4.1
20	Create a robust communication network to work as one team across sites to share best practices					x	C3.1
21	Implementing sustainable commercial practices	x					C4.1

The sharing of best practice of partnerships is a vital pilar for their response to scenario 2 'hibernating like a polar bear' as well. The reason is the same, to boost innovation adoption throughout the own company but also within partners. For this scenario additionally collaboration with the government should be increased to raise awareness about responsibility of politics and public institutions to support the aerospace sector as in this scenario funding is almost solely available through government sources. For this purpose, company 1 also wants to increase their collaboration with universities and influence on research to shift the focus to specific needs for investigation in the sector (ICD C4.2).

For both scenarios 1 'Hidden like a turtle in a shell' and 3 'working like a donkey' company 1 wants to collaborate more with universities on an educational level and influence education programmes for a more targeted and relevant education for the aerospace sector (ICD C4.2). The reason here is that access to international talent is significantly impacted by bad international relations. Therefore, they aim at supporting the development of domestic talent. One way is to shape educational programmes to be more relevant for the aerospace sector. For both scenarios company 1 also aims at increasing collaboration with suppliers and themselves but also encourage more collaboration with their own supply chain for more joint developments to produce solutions rather than a set of related products (ICD C4.2). These actions aim at overcoming the scatteredness of members of the supply chain in both scenarios. For both scenarios the development of IT infrastructure and capabilities have priority (ICD C3.2). For this purpose, company 1 wants to adopt more software solutions and invest in their own hardware (ICD C3.2). At the same time, they want to increase their encouragement of the Scottish government for more investment into the national IT infrastructure to enable better digital connectivity across companies across the country as both scenarios outline shortcomings in the development of digital infrastructure.

8.2.2 Company 2

Company 2 also aims at designing strategic actions for innovation capability improvement which they want to implement regardless of the scenario. Nevertheless, company 2 considers scenario 2 'hibernating like a polar bear' as the scenario closest to today's situation. However, the most strategic actions are developed for the response to scenario 1 'hidden like a turtle in a shell' and scenario 3 'working like a donkey' as it is believed that those scenarios require the most intervention. Company 2 develops a set of a total of twenty-six strategic actions. Table 8-6 shows how many actions are related to which scenario.

Table 8-6: Number of strategic actions per scenario (actions can aim at more than one scenario)

Scenario	**# strategic actions (Total 26)**
For all scenarios	12
1 – Hidden like a turtle in a shell	11
2 – Hibernating like a polar bear	3
3 – Working like a donkey	11
4 – Gliding like a dolphin	0

Just like for company 1 there is a clear is a clear focus on innovation capability dimension C4 'Innovation strategy, communication, and open innovation' for company 2. This accounts for 18 strategic actions. ICD C2 accounts for 10 strategic actions. Strategic actions can aim at improving more than one ICD. Table 8-7 shows how many actions are developed in relation to which ICD.

Table 8-7: Number of strategic actions in relation to ICDs (actions can aim at more than one ICD)

ICD	**Subdimension**	**# strategic actions**	**Current IC maturity level**
C2 Entrepreneurship and strategy	C2.2 Organisational flexibility and agility	1	1 – reactive
	C2.3 Entrepreneurial capability	2	2 – adaptive
	C2.4 Supply chain resilience	1	2 – adaptive
	C2.5 Accessing of innovation support and funding	2	2 – adaptive
	C2.6 Diversity of products / services and diversity of customers	4	3 – proactive
C3 Knowledge management and technology adoption	C3.2 Technology adoption strategy and processes	2	2 – adaptive
C4 Innovation strategy, communication, and open innovation	C4.1 Clear innovation strategy aligned with company strategy and innovation measurement and adequate recourse allocation	8	1 – reactive
	C4.2 Cooperation with suppliers, customers,	10	2 – adaptive

	public institutions, and openness to share information and to adopt new outside knowledge		
C6 Individual skills and learning	C6.1 Individual skills in one's field of knowledge	2	3 – proactive

In the following the strategic actions in relation to the different scenarios and the ICD they target are presented scenario by scenario. Strategic actions target ICDs of different innovation capability maturity levels regarding the assessment in chapter 6. A full list of strategic actions for company 2, for which scenario they are meant, and to which ICD they relate, can be found in Table 8-8, screenshots of the Miro board can be found in appendix A.C8.2.

For all four scenarios alike, company 2 wants to become more flexible and identify business opportunities in new markets referring to ICD C2.2 which is currently at a reactive maturity level and ICD C2.6 which already is at a proactive level. For this purpose, they want to introduce more data driven decision processes. One key topic of a future innovation strategy for them will be their NetZero approach, like for Company 1, and they aim at developing a full technology NetZero strategy. Further, they want to engage more in open innovation activities with customers and suppliers alike. They would like to establish fairer contracts and thus make them longer lasting in mutual interest. All these actions are related to ICD C4.1 and ICD C4.2. ICD 4.1 is at a reactive maturity level, whereas ICD 4.2 is at an adaptive maturity level at present.

The strategies for scenarios 1 'hidden like a turtle in a shell' and 3 'working like a donkey' are highly similar. An important part is the investment in digitalising the manufacturing processes (ICD C3.2 / adaptive) and increase digital connectivity of all workforce within the company as well as digitally connect with suppliers and customers on a manufacturing process data level (ICD C4.2). The technological advancements shall also help develop new markets especially emerging ones. Along with this additional training and qualifications for digitalisation are planned (ICD C4.1, ICD C6.1). Technological developments shall be monitored more regularly to assess potential business opportunities (ICD C4.1, ICD C2.6). Hence an improvement of ICD C3 'Knowledge management and technology adoption' and ICD C6 'Individual skills and learning' shall be used to enable an improvement of ICD C2 'entrepreneurship and strategy' and ICD C4 'Innovation strategy, communication, and open innovation'.

Table 8-8: Strategic actions with targeted scenario and ICDs for company 2

	Strategic Action	All scenarios	Scenario 1	Scenario 2	Scenario 3	Scenario 4	ICD
1	Improve supply chain resilience - Improve links with local suppliers and other companies in politically aligned countries.			x			C2.4
2	Pursue cooperation with government organisations		x		x		C2.5, C4.2
3	Market research and develop opportunities in the US - supply chain and customer base for existing and new products			x			C2.3, C2.6
4	Organisational Flexibility: investigate and implement processes that are relevant to emerging British industries	x					C2.2
5	Work with government organisations to identify current capabilities and workforce experience that could be used in other industries		x		x		C2.3, C2.6
6	Look at training programmes / internal development to up-skill and retain staff		x		x		C4.1 C6.1
7	Review employment practices and modernise to offer more appealing positions and attract skilled labour		x		x		C4.1
8	Put a high priority on digitalisation of current manufacturing processes to improve workshop capacity		x		x		C3.2
9	Use advanced technology/processes to develop niche, high-end product		x		x		C2.6
10	Develop relationships within our supply chain & manufacturing base network (e.g.: NMIS). Meet more people in our space	x					C4.2
11	Updating hardware to allow full integration of digitalisation		x		x		C3.2
12	Training workforce to enable the whole organisation to work together digitally		x		x		C4.1, C6.1
13	Use data to assess and aid decision making	x					C1.1
14	Implement meetings to review evolving operations from a technological perspective to identify what can be done better / identify constraints & possible solutions (requiring investment)		x		x		C4.1

	Strategic Action	All scenarios	Scenario 1	Scenario 2	Scenario 3	Scenario 4	ICD
15	Manage more difficult contracts through communication – engage stakeholders and make them "allies". This could be addressed through digitalisation	x					C4.2
16	Develop sustainability strategy through appreciation of our key industries challenges.	x					C4.2
17	Improving communication and means of communication to generate trust with customers	x					C4.2
18	Try to speak the same language as customers (common issues & expertise by industry) / build trust / be transparent in regular communications	x					C4.2
19	Employ someone (or outsource) who deals directly with government bodies to apply successfully for grants available for SMEs			x			C4.2
20	Co-investment and cooperation to prototype and apply for funding		x		x		C2.5, C4.2
21	Develop network and contacts within government organisations so that funding opportunities are highlighted to us early		x		x		C2.5, C4.2
22	Review current raw material recycling processes to improve our % wastage.	x					C2.6
23	Speak to local companies and see if any recycling efforts can be collaborated on	x					C4.1
24	Review company energy usage. Could this be supplemented with e.g. Solar paired with onsite energy storage system?	x					C4.1
25	Promote "green" credentials - customers increasingly aware and pushing towards low carbon solutions	x					C4.1
26	Develop sustainability strategy through appreciation of our key industries challenges.	x					C4.1

These actions shall be taken because technological advancements are not taken advantage of across the supply chain in these scenarios and the supply chain itself is largely scattered. This approach should also be used to make the company more attractive to potential new staff. Further, company 2 wants to increase their collaboration with public industry support organisations specially to develop a better understanding of their existing skills referring to ICD C2.5 which currently is at an adaptive maturity level and ICD C4.2. They want to use industry support organisation's network and knowledge of other industries to expand (ICD C2.3 / adaptive, ICD C2.6, ICD C4.2). This approach needs considerable effort as supply chain support remains scattered and difficult to access in these scenarios. However, company 2 sees the value of getting access to expertise and funding beyond the private sector.

For scenario 2 'hibernating like a polar bear', company 2 wants to increase supply chain resilience (ICD C2.4 / adaptive) especially in the UK and in politically aligned countries. Whereas the connectivity of supply chains in Scotland and the UK is already at a good level in this scenario, especially good collaboration with foreign members of the supply chain is believed to need a boost. Market research should additionally show opportunities to expand internationally. In this context more effort should be made to convince private investors to invest into the Scottish aerospace sector as existing funding opportunities are mostly only government related. Therefore, on a Scottish level, company 2 also wants to increase their awareness and capabilities of accessing public funding (ICD C2.5).

For scenario 4 'gliding like a dolphin' company 2 does not develop any specific strategic actions. Here solely the actions designed for all scenarios come into play as it is believed that they will help take even more advantage of the positive situation in scenario 4.

8.2.3 Supply chain

The supply chain group follows a similar approach to the strategizing exercise to improve the innovation capability of the supply chain scoring model as companies 1 and 2 do for the company level. They decide on a number of strategic actions which they intent to implement for all scenarios alike. Nevertheless, the supply chain group believes that current developments are closest to scenario 3 'working like a donkey'. Most intervention, however, needs scenario 1 'hidden like a turtle in a shell'. A total of 15 strategic actions is developed. How many actions are designed for which scenario can be found in Table 8-9. Strategic actions can be designed for more than one scenario.

Within these strategic actions there is a focus on ICD SC3 ‘Public supply chain support’ with 6 strategic actions and on ICD SC1 ‘Supply chain structure and governance’ with 10 actions. Within ICD SC1 there is a clear focus on ICD SC1.8 ‘Joint value capturing with supply chain members and public support organisations’ which accounts for 6 strategic actions alone.

Table 8-9: Number of strategic actions per scenario (actions can aim at more than one scenario)

Scenario	# strategic actions (Total 15)
For all scenarios	9
1 – Hidden like a turtle in a shell	5
2 – Hibernating like a polar bear	2
3 – Working like a donkey	4
4 – Gliding like a dolphin	0

Table 8-10 shows how many actions are developed in relation to which ICD. Strategic actions can be used for more than one scenario and can address more than one ICD.

Table 8-10: Number of strategic actions in relation to ICDs (actions can aim at more than one ICD)

ICD	Subdimension	# strategic actions	Current IC maturity level
SC1 Supply chain structure and governance	SC1.2 Communication	2	2 – adaptive
	SC1.4 Regulation	1	1 – reactive
	SC1.7 Supply chain visibility	1	3 – proactive
	SC1.8 Joint value capturing with supply chain members and public support organisations	6	2 – adaptive
SC2 Supply base	SC2.1 Supply base resilience	2	1 – reactive
	SC2.2 Technology adoption capability	1	2 – adaptive
SC3 Public supply chain support	SC3.1 Availability of public funding for supply chain and supply base development	2	2 – adaptive
	SC3.2 Availability of public support organisations for supply chain and supply base development	4	2 – adaptive

In the following the strategic actions in relation to the different scenarios and the supply chain ICD they target are presented scenario by scenario. Strategic actions target ICDs of different innovation capability maturity levels regarding the assessment in chapter 6. A full list of strategic actions for the supply chain level, for which scenario they are meant, and to which ICD they relate, can be found in Table 8-11, screenshots of the Miro board can be found in appendix A.C8.3.

The strategic actions designed for all scenarios alike aim at influencing policy making mainly. Actions here aim at collaboration along the supply chain and across the whole aerospace sector to raise awareness of the sector with Scottish government, as at present it is no priority. This way it is hoped to design support programmes and funding programmes which suit aerospace needs better aiming at increasing ICD SC3.1 and ICD SC3.2 from an adaptive level to a proactive level of maturity. As a part of this the supply chain group wants to encourage policy makers in Scotland to quickly simplify the Scottish industry support landscape to make it easier to comprehend, to navigate, and to access existing support (ICD SC3.1, ICD SC3.2).

Strategic alliances across the supply chain and the wider industry should not only aim at influencing policy making, they are also meant to aim at collaboration on innovation and research and development projects to raise the current adaptive level of innovation capability maturity of ICD SC1.8 to a proactive level. For this purpose, special collaboration programmes should be designed which also facilitate better communication between companies within the supply chain, the supply chain, the government, and universities and colleges (ICD SC1.2) which is currently at an adaptive maturity level. One important pillar for the design of such programmes is understanding the current capabilities of the supply chain. Even though in theory the visibility of capabilities is high (proactive maturity level), there is no database bringing together the data. The supply chain group wants to change this (ICD SC1.7). Another important pillar is the expected NetZero orientation of the industry worldwide. Hence, NetZero could be used as unifying interest of all parties (ICD SC1.8).

Table 8-11: Strategic actions with targeted scenario and ICDs for supply chain level

	Strategic Action	All scenarios	Scenario 1	Scenario 2	Scenario 3	Scenario 4	ICD
1	Engaging companies-state-academia in communication	x					SC1.2
2	Design public funding and investment programmes better suited for aero-space	x					SC3.1
3	Supporting collaboration, networking and strategic alliances across the industry	x					SC1.2, SC1.8
4	Push decarbonisation and NetZero	x					SC1.8
5	Generating and implementing policies to support the supply chain	x					SC3.2
6	Implementing policies to increase international collaboration with other parts of the supply chain			x			SC1.8
7	Connect Scottish supply base to create new supply chains of the future		x		x		SC1.8, SC2.1
8	Mandate local content of aerospace products manufactured in Scotland		x		x		SC1.4
9	Develop programmes to motive new Scottish entrants into aerospace		x		x		SC2.1, SC3.2
10	Design programmes for joint development of new products and services	x					SC1.8
11	Encourage collaboration for introduction of new technology to ensure simi-lar technology level across the supply chain		x		x		SC2.2
12	Facilitate collective actions to encourage Scottish government to pay more attention to aerospace needs	x					SC3.2
13	Explore defence market for supply chain as diversification option		x	x			SC1.8
14	Push to make public industry support landscape easier to manage and fund-ing easier to access	x					SC3.1, SC3.2
15	Create capability database to derive needs for capability development with-in the supply chain and the industry	x					SC1.7

The strategies for scenarios 1 'Hidden like a turtle in a shell' and 3 'working like a donkey' are highly similar as they aim at mitigating impacts posed by both scenarios alike, mainly the scatteredness and low competitiveness of the supply chain. Hence, strategic actions aim at strengthening the resilience of the Scottish supply base or ICD SC2.1 which is at a reactive maturity level at present. First, of all programmes should be designed that encourage companies from other sectors to enter aerospace. This would require lowering entry barriers where possible. At the same time, the existing supply base should be encouraged more to be involved in the creating new supply chains for new products (ICD SC1.8, ICD SC2.1). To be better prepared, the supply chain group suggests encouraging collaboration to ensure that large parts of the supply base are at a similar advanced level of technology referring to ICD SC2.2 which is at an adaptive level. One action, that has been proposed, would put more restriction in place and therefore would make ICSM SC1.4 even worse than it already is with a current reactive maturity level. It is demanding local content of products being assembled in Scotland.

For scenario 2 'hibernating like a polar bear' two strategic actions are developed. As in this scenario international collaboration is highly limited, the supply chain group wants to counter act this and actively encourage collaboration with parts of the supply chain located overseas and push for policies opening up the country (ICD SC1.8). At the same time the supply chain group wants to explore more domestic markets opportunities like developing capabilities to be more relevant for the defence sector (ICD SC1.8).

For scenario 4 'gliding like a dolphin' the supply chain group does not develop any specific strategic actions. Here solely the actions designed for all scenarios come into play as it is believed that they will help take even more advantage of the positive situation in scenario 4.

8.3 Answer to research question RQ-P4: Recommendations for policy making in Scotland to boost innovation capability

This chapter aims at deriving qualitative suggestions for policy making to support before developed strategies for the analysed aerospace supply chain in particular and for the whole of the Scottish aerospace industry in general from a government perspective. The two main policy documents that are relevant at the point in time of writing this thesis, are the manufacturing recovery plan for Scotland (ScotGov, 2021b) outlining an interims strategy to support Scottish manufacturing throughout the Covid-19 pandemic, and the future national innovation strategy for Scotland (ScotGov, 2023) which outlines a ten year strategy to make Scotland as an economy a leader in innovation within the community of small countries. Hence, these documents are used to position policy suggestions. No other relevant policy documents can be identified after conducting additional literature searches.

Most important for policy makers is to realise their importance for the development of the aerospace industry and its supply chains in Scotland and to realise the importance of the aerospace industry in Scotland for the Scottish economy. As the aerospace industry is not even listed as separate entity within the economy by the Scottish Government, there is a real need to raise awareness. Once the awareness is created, targeted policies should be developed addressing sector needs. Unfortunately, the manufacturing recovery plan for Scotland (ScotGov, 2021b) only focusses on the manufacturing sector as a whole as well as the new national innovation strategy (ScotGov, 2023). There is no specification for subsectors. However, needs of subsectors can be very different.

The main four needs identified by this study for the aerospace supply chain for innovation capability building relate to open innovation, supply chain resilience, funding, and skills. How policy makers could approach the shortcomings in these areas is explained in the following.

8.3.1 Open innovation

To support the development of new partnerships for joint innovation activities beyond existing collaborations, policy makers could support public industry support organisations like NMIS, Scottish Engineering, and Scottish Enterprise and private industry support organisations like ADS to foster more collaboration. This is already part of the manufacturing recovery plan for Scotland (ScotGov, 2021b) and the national innovation strategy (ScotGov, 2023) in its key area collaboration and networks, but it would also be needed to support innovation capability building in particular in the aerospace sector.

As both are not precise in its actions, at this point precise actions are suggested. First of all, the public support landscape could be made easier to navigate. With NMIS as general contact point a first step has already been made. However, an efficient system should be developed to easily connect an inquiry with the right people in the right industry support organisation. Once these processes are in place, these organisations can start creating data bases with companies, their markets and their capabilities. They can then find the right support or the right industry partners for each inquiry. Policy making should here focus on expanding their network as many companies are not members of any support organisations and networks and thereby under the radar of potential collaboration. To be efficient, private and public support organisations should be encouraged to work together more closely. Thus, an innovation system would be built. Public support organisation should also focus more on fostering the conversation between subsectors and policy making as aerospace needs are repeatedly not reflected in policy making.

8.3.2 Supply chain resilience

As the aerospace sector in Scotland is small and available capabilities are limited to certain areas like engine maintenance, policy makers could develop policies supporting the structural developments of new aerospace capabilities. This at a high level is reflected in the manufacturing recovery plan as well (ScotGov, 2021b) in the key area supply chains and competitiveness as well as in the national innovation strategy (ScotGov, 2023). However, again it is focussed on the whole of the manufacturing sector. There are no plans for subsectors. Supporting structural developments of the aerospace sector would not only support resilience and security of jobs but it would also directly support innovation capability building. The development of such support should be closely aligned with the needs of large aerospace OEMs. Thus, the Scottish aerospace sector would become more attractive for them. The development of new capabilities could be realised by motivating companies with needed capabilities from other sectors to move into aerospace. Public support organisations could foster the conversation between the sector and the government here as well. Precise support actions could be incentivised support for aerospace certification. Tax incentives could also be considered for these companies. Tax incentives for aerospace companies from other countries could also be an option if they agree to create jobs in Scotland as foreign direct investment. Focussing on special emerging subsectors of the industry like remanufacturing of aircrafts could be a suitable starting point.

8.3.3 Funding

Funding on UK level and on the Scottish level is simply too complicated. There are too many rules and regulations, too many institutions involved, and approval times are substantial. This requires companies to spend not unsignificant resources on solely navigating the funding landscape. Submitting application additionally require expertise and capabilities which many SMEs simply do not have. Hence, accessing public funding must be made easier and the processes must be sped up otherwise it is simply not an option for SMEs which are in return essential for building a resilient supply chain in general and for the development of supply chains of emerging subsectors. Funding regulations at present tie funding always to very specific purposes, broad innovation support funding is hardly available. This should be changed to support companies in the sector in general. Many SMEs do not have the financial capacities to invest into new production technology, thereby efficient upscaling becomes difficult. However, upscaling and commercialisation of innovation is explicitly exempt from public funding. Funding needs to be more sector needs focussed.

Whereas the manufacturing recovery plan (ScotGov, 2021b) and internal NMIS efforts aim at centralising the access to support in NMIS itself, there seems to be little emphasis on this in the national innovation strategy (ScotGov, 2023). The recovery plan and national innovation strategy aim only at providing more funding, which is a positive development, however, the impact will remain limited if funding rules are not simplified and processes sped up.

8.3.4 Skills shortage and education

The shortage of skills is after all the main issue for the future of the aerospace sector and of other sectors requiring talent and specially trained staff. The assessment of the status quo of innovation capability of the aerospace supply chain and the derived strategic actions for future development seem to point at a communication issue between the aerospace sector and education systems. Whereas the recovery plan speaks of creating meaningful work experience to fight graduate unemployment, education must become more relevant for aerospace in general. Universities need to incorporate aerospace requirements, including work placements of significant time would help creating a better bond between universities and the sector. What is needed is education in skills relevant to the sector, not only knowledge. Work placements could also help graduates going straight into jobs in the sector as the company the already work for knows them and has spent significant time and even money in integrating them into their operations already. This is a common approach in Germany across engineering and business disciplines. The NMIS skills academy is good start to train technicians on a non-academic level and the recovery plan aims at developing more such programmes.

This approach could help graduates being integrated more easily in the job world and would prevent them moving away from Scotland because they cannot find jobs. On the other hand, this would make it easier for employers to attract the workforce they need as they do not have to recruit them from far away.

8.3.5 Conclusion

The suggestions for policy making are not necessarily new topics as they are in some way or another reflected in the manufacturing recovery plan for Scotland (ScotGov, 2021b) even though the objective of the recovery plan was not specifically to raise innovation capability directly and in the national innovation strategy (ScotGov, 2023). The shortage of skills is as old as the complexity of the industry support landscape and the complexity and inadequateness of public funding. This shows two things. Policy makers either do not listen enough to specific industry needs, and the recovery plan highlights this by addressing only high-level issues without going into detail of specific subsectors, or they actively ignore to support these subsectors' needs. If it is an unawareness issue, this study can help raise awareness by pointing out what is needed to improve innovation capability in the aerospace supply chain from a policy making perspective. If the issue is ignoration, all this study can do is raise awareness within the aerospace sector that they need to increase their effort of being heard by politics.

8.4 Evaluation of MaSCICMAF as strategy guidance in connection with the scenario strategizing methodology

In this section the application of MaSCICMAF together with the scenario strategizing methodology is reflected on as field validation of MaSCICMAF as strategy guidance. For this purpose, an intellectual arbitrage approach had been chosen with the workshop host or researcher being an observer to the research while the participants reflect on MaSCICMAF and its application along with the scenario strategizing methodology after the workshop through a feedback questionnaire. Said questionnaire can be found in the appendix A.C8.4. A total of eleven questionnaires were returned from participants of the company workshops and the supply chain workshop. This constitutes in a 65% return rate.

Participants rate MaSCICMAF as very helpful to create innovation capability improvement strategies, as guidance for which innovation capability dimension to improve and in what way. A score 4.4 of five could be achieved. Hence, MaSCICMAF is considered validated as strategy guidance.

Most challenges which occurred during the workshop were rather related to scenario strategizing than MaSCICMAF. These challenges are put into context of findings of the application of the methodology for topics other than innovation capability development. Suggestions are derived for future application.

It is important to state that all participants from companies one and two and all participants of the supply chain group have not had any prior experience with scenario-based strategizing and that they are not involved in the initial development of the future scenarios for manufacturing in Scotland (see chapter 7). This had an influence on the application of the method and confirms Chermack (2011) findings that experience is an important factor for the application of scenarios in strategizing. Significant explanation is needed to explain the methodology itself and its objectives, but also the developed scenarios and what these scenarios are. Participants from company one struggle to get into the right mindset for scenario strategizing. They repeatedly solely want to work just with the scenario closest to the status quo. It takes significant convincing that the benefit of the methodology lays in planning for all scenarios. Further, representatives from company one repeatedly try to change the scenario story lines by strategic actions, requiring more explanation that the scenarios pose external developments influencing the business. The business itself reacts to these influences with internal strategic actions. The actions of a single company however will not change global macro-economic trends. This, however, is a common mistake made by people with little experience with scenario strategizing (Chermack, 2011).

Other obstacles to effective scenario strategizing are certain types of biases. The first bias that could be identified in all workshops is the neglect bias. The neglect bias is a bias where highly uncertain events are simply dismissed (O'Brien, 2004). Tightly connected to the neglect bias is the stability bias. This bias manifests itself by projecting the past into the future (O'Brien, 2004). Especially company one struggled here as described above when focussing on the status quo. Both biases lead to under exploration of the full range of possibilities. During all workshops participants drifted away from discussing scenarios and intuitively simply projected the past into the future, even though this was no scenario itself. Both these biases are common if there is little experience with scenario strategizing (O'Brien, 2004).

The application of the methodology for innovation capability building shows that certain innovation capability dimensions especially for the company scoring model are wanted to be developed regardless of the scenario and the different external impacts they pose. These dimensions mainly focus on leadership and culture, meaning inward facing developments and no direct reactions to external impacts. Nevertheless, once the scenarios themselves and the strategizing methodology is understood, company and supply chain group participants develop a deep understanding of the opportunities and threats which the different scenarios pose. For different scenarios different strategic focusses are adopted and useful strategic actions derived on company and on supply chain level. However, an innovation capability expert remains necessary as participants need to be guided through MaSCICMAF and its innovation capability dimensions.

One noteworthy observation of the strategies developed by both companies and the supply chain group is that designed strategic actions target ICDs of different current maturity levels. There is no pattern recognisable of focussing on ICDs at a reactive level or at ICDs with a proactive level to increase existing strengths. Motivation for which ICD to target seems more related to the ease of implementation and to actions which have been discussed in different context before the conducted workshops for this research.

On company scoring model level it is unexpected to see that no company aims at improving their innovation processes (ICD C4) despite both companies explicitly stating that they have shortcomings there which they would like to resolve. The same can be said for the change and risk attitude on supply chain scoring model (ICD SC1.5) and for the company scoring model for both companies (ICD C1.1), as it is at a reactive level in all cases and identified as one of the major barriers to innovation during the workshops but yet no strategic actions are designed to address the challenge.

Afterall, the issues that have been identified of the application of the method are all due to inexperience of the workshop participants and are all common mistakes in general scenario strategizing. No issues directly related to the application of the methodology for strategic innovation capability development could be identified, except that a good understanding of what innovation capability and its dimensions are, is required. Hence, it can be argued that scenario strategizing is a valid methodology for innovation capability development.

As a last comment, the based on provided feedback language of the framework was slightly adapted again after the strategizing workshops leading to a second revision of MaSCICMAF. This is the final version that is presented in this thesis. To improve the future application of the scenario methodology for innovation capability building, a number of changes to the workshop design is proposed. Firstly, the participants of at least the supply chain group workshop should participate in the development of the future scenarios and not only in the strategizing part. This way a better understanding of what future scenarios are, what the methodology is, and how to use them for strategizing can be developed. Further O'Brien (2004) and Chermack (2011) state that the engagement in the strategizing process is higher if participants also help designing the scenarios and before mentioned biases and inexperience impacts could be avoided. This, however, requires a much larger time commitment. Whereas the supply chain group might be able to offer this time, company representatives, especially from SMEs, are highly unlikely to have enough time available. The fact that for the present workshop setup not more companies could be found to take part, supports this hypothesis. The strategizing process itself does not require any modifications. However, before starting the process, it makes sense to identify innovation capability dimensions that are desired to be improved regardless of the scenarios, so that strategic actions can be developed once without being repeated for all four scenarios. Nevertheless, a future scenario expert and an innovation capability expert remain necessary to conduct the strategizing workshop.

8.5 Summary

Given the nature and complexity of findings developed in this chapter, at the end a short summary of said findings is presented. The aim of this chapter was to answer research questions RQ-P3 and RQ-P4. RQ-P3 aimed at developing improvement strategies for innovation capability based on the audit outcomes of chapter 6, where two companies and a supply chain group of the same aerospace supply chain were analysed for their current innovation capability. In this context for each of the two companies on a company level and for the supply chain group on supply chain level, a set of fife strategies for improvement were developed with one strategy as a response to each of the future scenarios developed in chapter 7. A fifth strategy comprises activities for innovation capability improvements that should be carried out regardless of the scenario. After this last strategy is put in place, the response strategies for each scenario can be triggered if the company or the supply chain group conclude that real developments over time jump from one scenario to another. The structure of these strategies in presented in Figure 8-1.

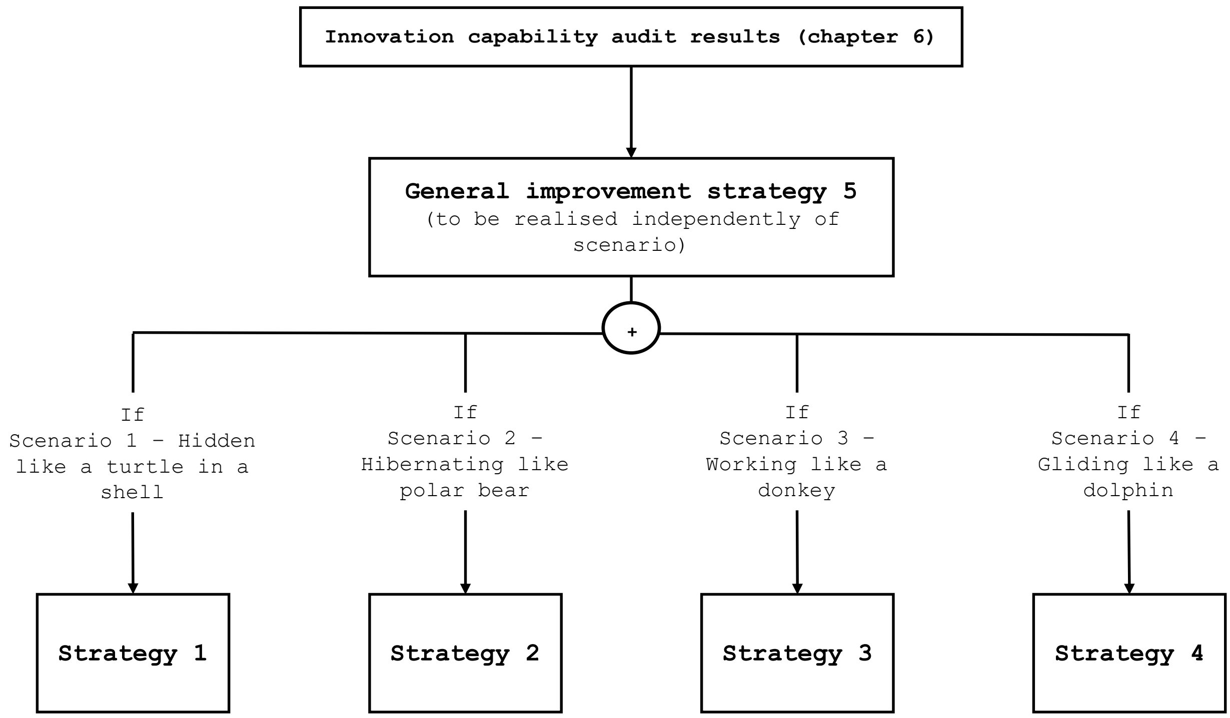


Figure 8-1: Overview over how innovation capability improvement strategies relate to scenarios (same structure of strategies for each company and supply chain group)

Research question RQ-P4 aimed at deriving advice for policy makers to support the feasibility of the before developed improvement strategies for the individual companies as well as for the supply chain on the supply chain scoring level. Four main points for improvement from policy side could be identified which are summarised in Table 8-12. However, it is important to state again that the findings of this research confirm known shortcomings and can only be understood as additional proof that policy makers should finally approach these shortcomings.

Table 8-12: Summary of policy advice

Policy area	Main improvement suggestions
Open innovation	• Simplify industry support landscape • Encourage public industry support to expand their networks and engage unengaged businesses **Main purpose:** Connect businesses and public support more closely
Supply chain resilience	• Incentivise investments into aerospace (not only general manufacturing) **Main purpose:** Attract more aerospace companies to Scotland or Scottish companies to move into aerospace to make sector more attractive for foreign investments
Funding	• Simplify funding landscape • Make funding rules more general and extent beyond only research and early-stage innovation support, i.e. for upscaling **Main purpose:** enable companies to access more available financial support and use it more broadly
Skills shortage and education	• Enable better communication of specific aerospace sector needs to universities **Main purpose:** develop graduates that have skills required by aerospace sector so that graduates are hired directly

CHAPTER 9

DISCUSSION

Now that all research questions have been answered, it is time to analyse the meaning of all findings of the research and to position them in the wider academic context along with a discussion about the research validity itself.

9.1 Discussing MaSCICMAF

The main research output of this research is naturally the answer to research question RQ-A1, the framework MaSCICMAF as framework to express innovation capability maturity of manufacturing supply chains. MaSCICMAF is the result of a systems approach to supply chains, considering supply chains socio-technical, dynamic, evolving, adaptive systems, with different organisations operating within the supply chain with internal dynamics and dynamic interactions of the organisations. As most supply chains in some way use the SCOR model, it is used in this thesis as a basis of all systemic considerations. The system perspective and the SCOR approach to intra and inter supply chain planning allows to separate the company scoring model of innovation capability from the supply chain scoring model highlighting that the innovation capability of a supply chain consists of the innovation capability of individual companies within a supply chain and the innovation capability of the supply chain as an innovation ecosystem. The developed framework MaSCICMAF offers a comprehensive visualisation of what innovation capability dimensions contribute to company level innovation capability and which ones contribute to the supply chain as innovation system. MaSCICMAF offers three maturity levels, reactive, adaptive, and proactive innovation capability. The descriptions of each maturity stage provide an understanding of how innovation capability dimensions can be characterised on these different maturity levels.

To understand the significance of MaSCICMAF, it makes sense to look back at the original research gap this thesis is built on. In the light of competition taking place more and more on the basis of the capabilities of whole end-to-end supply chains rather than the capabilities of single companies alone (Farahani et al., 2014), certain limitations of exiting literature was identified. Important to repeat here is that especially the end-to-end supply chain matters. Especially policy makers want to evenly raise capabilities within the whole supply chain to raise the overall competitiveness, resilience, and attractiveness for investments into a supply chain, or a whole sector within an industry.

Existing research like Iddris (2016) only focusses on the immediate supply chain, meaning direct suppliers and customers. This approach, however, is only for direct supply chain operations, it does not help to derive information for policy advice supporting the whole supply chain, nor does it help corporate decision making into which supply chain within which country to invest into. MaSCICMAF, however, allows such an end-to-end perspective. With the systems approach to supply chains, basically any type of supply chain can be analysed for innovation capability. The systems approach allows any number of supply chain actors on any amount of TIER levels to be analysed. The systems approach explicitly also allows only the view on a single company or only on the immediate supply chain. Hence, extends the findings of Iddris (2016).

A point of serious criticism within the existing literature was the use of singular metrics that do not take intangible aspects like company, or supply chain culture, and behaviour into account. Studies of innovation capability of single organisations had moved to using maturity models already to overcome this limitation, and MaSCICMAF has followed this approach consequently as well.

Another weakness in existing literature was about research being done either into only special types of innovation (Mendoza-Silva, 2021, Saunila, 2019) or only into special dimensions of innovation capability (Enkel et al., 2011, Arends and Advisory, 2018, Saunila and Ukko, 2014). MaSCICMAF has taken these limitations into account by taking a holistic stand. All dimensions that could be identified in existing literature, no matter if capabilities or supporting factors, have been integrated into MaSCICMAF. The broad approach allows not to focus on specific types of innovation but treat innovation as holistically as its definition given in chapter 2.1. In relation to this, a main point of criticism raised i.a. by Mendoza-Silva (2021) was the inconsistency of the dimensions used across studies. As MaSCICMAF takes all dimensions that have been researched individually into account, the set of dimensions used for MaSCICMAF could function as unification and as future basis for a more consistent use of what constitutes innovation capability of supply chains. However, this is out with the control of this thesis and depends on future developments within the research community.

Even though the framework is qualified to fill the research gap and answer research question RQ-A1, there are a few weaknesses which need to be discussed. Firstly, it is a conceptual, qualitative framework. There is no ranking of importance of different top-level or sublevel dimensions. The framework can just assess if a company performs well in a single sublevel dimension or a top-level dimension. Thus, there is no final score or classification if a company or the supply chain has an overall good innovation capability. This also means that no prioritisation for actions for improvement can be deducted solely from the framework. Improvement suggestions can just be given for either sublevel dimensions or top-level dimensions.

In general, the framework is meant to be holistic and cover all identifiable innovation capability dimensions. However, dimensions like technology adaption or knowledge management are complex matters in itself. Consequently, to identify roots of bad performance other specialised maturity framework or diagnostic tools might be needed.

The validation of MaSCICMAF in itself also holds a few limitations which need to be mentioned. As De Bruin et al. (2005) suggests there should be two levels of validation of the framework. One should be a verification of the academic reliability and validity of the framework's architecture and the maturity stage descriptions from a theory perspective, the other one a practical validation through application of the framework in the field. Both have been carried out and amendments have been made especially to maturity stage description wordings. Whereas MaSCICMAF passed both validations, especially the field validation is limited in its generalisability. The application method of MaSCICMAF using focus groups to determine the status quo and a workshop to develop an improvement strategy is very time intensive and, hence, it was complicated to find organisations which were willing to take part in the research. Therefore, only two companies out of the four companies of the selected aerospace supply chain agreed to participating. The reasons here is that the economy picked up again and the aerospace industry in general was very busy at the time of recruiting companies in late 2021. Whereas two companies' innovation capability analysed in depths created meaningful insights, more companies would have led to a richer picture. Analysing the supply chain group however, provided the necessary rigour on the supply chain level. Either way, MaSCICMAF has solely been applied to one supply chain and future application could raise reliability and trust into MaSCICMAF. To ensure more participation and to make MaSCICMAF usable for policy makers and managers without an innovation capability background, the application method of focus groups and strategy workshop should be made independent of a facilitator, with as much data collection for the audit of the status quo through individuals time independently. Only that way a broader adoption of MaSCICMAF seems realistic.

9.2 Discussing practical findings of the case study

The field validation of MaSCICMAF also holds some additional findings which should not be forgotten about in this discussion. The field validation itself offered sudden practical relevance when the Covid-19 pandemic hit. The idea was to support the Scottish Government's manufacturing recovery plan and the innovation strategy for Scotland by analysing current levels of innovation capability of supply chains and improvement strategies. However, to derive meaningful and impactful advice for policy making a better impression on how the Covid-19 pandemic had impacted innovation in different manufacturing sectors in Scotland had to be investigated. After conducting twenty-two interviews with eleven organisations, it can be said that innovation had become more of an imperative and worked as an accelerator for innovation. Many business across the whole of the manufacturing industry in Scotland had to make changes to some aspects of their business and innovate as a direct or indirect effect of the Covid-19 implications. Moving forward after the pandemic, climate change respectively NetZero and digitalisation are thought to be the biggest drivers for innovation across all manufacturing sectors. However, remaining Covid-19 impact, disrupted international electronics supply chains, and the energy crises caused by the Ukraine war, pose significant challenges for the industry. Besides these rather short-term challenges, the skills gap is believed to be the biggest longer-term challenge. In this context, three sectors were of special interest, the aerospace, the food and drink, and the chemical and pharmaceuticals sector. It was concluded that the food and drink sector and the chemical and pharmaceutical sector both are able, equipped, and proactive enough in their innovation behaviour to handle threats and seize opportunities. In contrast, the aerospace industry in Scotland, as the economically hardest hit industry, is in need of innovation capability building support. The sector has been affected significantly by travel bans during lockdowns. Especially larger aerospace manufacturers, in order to adjust their cashflows to the Covid-19 impact, made larger numbers of staff redundant or even closed down whole sites in Scotland. Redundancies were made hastily and without proper planning. Effectively, everyone who wanted to leave could receive a pay-out. This has led to uncontrolled loss of skills, skills companies were not even aware of that they lost, skills which are incredibly difficult and time consuming to rebuild. Within an already dire situation during the Covid-19 pandemic of international travel, this has impacted the innovation capability of the sector to react in a short-term way to disruption and also in a longer-term perspective to build back after the pandemic. Hence, the aerospace sector might still see more disruption and challenges in the aftermaths of the pandemic.

These findings are especially interesting when they are put into context of existing knowledge from before the Covid-19 pandemic. The skills gap as general issue for all Scottish manufacturing is an issue that has been known for years (MacBryde et al., 2009). That the aerospace sector was not in s good state in Scotland before the Covid-19 pandemic is also no secret (McGeoch and Spowage, 2020). Covid-19 consequently seems to have worked as an accelerator of these existing issues. During Covid-19 the Scottish government has developed two strategies to address these issues at least in part. The first one is the manufacturing recovery plan for Scotland (ScotGov, 2021b) which is an interims strategy to easy the situation in the short-term. The second one is the innovation strategy for Scotland (ScotGov, 2023) which remained in a pre-release state by the time this research was carried out. At this point, it was already clear that even though there are shared obstacles across manufacturing sectors, there are many unique obstacles and challenges in each sector. Whereas the findings of this research lead to the strong recommendation of developing improvement strategies like the recovery plan and the national innovation strategy in theory, both documents do not seem to take into account these differences in challenges and uniqueness of challenges across different sectors.

What especially the situation is in the aerospace sector and how special improvement strategies could look like, is the result of the field validation of MaSCICMAF as audit tool and the answer to research question RQ-P2. For one aerospace supply chain an audit of that current state is carried out as well as improvement strategies are developed. The current state of innovation capability depends on each innovation capability dimension. As for strengths, there is significant collaboration along the supply chain. Not all parts of the supply chain are necessarily connected but in parts there is collaboration that is based on longevity. There is good supply chain visibility. As for weaknesses, there is significant resistance to change within organisations and individuals. In general, the topic innovation does not seem to be considered important neither within the supply chain nor the analysed single companies. Hence, there are no individual innovation strategies and the few existing innovation projects remain significantly under resourced. The size of the aerospace industry in Scotland is another disadvantage for innovation capability. The existing industry solely covers certain parts of the whole aerospace value chain that is needed to produce whole aircrafts. This means that there are gaps in capabilities which make Scotland unattractive for international OEMs as they can get local innovation systems with a better capability base elsewhere. Lastly, current public funding practices in Scotland and the UK are highly disadvantageous for the aerospace sector as they are complex and complicated to navigate. The innovation support landscape itself is too complex and scattered to be easily navigable especially for SMEs making engagement unlikely.

It is important to highlight the limitation of generalisability of the results. Only two companies of the four TIER supply chain could be analysed in depth. The supply chain group gave significant further insights into the supply chain perspective beyond the single organisations as well as into the aerospace sector as a whole. Nevertheless, for a solidly reliable impression of the Scottish aerospace sector as a whole, more supply chains within the sector have to be analysed (Saunders et al., 2016). As the main focus of the current case study was to validate the framework, more in depths application of the framework is considered an avenue for future research.

From these audit findings a set of improvement strategies has been derived for which policy support would be wished for to make their implementation more successful. This constitutes the answer to research question RQ-P3. Whereas the individual strategies for improvement depend on internal priority setting by the companies, the supply chain group aimed more at a direct policy improvement for the sector. Four main areas for changes in policies were identifies. These were open innovation support, building more supply chain resilience, changing funding practices, and advice on skills shortages and education. For open innovation, policy making could aim at making capabilities within the sector and the wider manufacturing industry more transparent and actively encourage companies to collaborate. A first start could be to reform the innovation landscape and make it more accessible and navigable. For supply chain resilience purposes, policy makers need to realise the importance of the sector as it is for Scotland and more needs to be done to develop and grow the sector actively. Just with growth significant improvements in supply chain resilience can be achieved is the attitude, relating to competition of supply chains and not only single companies (Farahani et al., 2014). However, the national innovation strategy (ScotGov, 2023) and the manufacturing recovery plan (ScotGov, 2021b) both do not outline specific plans for the aerospace sector in Scotland only for manufacturing as a whole, missing an important opportunity.

The complicated funding rules need to be simplified. Simplification needs to target accessibility of funding on the one hand by broadening the spectrum of what can be funded, and, on the other hand, application and approval processes need to be made more straightforward and less time intensive. Just this way, the aerospace sector would see significant raises in engagement with public funding. The biggest challenge, however, is the skills shortage in the aerospace sector. In relation to this, the innovation capability assessment shows an estrangement of the sector needs and the education system offering. Policy making, in line with the triple helix idea (Leydesdorff and Etzkowitz, 1998), should foster communication between the aerospace sector and the education sector, to create meaningful and suitable education needed by the aerospace sector. The national innovation strategy (ScotGov, 2023), however, sets no clear objective for learning from industry. Industry is merely seen as a source for money.

As those strategies and the policy making advice are based on the future scenarios developed in chapter 7, the scenario approach as such has to be discussed as well. Together with an expert panel of the manufacturing industry in Scotland four scenarios were developed. The expert panel concluded that the critical driving forces of future development of the sector are innovation and its diffusion and international relationships and trade, as these are highly uncertain and impactful. Along these driving forces four scenarios were developed for a fifteen-year timeframe outlining a scenario with both driving forces being negative, two scenarios with one positive and one negative development of the driving forces, and one scenario with both driving forces developing positively. The scenarios as such are representative at the time of creation and at the time of the strategizing workshops. However, as they were meant to be used for future strategy making application of MaSCICMAF, an important limitation of the developed scenarios needs to be mentioned. That is that the scenarios are only as good as the information available at the time of creation of the scenarios (Wright et al., 2013). In the present case this means that there was no indication in the first half of 2021 that there would be a chance for a war in Ukraine. Hence, this was not covered in the scenarios. This means consequently that for future application of MaSCICMAF new scenarios have to be developed.

The use of the scenario approach for innovation capability strategizing, however, in itself is new to the research community. The approach could be validated throughout the field validation of MaSCICMAF and, hence, can confidently be used moving forward. Nevertheless, the same limitations to the validation of the scenario approach apply as to the validation of MaSCICMAF itself. The scenario approach has only been used with two companies and one supply chain group. To build more reliability further application is recommended. Further, issues with the application of the method itself are common issues occurring in other fields of application as well and can be related mainly to the inexperience of participants (Wright et al., 2013).

9.3 Discussing the research validity

Besides discussing the findings of this thesis within the wider research context, the validity of these findings needs to be discussed at the end of this chapter from a methodological point of view. In chapter 3 important remarks have been made about how research validity and reliability are meant to be ensured.

As a reminder, for qualitative research, like the present research, Saunders et al. (2016) state explicitly that research does not have to fulfil statistical viability like within quantitative research. Merely, research in qualitative setting is considered valid and reliable based on the appropriateness of the research methods and how they are applied.

The chosen maturity framework development methodology by De Bruin et al. (2005) has been applied in many instances hence the methodology is valid and reliable. In detail, to ensure that the framework content and architecture are based on all available research, a structured content analysis with suitable search terms was carried out, which Saunders et al.

(2016) deem as an appropriate approach to generate reliable output. The academic validation of the framework was carried out as suggested within De Bruin et al. (2005) methodology directly including feedback from the experts carrying out the academic validation. This has led to a first revised framework. As in other contexts this form of validation has been considered reliable, in the present context this is considered as reliable as well. The field validation of the framework is carried out as a case study, again following De Bruin et al. (2005) methodology directly, creating reliability of the research output as a consequence. De Bruin et al. (2005) a successful application including adaptation of the maturity framework means formal validation in the field. The field validation and gathered feedback about the framework itself and about the application method have let to the second revised framework and final framework that is presented in this thesis.

However, it is important to explicitly state that this field validation validates the framework officially as De Bruin et al. (2005) state, but that technically the results of the case study are only true for the case study setting. To increase the reliability, the framework needs to be applied in different contexts or case studies over time.

As for the interviews, as there is only a limited number of interviews conducted, the selection of suitable participants significantly contributes to the validity and reliability of the research. The selection criteria here ensure that participants have significant insights into the manufacturing respectively one of the subsectors and into the internal strategy of the organisations they represent. Specially the industry support organisations have a pivotal role as they as an organisation need to know what is going on these sectors. As the number of participants is small, avoiding respondent's bias is important. Therefore, questionnaires and precise wording of questions are developed with an expert.

Further, for research validity, all crossovers of participants have been highlighted in chapter 3 stating there is no implication on the validity of the research. Also, always the researcher has ensured that the best suitable individual leads the research, meaning that the development of the scenarios was led by an external expert as the researcher did not hold enough in-depth knowledge.

Hence, it can be concluded that the applied strategy to ensure validity and reliability of the research output stated in chapter 3 was followed and that consequently these results are reliable and valid.

CHAPTER 10

CONCLUSION

At the end of this thesis, it is time for looking at the contribution of the research and what implications it poses for academia, practitioners, and policy making. For this purpose, in a first step, the results discussed in previous chapters are summarised. Then formal contributions of the research are deducted. The chapter ends with highlighting limitations impacting the research and its results and emerging new avenues for further research beyond this thesis.

10.1 A review of the research results

This research has produced a number of different results in response to the research aims set out in chapter 1. The main purpose was to answer research question

RQ-A1) How can innovation capability maturity of manufacturing supply chains be determined?

and thereby closing the research gap identified in chapter 2.5.3. The answer is the manufacturing supply chain innovation capability maturity assessment framework MaSCICMAF. MaSCICMAF is based on the trend that competition takes place more and more on the level of capabilities and resilience of whole supply chains rather than only single organisations (Farahani et al., 2014). In this context it is important to explicitly analyse the innovation capability of a whole end-to-end supply chain. To allow this, MaSCICMAF is built on a systems approach to supply chains, allowing the analysis of supply chains of any length. MaSCICMAF is a literature-based maturity framework with three maturity stages, reactive, adaptive, and proactive. MaSCICMAF takes into account common criticism of existing approaches to innovation capability and adopts a multi-dimensional approach in addition to the systems approach. The framework architecture is shown in Figure 10-1.

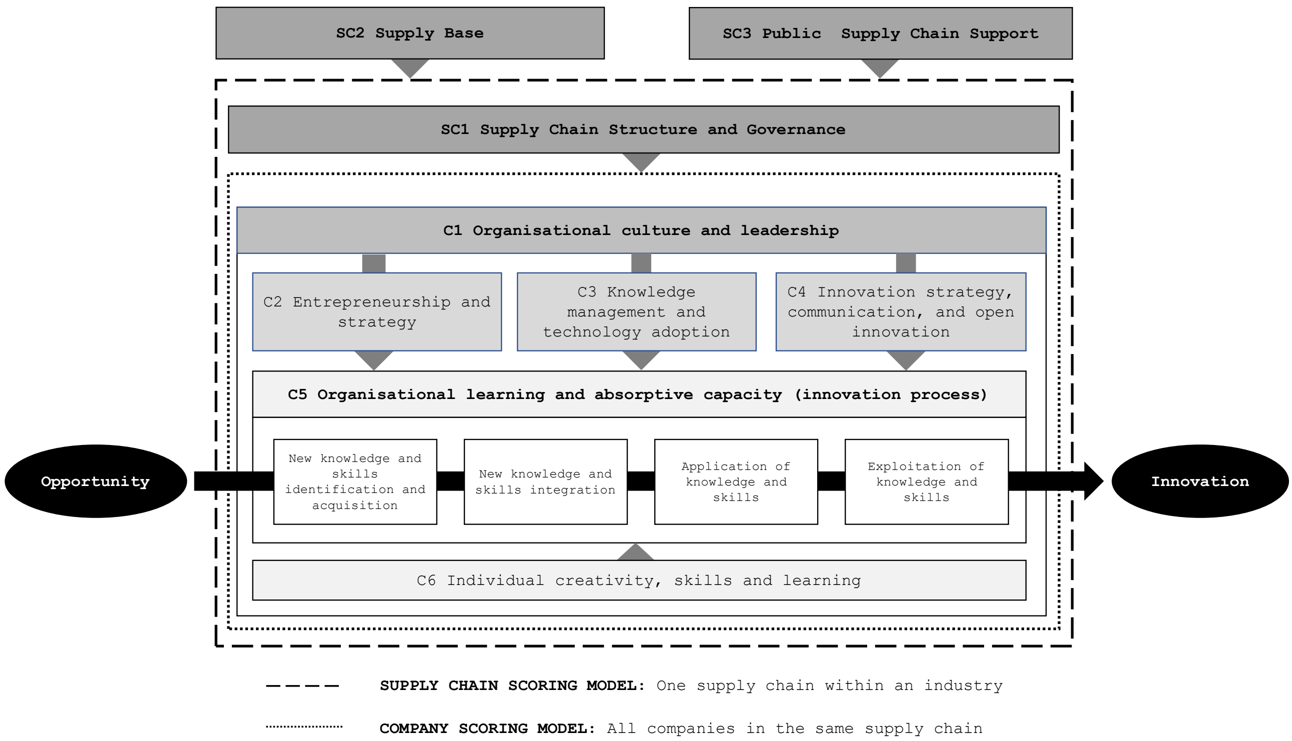


Figure 10-1: Visual representation of MaSCICMAF

MaSCICMAF, following the systems approach, has a company scoring model which can be applied to every organisation within a supply chain and a supply chain scoring model which aims at analysing the interconnection of all individual organisations. The company scoring model consists of six different innovation capability dimensions as shown in and the supply chain scoring model consists of three innovation capability dimensions as shown in Figure

10-1. As most supply chains in some way use the SCOR model, it is used in this thesis as a basis of all systemic considerations. MaSCICMAF can be used as a diagnostics tool as well as a strategy making tool for directed innovation capability improvement. MaSCICMAF is an academic literature-based framework, which has been validated in two steps. The first validation was a validation of the architecture and maturity stages on an academic level with academic experts. The second validation took place as an application of the framework as audit tool and strategy tool within a case study. This field validation offered further insights which let to revisions of the framework and its final version as presented in this thesis. Further, the field validation case study let to the answers to all remaining practical research questions.

The field validation of MaSCICMAF offered also sudden practical relevance when the Covid-19 pandemic hit. The idea was to support the Scottish Government's manufacturing recovery plan and the innovation strategy for Scotland by analysing current levels of innovation capability of supply chains and improvement strategies. However, to derive meaningful and impactful advice for policy making a better impression on how the Covid-19 pandemic had impacted the innovation behaviour in different manufacturing sectors in Scotland had to be investigated. After conducting twenty-two interviews with eleven organisations, it can be said that innovation had become more of an imperative and worked as an accelerator for innovation. Nearly every business across the whole of the manufacturing industry in Scotland had to make changes to some aspects of their business and innovate as a direct or indirect effect of the Covid-19 implications. Moving forward after the pandemic, climate change respectively NetZero and digitalisation are thought to be the biggest drivers for innovation across all manufacturing sectors. However, remaining Covid-19 impact, disrupted international electronics supply chains, and the energy crises caused by the Ukraine war, pose significant challenges for the industry. Besides these rather short-term challenges, the skills gap is believed to be the biggest longer-term challenge. In this context three sectors were of special interest, the aerospace, the food and drink and the chemical and pharmaceuticals sector. It was concluded that the food and drink sector and the chemical and pharmaceutical sector both are able, equipped, and proactive enough in their innovation behaviour to handle threats and seize opportunities. In contrast, the aerospace industry in Scotland, as the economically hardest hit industry, is in need of innovation capability building. The sector has been affected significantly by travel bans during lockdowns. Especially larger aerospace manufacturers, in order to adjust their cashflows to the Covid-19 impact, made larger numbers of staff redundant or even closed down whole sites in Scotland. Redundancies were made hastily and without proper planning. Effectively everyone who wanted to leave could receive a pay-out. This has led to uncontrolled loss of skills, skills companies were not even aware of that they lost, skills which are incredibly difficult and time consuming to rebuild. Within an already dire situation during the Covid-19 pandemic of international travel, this has impacted the innovation capability of the sector to react in a short-term way to disruption and also in a longer-term perspective to build back after the pandemic. Hence, the aerospace sector might still see more disruption and challenges in the aftermaths of the pandemic.

In the next step, MaSCICMAF is applied to one supply chain in the aerospace sector to determine the status quo of innovation capability within this particular supply chain to answer research question RQ-P2. The main objective of this application, however, was the field validation of the framework. Two companies were analysed in two separate workshops along with a supply chain representation group, comprising industry support organisations and policy makers as well in a third workshop. Three strengths and four weaknesses of innovation capability could be identified. As for strengths, there is significant collaboration along the supply chain. Not all parts of the supply chain are necessarily connected but in parts there is collaboration that is based on longevity. These collaborations are characterised by mutual trust, reliability, and no market power abuse. There is good supply chain visibility. As a side effect of the high regulation in the aerospace sector, the supply chain is, at least in theory, completely transparent. Further, there is a positive attitude towards learning and building new capabilities on an individual level which is encouraged by organisations. As for weaknesses, there is significant resistance to change within organisations and individuals. In general, the topic innovation does not seem to be considered important neither within the supply chain nor the analysed single companies. Hence, there are no individual innovation strategies and the few existing innovation projects remain significantly under resourced. The size of the aerospace industry in Scotland is another disadvantage for innovation capability. The existing industry solely covers certain parts of the whole aerospace value chain that is needed to produce whole aircrafts. This means that there are gaps in capabilities which make Scotland unattractive for international OEMs as they can get local innovation systems with a better capability base elsewhere. Also in need of mentioning is the high regulation in the aerospace sector, which has a negative impact on innovation capability compared to sectors with less regulation. Lastly, current public funding practices in Scotland and the UK are highly disadvantageous for the aerospace sector. Funding practices are too complicated, decision making takes too much time, and funding is just available for special initiatives. Further, the innovation support landscape itself is too complex and scattered to be easily navigable especially for SMEs making engagement unlikely.

In a next step, it was proposed to include a strategy component into the application of MaS-CICMAF to derive improvements of the before measured status quo of innovation capability. This strategy element is future scenario strategizing which aims at developing different strategies to react to different potential futures. In preparation of developing these strategies, the future scenarios themselves had to be developed. Together with an expert panel of the manufacturing industry in Scotland four scenarios were developed. The expert panel concluded that the critical driving forces of future development of the sector are innovation and its diffusion and international relationships and trade, as these are highly uncertain and impactful. Along these driving forces four scenarios were developed for a fifteen-year timeframe outlining a scenario with both driving forces being negative, two scenarios with one positive and one negative development of the driving forces, and one scenario with both driving forces developing positively.

In the following step these scenarios are used to create said strategies for improvement of innovation capability and answer research question RQ-P3. Strategies are developed with the same two companies and supply chain group which were analysed before. In each case one innovation capability improvement strategy is developed to respond to each future scenario based on the result of the innovation capability assessment. Both companies focus mostly on creating an innovation strategy and open innovation practices with different aspects depending on the scenario. The supply chain group also focusses on open innovation and joint value creation mostly but aspects of public supply chain support including funding are discussed.

Based on these strategies, qualitative advice for policy making was derived to support the effectiveness of these strategies in particular and innovation capability building in the sector in general. This policy advice is the formal answer to research question RQ-P4. Four main areas for changes in policies were identifies. These were open innovation support, building more supply chain resilience, changing funding practices, and advice on skills shortages and education. For open innovation, policy making could aim at making capabilities within the sector and the wider manufacturing industry more transparent and actively encourage companies to collaborate. A first start could be to reform the innovation landscape and make it more accessible and navigable. For supply chain resilience purposes, policy makers need to realise the importance of the sector as it is for Scotland and more needs to be done to develop and grow the sector actively. Just with growth significant improvements in supply chain resilience can be achieved. The complicated funding rules need to be simplified. Simplification needs to target accessibility of funding on the one hand by broadening the spectrum of what can be funded, and, on the other hand, application and approval processes need to be made more straightforward and less time intensive. Just this way, the aerospace sector would see significant raises in engagement with public funding. The biggest challenge, however, is the skills shortage in the aerospace sector. In relation to this, the innovation capability assessment shows an estrangement of the sector needs and the education system offering. Policy making, in line with the triple helix idea, should foster communication between the aerospace sector and the education sector, to create meaningful and suitable education needed by the aerospace sector.

10.2 Different contributions

These results have a number of implications and contributions for the academic community, for practitioners, and for policy makers. These are highlighted in the following.

10.2.1 Implications for academia

On an academic level, there are several contributions of this research. As a main contribution there is the framework MaSCICMAF itself. As explained in the literature review chapter 2, there was a significant research gap of what innovation capability of supply chains actually constitutes. Up to this point only innovation capability of single organisations had been analysed (Mendoza-Silva, 2021), or the impact of only certain innovation capability dimensions, like communication with direct suppliers or customers on only certain types of innovation. No holistic model had been available to describe, first of all, what innovation capability of supply chains is from a general perspective. No model has been available that takes into account an end-to-end supply chain, whereas being able to analyse a whole supply chain is crucial to build capabilities and resilience across a whole supply chain in times of competition of capabilities of whole supply chains instead of only capabilities of single organisations. With its systems approach, MaSCICMAF offers such a holistic understanding of what innovation capability is for supply chains regardless, of the length of a supply chain or the type of innovation. With its company scoring model for individual organisations and its supply chain scoring model for the interconnection of individual organisations, it sets out clear dimensions that contribute to innovation capability of supply chains.

Second of all, the present research makes these dimensions measurable with the maturity character of the framework. Not only innovation capability dimensions have been developed but they have been made measurable in three maturity stages with clear definition of what each maturity stage looks like for each dimension. These maturity stages offer a way to standardize innovation capability investigation of supply chains and hence offer comparability. The application of MaSCICMAF in the aerospace supply chain as field validation gives MaSCICMAF further credibility as assessment or diagnostic tool, as well as strategy tool which can be used for further standardised research into supply chain innovation capability.

During the field validation the future scenario approach was used to generate scenarios for Scottish manufacturing as guidelines for strategic innovation capability building. The application of scenarios in itself is a significant contribution to academia as it had not been applied for strategic innovation capability building. The successful application of the future scenario method shows that the method can be successfully applied for innovation capability building. Detailed strategies can be derived in connection with MaSCICMAF.

Further, a better understanding of how innovation in the manufacturing sector in Scotland has changed through Covid-19 was generated, adding to other studies on a more general economic impact. It was highlighted that innovation has become an imperative in manufacturing changing the focus much more on active innovation behaviour and capability building. Further, the study has shown that different sectors have reacted to the Covid-19 impact in different ways, impacting their own innovation capability either positively or negatively showing that other strategic actions impact innovation capability unwanted.

10.2.2 Implications for practitioners and policy makers

On a practical level, MaSCICMAF offers the option to measure innovation capability with regards to the maturity stages. This assessment can be used to measure the status quo of innovation capability of a supply chain and to derive strategic actions for improvements as higher maturity stages can be used as improvement goals to reach. MaSCICMAF can be applied by industry support organisations, by supply chain representation groups like in this research, or directly by policy makers. Solely the company scoring model of MaSCICMAF can be applied by single companies to measure their own internal innovation capability and derive strategies.

In this context, the future scenario method has been proven to be a reliable and valid method for the creation of improvement strategies for innovation capability for whole supply chains and for single companies alike. Hence, practitioners now have a whole methodology at hand they can use for diagnosis of the status quo of innovation capability and how to strategically improve it in the future. In this context the in this research developed future scenarios can be used by practitioners in the future as long as they are valid. The applicability of MaSCICMAF and the future scenario strategizing method for innovation capability building have been proven by the case study application in this research.

For policy makers this research has a number of important implications as main target group of this research. First of all, the derived policy advice has a clear message. Policy making in Scotland needs to understand the importance of the aerospace sector for the economy in Scotland and needs to address their needs more precisely.

In terms of the triple helix model of innovation (Leydesdorff and Etzkowitz, 1998) the analysis of the aerospace supply chain can be understood as a wider diagnosis of how close the different parts of the triple helix model are in the aerospace sector. Understanding that there are considerable miss communication and not aligned targets between the industry sector, the education and research sector, and the government is key to improvement of innovation capability. This diagnosis can be used as a starting point to get all three parts collaborate more and effectively create a joint space of all three that is able to foster this collaboration.

Further, the research contributes to policy making by supporting the manufacturing recovery plan for Scotland (ScotGov, 2021b) and national innovation strategy (ScotGov, 2023) by understanding innovation capability of said aerospace supply chain and possible improvements to raise resilience but also to raise competitiveness compared to other international competitors. The research can also be utilised to amend the national innovation strategy for Scotland. As an innovation strategy would mainly focus on generating innovation capability, MaSCICMAF could be used by policy makers to determine existing innovation capability as well as deriving strategies for improvement in different supply chains and in different sectors. Hence, MaSCICMAF could be a crucial tool for policy making.

10.3 Limitations and future research

Whereas the research has led to important contribution to theory and practice, there are certain limitations. The important limitations in relation to the development and application of MaSCICMAF and how they can be overcome are presented in the following. However, before, it is important to state again that all research carried out is of qualitative nature for example. Hence, there is no quantification possible of any results. All application of MaSCICMAF for the audits of the current state of innovation capability, strategizing, and derived feedback is only based on a case study. Whereas this case study approach is a valid validation of framework and application, it is only true for that one case study. To increase rigor, more case studies need to be carried out.

MaSCICMAF itself as a framework has certain limitations. Whereas the three used maturity stages serve the purpose of the present research, three maturity stages do not offer a high granularity of maturity like regular five stage models would do. Hence, the first starting point for future research could be to extend the three current maturity stages to five.

The application method of MaSCICMAF using focus groups to determine the status quo and one workshop to develop an improvement strategy is very time intensive and, hence, it was complicated to find organisations which were willing to take part in the research. Therefore, only two companies out of the four companies of the selected aerospace supply chain agreed to participating. Reasons were, that the economy picked up again after the initial Covid-19 lockdowns and the aerospace industry in general was very busy at the time of recruiting companies in late 2021. Whereas two companies' innovation capability analysed in depths created meaningful insights, more companies would have led to a richer picture. Analysing the supply chain group however, provided the necessary rigour on the supply chain level. Either way, MaSCICMAF has solely been applied to one supply chain.

Hence another avenue for future research, could be the transformation of the assessment system into an online questionnaire that companies can fill in independently from the researcher. Thus, data about several different supply chains could be collected simultaneously. This way the data collection for determining the status quo could be reduced to roughly thirty minutes per participant. Number of participants could be extended significantly as participants can fill in the survey in their own time. The strategy workshop could be transferred into an online tool as well where each company and the supply chain group can develop strategic actions independently of a researcher. This, however, should still be done in a group setting to leverage opinions and ideas from different people. As this will still be a workshop, it has to be anticipated that the application time will remain at about three hours.

Whereas the framework allows innovation capability maturity analysis on a relative level, there is no reference point yet to where the relative scale is located on an absolute scale. Hence, many supply chains within the same industry would need to be analysed to establish benchmarks for industries. As MaSCICMAF is meant to be applicable for different supply chains in different industries and different companies of different sizes, it is held general. Some innovation capability dimensions might not be needed in some industries or some certain company sizes. However, to establish this, more application of MaSCICMAF is needed as well. Consequently, as supply chains and industries differ, one main direction for future research, is to analyse which innovation capability dimensions are relevant for which industry and which supply chain. Further, average maturity levels of innovation capability dimensions in different supply chains in different industries have to be identified to set benchmarks. Setting benchmarks is important, as not every supply chain and every company within a supply chain can or want to reach the highest maturity stage for all innovation capability dimension. Some dimension maturity levels, like the high regulation in aerospace, are simply industry inherent and will not be changed for higher innovation capability. Further assessments of other supply chains in different manufacturing sectors would contribute to generating a general picture of where different supply chains and whole sectors are in terms of innovation capability compared to others. Just after such a larger holistic investigation, truly significant policy advice could be deducted. For the national innovation strategy such new findings should be taken into account and the national innovation strategy itself should be amended accordingly. Lastly, MaSCICMAF does not offer a ranking of which innovation capability dimension are more important than others in order to achieve a higher innovation capability. More research with innovation specialists could be done to establish such a ranking system and allow strategy makers to focus their resources. Such a ranking system has deliberately been excluded from the present research as substantially more explorative research would have been needed. As it is not clear how such a ranking system could look like and if there are differences between types of innovation and industries, this as a whole block is recommended as future research.

The applicability of the future scenario strategizing method for innovation capability building has been proven to work with the same small sample. However, further generalisation needs to be investigated by applying the approach in other supply chains as well. The developed strategies for companies and for the supply chain represent only the development of said strategies, their implementation has not been investigated. This, however, would be interesting, as new advice for policy making could be derived including the design of support for implementing such strategies. The developed scenarios can be used in the future for strategy building in other supply chains. However, they might become irrelevant at some point and new scenarios would have to be developed.

In this context, the applicability of the scenario strategizing method for innovation capability building could be further investigated along with how organisations and supply chains implement these strategies. Then, further policy advice for supporting this process could be deducted also leading to improvements of the national innovation strategy.

All limitations and related future research avenues are shown in Table 10-1 for summary purposes.

Table 10-1: Summary of limitations and future research avenues

Topic	Limitations	Future research
MaSCICMAF architecture	Only three stage maturity model	Extend to five stages
MaSCICMAF application	Application in focus groups for audits and workshops for strategy making is very time intense (3 hours each)	Transfer audit into online hosted questionnaire (shorten audit to 30min time commitment per participant)
Industry benchmarks and ranking	Only relative innovation capability scoring possible No ranking of innovation capability dimension importance	Develop benchmarks for each industry to locate supply chains on an absolute scale Introduce ranking of importance of innovation capability dimensions to help allocate resources to dimensions development effectively
Scenario approach	Scenario strategizing for innovation capability development only validated with one supply chain	Apply approach with more supply chains to improve rigor

This research, after all, has laid some groundwork in the field of innovation capability assessment and strategic development of such in supply chains, but more investigation is needed to cement the findings of this research and improve general validity. The same is true for policy making in Scotland to support innovation capability building. A start has been made with the analysis of one aerospace supply chain and their needs, but more investigation is needed into other sectors for holistic policy making.

Hence, this thesis shall be closed with the famous quote:

"What we know is a drop, what we don't know is an ocean"

Sir Isaac Newton

REFERENCES

ABDERRAZAK, R. & YOUSSEF, D. Supply Chain Innovation Between Risk and Competitive Advantage. 2022 14th International Colloquium of Logistics and Supply Chain Management (LOGISTIQUA), 2022. IEEE, 1-6.

ADNER, R. 2006. Match your innovation strategy to your innovation ecosystem. *Harvard business review,* 84**,** 98-107.

ADS 2019. Industry Facts & Figures: A guide to the UK's aerospace, defence, security & space sectors.

AFFAIRS, D. F. E. F. A. R. 2020. Food Statistics in your pocket: Summary.

AKGÜN, A. E. & KESKIN, H. 2014. Organisational resilience capacity and firm product innovativeness and performance. *International Journal of Production Research,* 52**,** 6918-6937.

AL-DEBEI, M. M. & AVISON, D. 2010. Developing a unified framework of the business model concept. *European journal of information systems,* 19**,** 359-376.

ALI, A. 1994. Pioneering versus incremental innovation: Review and research propositions. *Journal of Product Innovation Management,* 11**,** 46-61.

ALOINI, D., PELLEGRINI, L., LAZZAROTTI, V. & MANZINI, R. 2015. Technological strategy, open innovation and innovation performance: evidences on the basis of a structural-equation-model approach. *Measuring business excellence*.

AMER, M., DAIM, T. U. & JETTER, A. 2013. A review of scenario planning. *Futures,* 46**,** 23-40.

ANTONY, J., KUMAR, M. & LABIB, A. 2008. Gearing Six Sigma into UK manufacturing SMEs: results from a pilot study. *Journal of the Operational Research Society,* 59**,** 482-493.

ARENDS, S. & ADVISORY, B. 2018. *Development of a firm-level innovation capability maturity model and identification of innovation archetypes.* Master Thesis, Eindhoven University of Technology.

ARUNDEL, A., CASALI, L. & HOLLANDERS, H. 2015. How European public sector agencies innovate: The use of bottom-up, policy-dependent and knowledge-scanning innovation methods. *Research Policy,* 44**,** 1271-1282.

ARZUBIAGA, U. & ITURRALDE, T. 2014. Entrepreneurial Orientation and Innovation in a Context of Crisis: Some Relevant Factors in the Case of Family Firms. *Entrepreneurship, Innovation and Economic Crisis.* Springer.

ATES, A. Joining forces in manufacturing value chains for collaborative R&D and innovation: An SME perspective. 5th World Conference on Production and Operations Management P&OM, 2016.

AYOUB, H. F., ABDALLAH, A. B. & SUIFAN, T. S. 2017. The effect of supply chain integration on technical innovation in Jordan: the mediating role of knowledge management. *Benchmarking: An International Journal*.

BAILEY, D. & DE PROPRIS, L. 2014. Manufacturing reshoring and its limits: the UK automotive case. *Cambridge Journal of Regions, Economy Society,* 7**,** 379-395.

BAILEY, D., PITELIS, C. & TOMLINSON, P. 2019. Strategic management and regional industrial strategy: cross-fertilization to mutual advantage. *Regional Studies***,** 1-13.

BAREGHEH, A., ROWLEY, J. & SAMBROOK, S. 2009. Towards a multidisciplinary definition of innovation. *Management decision,* 97**,** 1323-1339.

BARNEY, J. 1991. Firm resources and sustained competitive advantage. *Journal of management,* 17**,** 99-120.

BARTON, D. L. 1995. Wellsprings of knowledge: Building and sustaining the sources of innovation. *Harvard Business School*.
BAXTER, G. & SOMMERVILLE, I. 2011. Socio-technical systems: From design methods to systems engineering. *Interacting with computers,* 23**,** 4-17.
BECHEIKH, N., LANDRY, R. & AMARA, N. 2006. Lessons from innovation empirical studies in the manufacturing sector: A systematic review of the literature from 1993–2003. *Technovation,* 26**,** 644-664.
BECKER, J., KNACKSTEDT, R. & PÖPPELBUß, J. 2009. Developing Maturity Models for IT Management. Business & Information Systems Engineering, 1 (3), 213-222.
BEHDANI, B. Evaluation of paradigms for modeling supply chains as complex socio-technical systems. Proceedings of the 2012 Winter Simulation Conference (WSC), 2012. IEEE, 1-15.
BEIS 2017. Industrial Strategy: Building a Britain fit for the future.
BELKAHLA, W. & TRIKI, A. 2011. Customer knowledge enabled innovation capability: proposing a measurement scale. *Journal of knowledge management*.
BELL, E., HARLEY, B. & BRYMAN, A. 2022. Business research methods. *Oxford university press*.
BELLAMY, M. A., GHOSH, S. & HORA, M. 2014. The influence of supply network structure on firm innovation. *Journal of Operations Management,* 32**,** 357-373.
BIAZZO, S. & FILIPPINI, R. 2021. *Product Innovation Management: Intelligence, Discovery, Development*, Springer.
BIRD, M. & WENNBERG, K. 2014. Regional influences on the prevalence of family versus non-family start-ups. *Journal of Business Venturing,* 29**,** 421-436.
BIRKINSHAW, J., BOUQUET, C. & BARSOUX, J. 2011. The 5 myths of innovation. *MIT Sloan management review,* 4**,** 1-8.
BOLY, V., MOREL, L. & CAMARGO, M. 2014. Evaluating innovative processes in french firms: Methodological proposition for firm innovation capacity evaluation. *Research Policy,* 43**,** 608-622.
BONO, J. E. & MCNAMARA, G. 2011. Publishing in AMJ—part 2: research design. Academy of Management Briarcliff Manor, NY.
BOUNCKEN, R. B. 2011. Supply chain contingencies: The effects of up-stream directives on supplier's innovation performance. *Engineering Management Journal,* 23**,** 36-46.
BRAUN, V. & CLARKE, V. 2006. Using thematic analysis in psychology. *Qualitative research in psychology,* 3**,** 77-101.
CARTER, C. R., ROGERS, D. S. & CHOI, T. Y. 2015. Toward the theory of the supply chain. *Journal of Supply Chain Management,* 51**,** 89-97.
CHANG, Y.-C., CHEN, M.-H., LIN, Y.-P. & GAO, Y.-S. 2012. Measuring regional innovation and entrepreneurship capabilities. *Journal of the Knowledge Economy,* 3**,** 90-108.
CHAPMAN, R. L., SOOSAY, C. & KANDAMPULLY, J. 2003. Innovation in logistic services and the new business model: a conceptual framework. *International journal of physical distribution & logistics management*.
CHARMAZ, K. 2008. Constructionism and the grounded theory method. *Handbook of constructionist research,* 1**,** 397-412.
CHERMACK, T. J. 2011. *Scenario planning in organizations: how to create, use, and assess scenarios*, Berrett-Koehler Publishers.
CHESBROUGH, H. 2003. The logic of open innovation: managing intellectual property. *California management review,* 45**,** 33-58.
CHESBROUGH, H. 2012. Open innovation: Where we've been and where we're going. *Research-Technology Management,* 55**,** 20-27.

CHOI, T. Y., DOOLEY, K. J. & RUNGTUSANATHAM, M. 2001. Supply networks and complex adaptive systems: control versus emergence. *Journal of operations management,* 19**,** 351-366.
CHOI, T. Y. & KRAUSE, D. R. 2006. The supply base and its complexity: Implications for transaction costs, risks, responsiveness, and innovation. *Journal of operations management,* 24**,** 637-652.
CHOPRA, S. & MEINDL, P. 2007. Supply chain management. Strategy, planning & operation. *Das summa summarum des management.* Springer.
CHRISTENSEN, C. 1997. *The innovator's dilemma: when new technologies cause great firms to fail*, Harvard Business Review Press.
CHRISTENSEN, C. & RAYNOR, M. 2003. *The innovator's solution: Creating and sustaining successful growth*, Harvard Business Review Press.
COHEN, W. M. & LEVINTHAL, D. A. 1990. Absorptive capacity: A new perspective on learning and innovation. *Administrative science quarterly***,** 128-152.
CRAIGHEAD, C. W., BLACKHURST, J., RUNGTUSANATHAM, M. J. & HANDFIELD, R. B. 2007. The severity of supply chain disruptions: design characteristics and mitigation capabilities. *Decision sciences,* 38**,** 131-156.
CROSBY, P. B. 1996. *Quality is still free: making quality certain in uncertain times*, McGraw-Hill Companies.
CROWE, S., CRESSWELL, K., ROBERTSON, A., HUBY, G., AVERY, A. & SHEIKH, A. 2011. The case study approach. *BMC medical research methodology,* 11**,** 1-9.
D'ESTE, P., IAMMARINO, S., SAVONA, M. & VON TUNZELMANN, N. 2012. What hampers innovation? Revealed barriers versus deterring barriers. *Research policy,* 41**,** 482-488.
DALY, J., KELLEHEAR, A. & GLIKSMAN, M. 1997. *The public health researcher: A methodological approach,* Melbourne, Australia, Oxford University Press.
DAMANPOUR, F. 1991. Organizational innovation: A meta-analysis of effects of determinants and moderators. *Academy of management journal,* 34**,** 555-590.
DAMANPOUR, F. & SCHNEIDER, M. 2006. Phases of the adoption of innovation in organizations: effects of environment, organization and top managers 1. *British journal of Management,* 17**,** 215-236.
DANKS, S., RAO, J. & ALLEN, J. M. 2017a. Measuring culture of innovation: A validation study of the innovation quotient instrument (part one). *Performance Improvement Quarterly,* 29**,** 427-454.
DANKS, S., RAO, J. & ALLEN, J. M. 2017b. Measuring culture of innovation: A validation study of the innovation quotient instrument (part 2). *Performance Improvement Quarterly,* 30**,** 29-53.
DANNEELS, E. 2011. Trying to become a different type of company: Dynamic capability at Smith Corona. *Strategic management journal,* 32**,** 1-31.
DAVIES, S. & MICHIE, R. 2011. Peripheral regions: a marginal concern. *European Policies Research Centre Paper,* 11.
DE BRUIJN, H., HERDER, P. M. J. I. T. O. S., MAN,, SYSTEMS, C.-P. A. & HUMANS 2009. System and actor perspectives on sociotechnical systems. 39**,** 981-992.
DE BRUIN, T., ROSEMANN, M., FREEZE, R. & KAULKARNI, U. Understanding the main phases of developing a maturity assessment model. Australasian Conference on Information Systems (ACIS), 2005. Australasian Chapter of the Association for Information Systems, 8-19.
DEKKERS, R., KOUKOU, M. I., MITCHELL, S. & SINCLAIR, S. 2019. Engaging with open innovation: A Scottish perspective on its opportunities, challenges and risks. *Journal of Innovation Economics Management,* 28**,** 193-226.

DELBUFALO, E. 2015. The influence of supply network structure on firm's multiple innovation capabilities: a longitudinal study in the fashion industry. *Management Decision*.

DELGADO-CEBALLOS, J., ARAGON-CORREA, J., ORTIZ-DE-MANDOJANA, N. & RUEDA-MANZANARES, A. 2012. The Effect of Internal Barriers on the Connection Between Stakeholder Integration and Proactive Environmental Strategies. *Journal of Business Ethics,* 107**,** 281-293.

DELIPINAR, G. E. & KOCAOGLU, B. 2016. Using SCOR model to gain competitive advantage: A Literature review. *Procedia-Social and Behavioral Sciences,* 229**,** 398-406.

DENZIN, N. K. & LINCOLN, Y. S. 2005. The discipline and practice of qualitative research introduction. *The landscape of qualitative research***,** 1-43.

DETARSIO, R., NORTH, K. & ORMAETXEA, M. 2016. Surviving and competing in times of crisis: Cases of strategies by Argentine SMEs. *Competitive Strategies for Small and Medium Enterprises.* Springer.

DEWICK, P. & MIOZZO, M. 2004. Networks and innovation: sustainable technologies in Scottish social housing. *R&D Management,* 34**,** 323-333.

DIDONET, S. R. & DÍAZ, G. 2012. Supply chain management practices as a support to innovation in SMEs. *Journal of technology management & innovation,* 7**,** 91-109.

DIRECTION, S. 2019. How to enhance the innovation capabilities of manufacturing SMEs: The impact of organizational culture and operations strategy dimensions. *Strateg. Dir,* 35**,** 31-33.

DUBEY, R., SINGH, T. & TIWARI, S. 2012. Supply chain innovation is a key to superior firm performance an insight from indian cement manufacturing. *International Journal of Innovation Science*.

DURST, S. & FERENHOF, H. A. 2016. Knowledge risk management in turbulent times. *Competitive strategies for small and medium enterprises.* Springer.

EDMONDSON, A. C. & HARVEY, J.-F. 2018. Cross-boundary teaming for innovation: Integrating research on teams and knowledge in organizations. *Human Resource Management Review,* 28**,** 347-360.

EHIE, I. & FERREIRA, L. M. D. 2019. Conceptual development of supply chain digitalization framework. *IFAC-PapersOnLine,* 52**,** 2338-2342.

EISENHARDT, K. M. & MARTIN, J. A. 2000. Dynamic capabilities: what are they? *Strategic management journal,* 21**,** 1105-1121.

ENKEL, E., BELL, J. & HOGENKAMP, H. 2011. Open innovation maturity framework. *International Journal of Innovation Management,* 15**,** 1161-1189.

ESTERHUIZEN, D., SCHUTTE, C. S. & DU TOIT, A. S. 2012. Knowledge creation processes as critical enablers for innovation. *International Journal of Information Management,* 32**,** 354-364.

EVANGELISTA, P. 2010. The adoption of knowledge management systems in small firms. *Electronic Journal of Knowledge Management,* 8**,** pp33-42-pp33-42.

FAGHAT, E. R. B., KHANI, N. & ALEMTABRIZ, A. 2020. A paradigmatic model for shared value innovation management in the supply chain: a grounded theory research. *International Journal of Innovation Science*.

FAI 2019. A Guide to Scottish GDP.

FARAHANI, R. Z., REZAPOUR, S., DREZNER, T. & FALLAH, S. 2014. Competitive supply chain network design: An overview of classifications, models, solution techniques and applications. *Omega,* 45**,** 92-118.

FELL, D. R., HANSEN, E. N. & BECKER, B. W. 2003. Measuring innovativeness for the adoption of industrial products. *Industrial Marketing Management,* 32**,** 347-353.

FEREDAY, J. & MUIR-COCHRANE, E. 2006. Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *International journal of qualitative methods,* 5, 80-92.
FERRER, M., SANTA, R., STORER, M. & HYLAND, P. 2011. Competences and capabilities for innovation in supply chain relationships. *International Journal of Technology Management,* 56, 272-289.
FLYNN, B. B., HUO, B. & ZHAO, X. 2010. The impact of supply chain integration on performance: A contingency and configuration approach. *Journal of operations management,* 28, 58-71.
FONTELA, E. & HINGEL, A. 1993. Scenarios on economic and social cohesion in Europe. *Futures,* 25, 139-154.
FRANKEL, R., BOLUMOLE, Y. A., ELTANTAWY, R. A., PAULRAJ, A. & GUNDLACH, G. T. 2008. The domain and scope of SCM's foundational disciplines—insights and issues to advance research. *Journal of Business Logistics,* 29, 1-30.
FREEMAN, R. E., HARRISON, J. S., WICKS, A. C., PARMAR, B. L. & DE COLLE, S. 2010. Stakeholder theory: The state of the art.
FREIJE, I., DE LA CALLE, A. & UGARTE, J. V. 2022. Role of supply chain integration in the product innovation capability of servitized manufacturing companies. *Technovation,* 118, 102216.
FRIEDRICH, P. & HIBA, J. C. 2016. Learning to Cope with Turbulent Situations: A Study of Owner—Managers in Argentine SMEs. *Competitive Strategies for Small and Medium Enterprises.* Springer.
FTICONSULTING 2020. Impacts of Brexit on the Chemicals Industry.
GALBRAITH, B., MCADAM, R., WOODS, J. & MCGOWAN, T. 2017. Putting policy into practice: an exploratory study of SME innovation support in a peripheral UK region. *Entrepreneurship & Regional Development,* 29, 668-691.
GLASER, B. G. & STRAUSS, A. L. 2017. *The discovery of grounded theory: Strategies for qualitative research*, Routledge.
GODET, M. 2000. The art of scenarios and strategic planning: tools and pitfalls. *Technological forecasting and social change,* 65, 3-22.
GOFFIN, K., LEMKE, F. & SZWEJCZEWSKI, M. 2006. An exploratory study of 'close'supplier–manufacturer relationships. *Journal of operations management,* 24, 189-209.
GOLGECI, I. & PONOMAROV, S. Y. 2013. Does firm innovativeness enable effective responses to supply chain disruptions? An empirical study. *Supply Chain Management: An International Journal*.
GOODRIDGE, P., HASKEL, J. & WALLIS, G. 2018. Accounting for the UK productivity puzzle: a decomposition and predictions. *Economica,* 85, 581-605.
GRANSTRAND, O. & HOLGERSSON, M. 2020. Innovation ecosystems: A conceptual review and a new definition. *Technovation,* 90, 102098.
GRANT, R. M. 1991. The resource-based theory of competitive advantage: implications for strategy formulation. *California management review,* 33, 114-135.
GUPTA, H., KUSI-SARPONG, S. & REZAEI, J. 2020. Barriers and overcoming strategies to supply chain sustainability innovation. *Resources, Conservation and Recycling,* 161, 104819.
HADJIMANOLIS, A. 1999. Barriers to innovation for SMEs in a small less developed country (Cyprus). *Technovation,* 19, 561-570.
HALDMA, T., NÄSI, S., GROSSI, G., SAUNILA, M. & UKKO, J. 2012. A conceptual framework for the measurement of innovation capability and its effects. *Baltic Journal of Management,* 7, 355-375.
HAMEL, G. & PRAHALAD, C. 1990. Strategic intent. *Mckinsey quarterly*, 36-61.

HARRIS, R., MCADAM, R., MCCAUSLAND, I. & REID, R. 2013. Knowledge management as a source of innovation and competitive advantage for SMEs in peripheral regions. *The International Journal of Entrepreneurship and Innovation,* 14, 49-61.

HEARNSHAW, E. J. & WILSON, M. M. 2013. A complex network approach to supply chain network theory. *International Journal of Operations & Production Management*.

HELFAT, C. E. & PETERAF, M. A. 2003. The dynamic resource-based view: Capability lifecycles. *Strategic management journal,* 24, 997-1010.

HEWITT-DUNDAS, N. 2006. Resource and capability constraints to innovation in small and large plants. *Small Business Economics,* 26, 257-277.

HILTUNEN, E. 2009. Scenarios: process and outcome. *Journal of Futures Studies,* 13, 151-152.

HITT, M. A., CARNES, C. M. & XU, K. 2016. A current view of resource based theory in operations management: A response to Bromiley and Rau. *Journal of Operations Management,* 41, 107-109.

HOC 2017. Chemicals Sector Report.

HOC 2022. Manufacturing: Key Economic Indicators.

HOLLAND, J. 1995. Basic elements. *Hidden Order: How Adaptation Builds Complexity*, 1-40.

HOLLANDERS, H., ES-SADKI, N. & KANERVA, M. 2016. European innovation scoreboard 2016. European Commission.

HOLSTI, O. R. 1969. Content analysis for the social sciences and humanities. *Reading. MA: Addison-Wesley (content analysis)*.

HOONAKKER, P., CARAYON, P. & LOUSHINE, T. 2010. Barriers and benefits of quality management in the construction industry: an empirical study. *Total Quality Management and Business Excellence,* 21, 953-969.

HOSSAIN, M., ISLAM, K. Z., SAYEED, M. A. & KAURANEN, I. 2016. A comprehensive review of open innovation literature. *Journal of Science & Technology Policy Management*.

HUACCHO HUATUCO, L., MARTINEZ, V., BURGESS, T. F. & SHAW, N. E. 2019. High value manufacturing (HVM) in the UK: case studies and focus group insights. *Production Planning & Control,* 30, 60-75.

HUAN, S. H., SHEORAN, S. K. & WANG, G. 2004. A review and analysis of supply chain operations reference (SCOR) model. *Supply chain management: An international Journal,* 9, 23-29.

HUESKE, A.-K. & GUENTHER, E. 2015. What hampers innovation? External stakeholders, the organization, groups and individuals: a systematic review of empirical barrier research. *Management Review Quarterly,* 65, 113-148.

HURMELINNA-LAUKKANEN, P., SAINIO, L. M. & JAUHIAINEN, T. 2008. Appropriability regime for radical and incremental innovations. *R&D Management,* 38, 278-289.

HUSS, W. R. & HONTON, E. J. 1987. Scenario planning—what style should you use? *Long range planning,* 20, 21-29.

IDDRIS, F. 2016. Innovation capability: A systematic review and research agenda. *Interdisciplinary Journal of Information, Knowledge and Management,* 11, 235-260.

IDDRIS, F. 2018. Examining innovation capability in a supply chain context. *International Journal of Business Research and Management,* 9, 62-71.

JACOBIDES, M. G., CENNAMO, C. & GAWER, A. 2018. Towards a theory of ecosystems. *Strategic management journal,* 39, 2255-2276.

JAFARI, Y. & BRITZ, W. 2020. Brexit: an economy-wide impact assessment on trade, immigration, and foreign direct investment. *Empirica,* 47, 17-52.

JANSSEN, M. J., CASTALDI, C. & ALEXIEV, A. 2016. Dynamic capabilities for service innovation: conceptualization and measurement. *R&D Management,* 46, 797-811.

JETTER, A. J. Educating the guess: strategies, concepts and tools for the fuzzy front end of product development. PICMET'03: Portland International Conference on Management of Engineering and Technology Technology Management for Reshaping the World, 2003., 2003. IEEE, 261-273.

JOHNSON, P. & GILL, J. 2010. Research methods for managers. *Research Methods for Managers*, 1-288.

JONES, R. 2016. Innovation, research and the UK's productivity crisis. *SPERI paper*.

JUNG, D. D., WU, A. & CHOW, C. W. 2008. Towards understanding the direct and indirect effects of CEOs' transformational leadership on firm innovation. *The leadership quarterly,* 19, 582-594.

KAHN, H. & WIENER, A. J. 1967. year 2000; a framework for speculation on the next thirty-three years.

KAMALAHMADI, M. & PARAST, M. M. 2016. A review of the literature on the principles of enterprise and supply chain resilience: Major findings and directions for future research. *International Journal of Production Economics,* 171, 116-133.

KAMARUDDEEN, A. M., YUSOF, N. A. & SAID, I. 2009. A proposed framework for measuring firm innovativeness in the housing industry. *International Journal of Organizational Innovation,* 2, 101-132.

KAMASAK, R. 2015. Determinants of innovation performance: a resource-based study. *Social and Behavioral Sciences,* 195, 1330-1337.

KAUF, F. & KNIESS, J. 2014. Managing Innovation During Economic Changes and Crisis:"How Small and Mid-Sized Enterprises React". *Entrepreneurship, Innovation and Economic Crisis.* Springer.

KAUFFMAN, S. & MACREADY, W. 1995. Technological evolution and adaptive organizations. *Complexity,* 1, 26-43.

KEELEY, L., WALTERS, H., PIKKEL, R. & QUINN, B. 2013. *Ten types of innovation: The discipline of building breakthroughs*, John Wiley & Sons.

KELEMEN, M. & BANSAL, P. 2002. The conventions of management research and their relevance to management practice. *British Journal of Management,* 13, 97-108.

KESKIN, H. 2006. Market orientation, learning orientation, and innovation capabilities in SMEs. *European Journal of innovation management,* 9, 396-417.

KETCHEN, D. & HULT, T. 2007. Bridging organization theory and supply chain management: The case of best value supply chains. *Journal of operations management,* 25, 573-580.

KLIMKO, G. Knowledge management and maturity models: Building common understanding. Proceedings of the 2nd European conference on knowledge management, 2001. Bled, Slovenia, 269-278.

KOHOUTEK, H. J. 1996. Reflections on the capability and maturity models of engineering processes. *Quality and reliability engineering international,* 12, 147-155.

KOTTER, J. P. 2012. *Leading change*, Harvard business press.

KOZLENKOVA, I. V., SAMAHA, S. A. & PALMATIER, R. W. 2014. Resource-based theory in marketing. *Journal of the academy of marketing science,* 42, 1-21.

KRIPPENDORFF, K. 2018. *Content analysis: An introduction to its methodology*, Sage publications.

KRISHNAN, R., YEN, P., AGARWAL, R., ARSHINDER, K. & BAJADA, C. 2021. Collaborative innovation and sustainability in the food supply chain-evidence from farmer producer organisations. *Resources, Conservation and Recycling,* 168, 105253.

KRUEGER, R. A. 2014. *Focus groups: A practical guide for applied research*, Sage publications.

KRUGMAN, P. R. 1997. *The age of diminished expectations: US economic policy in the 1990s*, MIT press.

KURTZ, D. J. & VARVAKIS, G. 2016. Dynamic capabilities and organizational resilience in turbulent environments. *Competitive strategies for small and medium enterprises.* Springer.
LANE, P. J., KOKA, B. R. & PATHAK, S. 2006. The reification of absorptive capacity: A critical review and rejuvenation of the construct. *Academy of management review,* 31**,** 833-863.
LANE, P. J. & LUBATKIN, M. 1998. Relative absorptive capacity and interorganizational learning. *Strategic management journal,* 19**,** 461-477.
LAWSON, B. & SAMSON, D. 2001. Developing innovation capability in organisations: a dynamic capabilities approach. *International journal of innovation management,* 5**,** 377-400.
LEDERER, A. L. & SETHI, V. 1992. Meeting the challenges of information systems planning. *Long Range Planning,* 25**,** 69-80.
LEE, D. H., CHOI, S. B. & KWAK, W. J. 2014. The effects of four dimensions of strategic orientation on firm innovativeness and performance in emerging market small-and medium-size enterprises. *Emerging Markets Finance and Trade,* 50**,** 78-96.
LEYDESDORFF, L. & ETZKOWITZ, H. 1998. The triple helix as a model for innovation studies. *Science and public policy,* 25**,** 195-203.
LI, L., SU, Q. & CHEN, X. 2011. Ensuring supply chain quality performance through applying the SCOR model. *International Journal of Production Research,* 49**,** 33-57.
LII, P. & KUO, F.-I. 2016. Innovation-oriented supply chain integration for combined competitiveness and firm performance. *International Journal of Production Economics,* 174**,** 142-155.
LIN, C., WU, Y.-J., CHANG, C., WANG, W. & LEE, C.-Y. 2012. The alliance innovation performance of R&D alliances - the absorptive capacity perspective. *Technovation,* 32**,** 282-292.
LIN, Y. & WU, L.-Y. 2014. Exploring the role of dynamic capabilities in firm performance under the resource-based view framework. *Journal of business research,* 67**,** 407-413.
LLACH, J. & NORDQVIST, M. 2010. Innovation in family and non-family businesses: A resource perspective. *International Journal of Entrepreneurial Venturing,* 2**,** 381-399.
LOCKAMY, A. & MCCORMACK, K. 2004. Linking SCOR planning practices to supply chain performance: An exploratory study. *International journal of operations & production management,* 24**,** 1192-1218.
LOCKETT, A., THOMPSON, S. & MORGENSTERN, U. 2009. The development of the resource-based view of the firm: A critical appraisal. *International journal of management reviews,* 11**,** 9-28.
LOPES, J. N. M. & FARINHA, L. 2018. Measuring the performance of innovation and entrepreneurship networks. *Journal of the Knowledge Economy,* 9**,** 402-423.
MACBRYDE, J., MENDIBIL, K., PATON, S., DAVIDSON, L. & BITITCI, U. 2009. Manufacturing in Scotland.
MACBRYDE, J., PATON, S. & CLEGG, B. 2013. Understanding high-value manufacturing in Scottish SMEs. *International Journal of Operations & Production Management*.
MACHIKITA, T. & UEKI, Y. 2015. Measuring and Explaining Innovative Capability: Evidence from S outheast A sia. *Asian Economic Policy Review,* 10**,** 152-173.
MARTELLI, A. 2001. Scenario building and scenario planning: state of the art and prospects of evolution. *Futures Research Quarterly,* 17**,** 57-74.
MARTINI, A. & PELLEGRINI, L. 2005. Barriers and levers towards knowledge management configurations: A case study-based approach. *Journal of Manufacturing Technology Management*.

MAYRING, P. 2004. Qualitative content analysis. *A companion to qualitative research,* 1**,** 159-176.
MCADAM, R., MILLER, K., MCMACKEN, N. & DAVIES, J. 2010. The development of absorptive capacity-based innovation in a construction SME. *The International Journal of Entrepreneurship and Innovation,* 11**,** 231-244.
MCBRIDE, T. 2010. Organisational theory perspective on process capability measurement scales. *Journal of Software Maintenance and Evolution: Research and Practice,* 22**,** 243-254.
MCGEOCH, A. & SPOWAGE, M. 2020. The Economic Impact of Job Losses in the Civil Aviation and Aerospace Engineering Sectors.
MELNYK, S. A., CLOSS, D. J., GRIFFIS, S. E., ZOBEL, C. W. & MACDONALD, J. R. 2014. Understanding supply chain resilience. *Supply Chain Management Review,* 18**,** 34-41.
MENDOZA-SILVA, A. 2021. Innovation capability: a systematic literature review. *European Journal of Innovation Management,* 24**,** 707-734.
MENTZER, J. T., DEWITT, W., KEEBLER, J. S., MIN, S., NIX, N. W., SMITH, C. D. & ZACHARIA, Z. G. 2001. Defining supply chain management. *Journal of Business logistics,* 22**,** 1-25.
MILES, M. B. & HUBERMAN, A. M. 1994. *Qualitative data analysis: An expanded sourcebook*, sage.
MILLER, J. H., PAGE, S. E. & LEBARON, B. 2008. Complex adaptive systems: an introduction to computational models of social life. *Journal of Economic Literature,* 46**,** 427-428.
MITCHELL, R., BOYLE, B., BURGESS, J. & MCNEIL, K. 2014. You Can't Make a Good Wine without a Few Beers: Gatekeepers and knowledge flow in industrial districts. *Journal of Business Research,* 67**,** 2198-2206.
MOLDAVSKA, A. & WELO, T. 2017. The concept of sustainable manufacturing and its definitions: A content-analysis based literature review. *Journal of Cleaner Production,* 166**,** 744-755.
MONTGOMERY, C. A. & COLLIS, D. 1995. Competing on resources: strategy in the 1990s. *Harvard Business Review,* 73**,** 118-128.
MWAURA, S., SAHASRANAMAM, S., HART, M., BONNER, K., PRASHAR, N., RI, A. & LEVIE, J. 2021. Global Entrepreneurship Monitor: Scotland 2020 Report.
NARASIMHAN, R. & NARAYANAN, S. 2013. Perspectives on supply network–enabled innovations. *Journal of Supply Chain Management,* 49**,** 27-42.
NATH, P., NACHIAPPAN, S. & RAMANATHAN, R. 2010. The impact of marketing capability, operations capability and diversification strategy on performance: A resource-based view. *Industrial Marketing Management,* 39**,** 317-329.
NILSSON, S. & RITZÉN, S. 2014. Exploring the use of innovation performance measurement to build innovation capability in a medical device company. *Creativity and Innovation Management,* 23**,** 183-198.
NTABE, E. N., LEBEL, L., MUNSON, A. D. & SANTA-EULALIA, L.-A. 2015. A systematic literature review of the supply chain operations reference (SCOR) model application with special attention to environmental issues. *International Journal of Production Economics,* 169**,** 310-332.
O'BRIEN, F. A. 2004. Scenario planning––lessons for practice from teaching and learning. *european Journal of operational research,* 152**,** 709-722.
OECD 2015. The future of productivity. Joint Economics Department the Directorate for Science, Technology Innovation Policy Note: OECD Publishing Paris, France.
OH, D.-S., PHILLIPS, F., PARK, S. & LEE, E. 2016. Innovation ecosystems: A critical examination. *Technovation,* 54**,** 1-6.
ONS 2021b. Coronavirus and the impact on output in the UK economy: January 2021.

OTTENS, M., FRANSSEN, M., KROES, P. & VAN DE POEL, I. 2006. Modelling infrastructures as socio-technical systems. *Int. J. Crit. Infrastructures,* 2, 133-145.
PAGELL, M. & WU, Z. 2009. Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars. *Journal of supply chain management,* 45, 37-56.
PAPAIOANNOU, T., WIELD, D. & CHATAWAY, J. Knowledge ecologies and ecosystems? An empirically grounded reflection on recent developments in innovation systems theory. 6th International Triple Helix Conference on University-Government-Industry Relations, 2007 Singapore. 1–31.
PELLEGRINO, G. 2018. Barriers to innovation in young and mature firms. *Journal of Evolutionary Economics,* 28, 181-206.
PFEFFER, J. & FONG, C. T. 2002. The end of business schools? Less success than meets the eye. *Academy of management learning & education,* 1, 78-95.
PFEFFER, J. & SALANCIK, G. R. 2003. *The external control of organizations: A resource dependence perspective*, Stanford University Press.
PILLKAHN, U. 2008. *Using trends and scenarios as tools for strategy development: shaping the future of your enterprise*, John Wiley & Sons.
PLATTNER, H., MEINEL, C. & WEINBERG, U. 2009. *Design-thinking*, Springer.
PORTER, M. E. 1990. *Competitive advantage of nations: creating and sustaining superior performance,* New York, The Free Press.
PORTER, M. E. 1997. Competitive strategy. *Measuring business excellence*.
POSCH, A. & WIEDENEGGER, A. 2014. Innovativeness in family firms: drivers of innovation and their mediating role. *Mittelständische Unternehmen*, 91-129.
PURWANGGONO, B. & AMALIA, A. N. 2019. Modified assessment tools for measuring innovativeness level of companies. *Cogent Engineering,* 6, 1649006.
PWC 2020. COVID-19: Consequences for the chemicals industry – preparing for 'the day after' the global pandemic.
RAGHUVANSHI, J., AGRAWAL, R. & GHOSH, P. K. 2019. Measuring the innovation capability of micro enterprises in India: Construct development and validation. *Benchmarking: An International Journal*.
RAHMAN, M., DOROODIAN, M., KAMARULZAMAN, Y. & MUHAMAD, N. 2015. Designing and validating a model for measuring sustainability of overall innovation capability of small and medium-sized enterprises. *Sustainability,* 7, 537-562.
RASHIDIRAD, M., SALIMIAN, H., SOLTANI, E. & FAZELI, Z. 2017. Competitive strategy, dynamic capability, and value creation: Some empirical evidence from UK telecommunications firms. *Strategic Change,* 26, 333-342.
RAYNARD, M., JOHNSON, G. & GREENWOOD, R. 2015. Institutional theory and strategic management. *Advanced strategic management: A multi-perspective approach*, 9-34.
REINMOELLER, P. & VAN BAARDWIJK, N. 2005. The link between diversity and resilience. *MIT Sloan management review,* 46, 61.
RHEE, J., PARK, T. & LEE, D. H. 2010. Drivers of innovativeness and performance for innovative SMEs in South Korea: Mediation of learning orientation. *Technovation,* 30, 65-75.
RING, P. S., DOZ, Y. L. & OLK, P. M. 2005. Managing formation processes in R&D consortia. *California Management Review,* 47, 137-156.
ROSENKOPF, L. & NERKAR, A. 2001. Beyond local search: boundary-spanning, exploration, and impact in the optical disk industry. *Strategic management journal,* 22, 287-306.

SABAHI, S. & PARAST, M. M. 2020. Firm innovation and supply chain resilience: a dynamic capability perspective. *International Journal of Logistics Research and Applications,* 23**,** 254-269.

SAMSON, D., GLOET, M. & SINGH, P. 2017. Systematic innovation capability: Evidence from case studies and a large survey. *International Journal of Innovation Management,* 21**,** 1750058.

SANKOWSKA, A. & PALISZKIEWICZ, J. 2016. Dimensions of institutionalized organizational trust and firm's innovativeness. *Journal of Computer Information Systems,* 56**,** 168-174.

SAUNDERS, M., LEWIS, P. & THORNHILL, A. 2016. *Research methods for business students,* Harlow, Pearson.

SAUNILA, M. 2016. Performance measurement approach for innovation capability in SMEs. *International Journal of Productivity and Performance Management*.

SAUNILA, M. 2017a. Innovation capability in achieving higher performance: perspectives of management and employees. *Technology Analysis & Strategic Management,* 29**,** 903-916.

SAUNILA, M. 2017b. Understanding innovation performance measurement in SMEs. *Measuring Business Excellence*.

SAUNILA, M. 2019. Innovation capability in SMEs: A systematic review of the literature. *Journal of Innovation Knowledge*.

SAUNILA, M., PEKKOLA, S. & UKKO, J. 2014. The relationship between innovation capability and performance. *International Journal of Productivity and Performance Management,* 63**,** 234-249.

SAUNILA, M. & UKKO, J. 2013. Facilitating innovation capability through performance measurement: A study of Finnish SMEs. *Management Research Review*.

SAUNILA, M. & UKKO, J. 2014. Intangible aspects of innovation capability in SMEs: Im-pacts of size and industry. *Journal of Engineering and Technology Management,* 33**,** 32-46.

SAUNILA, M., UKKO, J. & RANTANEN, H. 2012. Innovation capability and its measurement in Finnish SMEs. *Practice-Based Innovation: Insights, Applications and Policy Implications.* Springer.

SCHILLING, M. A. 1998. Technological lockout: An integrative model of the economic and strategic factors driving technology success and failure. *Academy of management review,* 23**,** 267-284.

SCHNAARS, S. P. 1987. How to develop and use scenarios. *Long range planning,* 20**,** 105-114.

SCHOEMAKER, P. J. 1991. When and how to use scenario planning: a heuristic approach with illustration. *Journal of forecasting,* 10**,** 549-564.

SCHOEMAKER, P. J. 1995. Scenario planning: a tool for strategic thinking. *Sloan management review,* 36**,** 25-50.

SCHUMPETER, J. 1934. *The theory of economic development* Harvard University Press, Cambridge, MA.

SCHUMPETER, J. 1950. *Capitalism, socialism and democracy*, Harper & Row, New York.

SCOTGOV 2021a. First estimate of GDP: 2020 Q4.

SCOTGOV 2021b. Making Scotland's future - a recovery plan for manufacturing.

SCOTGOV 2022a. Monthly economic brief: February 2022.

SCOTGOV 2023. Scotland's National Innovation Strategy.

SEO, Y.-J., DINWOODIE, J. & KWAK, D.-W. 2014. The impact of innovativeness on supply chain performance: is supply chain integration a missing link? *Supply Chain Management: An International Journal*.

SEURING, S. & GOLD, S. 2012. Conducting content-analysis based literature reviews in supply chain management. *Supply Chain Management: An International Journal*.

SHEPHERD, D. A. & SUDDABY, R. 2017. Theory building: A review and integration. *Journal of Management,* 43**,** 59-86.

SHI, H., PENG, S., LIU, Y. & ZHONG, P. 2008. Barriers to the implementation of cleaner production in Chinese SMEs: government, industry and expert stakeholders' perspectives. *Journal of cleaner production,* 16**,** 842-852.

SICOTTE, H., DROUIN, N. & DELERUE, H. 2014. Innovation portfolio management as a subset of dynamic capabilities: Measurement and impact on innovative performance. *Project Management Journal,* 45**,** 58-72.

SIMON, H. A. 1962. The Architecture of Complexity. *Proceedings of the American Philosophical Society,* 106**,** 467-482.

SNYDER, H. 2019. Literature review as a research methodology: An overview and guidelines. *Journal of business research,* 104**,** 333-339.

SOOSAY, C. A. & HYLAND, P. W. 2004. Driving innovation in logistics: case studies in distribution centres. *Creativity and Innovation Management,* 13**,** 41-51.

SPANO, R. 2005. Potential sources of observer bias in police observational data. *Social science research,* 34**,** 591-617.

SRIVASTAVA, A. & THOMSON, S. B. 2009. Framework analysis: a qualitative methodology for applied policy research.

SURANA, A., KUMARA, S., GREAVES, M. & RAGHAVAN, U. N. 2005. Supply-chain networks: a complex adaptive systems perspective. *International Journal of Production Research,* 43**,** 4235-4265.

SWARTZ, E., MONEY, A., WILLIAMS, B. & REMENYI, D. 1998. Doing research in business and management: an introduction to process and method. *Doing Research in Business and Management***,** 1-320.

SWINK, M., NARASIMHAN, R. & WANG, C. 2007. Managing beyond the factory walls: effects of four types of strategic integration on manufacturing plant performance. *Journal of operations management,* 25**,** 148-164.

SZULANSKI, G. 1996. Exploring internal stickiness: Impediments to the transfer of best practice within the firm. *Strategic management journal,* 17**,** 27-43.

TAN, K. H., ZHAN, Y., JI, G., YE, F. & CHANG, C. 2015. Harvesting big data to enhance supply chain innovation capabilities: An analytic infrastructure based on deduction graph. *International Journal of Production Economics,* 165**,** 223-233.

TECHNOLOGYSCOTLAND 2022. Scottish Government launch Innovation Strategy Call for Evidence.

TEECE, D. J. 2007. Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. *Strategic management journal,* 28**,** 1319-1350.

TEECE, D. J., PISANO, G. & SHUEN, A. 1997. Dynamic capabilities and strategic management. *Strategic management journal,* 18**,** 509-533.

TEGARDEN, L. F., HATFIELD, D. E. & ECHOLS, A. E. 1999. Doomed from the start: What is the value of selecting a future dominant design? *Strategic Management Journal,* 20**,** 495-518.

THOMPSON, V. 1965. Bureaucracy and innovation. *Administrative science quarterly,* 10**,** 1-20.

THUN, J. H. & MÜLLER, A. 2010. An empirical analysis of green supply chain management in the German automotive industry. *Business strategy and the environment,* 19**,** 119-132.

TIDD, J. & BESSANT, J. 2018. *Managing innovation: integrating technological, market and organizational change*, John Wiley & Sons.

TRANFIELD, D., DENYER, D. & SMART, P. 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British journal of management,* 14**,** 207-222.

TRANFIELD, D. & STARKEY, K. 1998. The nature, social organization and promotion of management research: Towards policy. *British journal of Management,* 9**,** 341-353.
TURHAN, Z. D., VAYVAY, O. & BIRGUN, S. 2011. Supply chain reengineering in a paint company using axiomatic design. *The International Journal of Advanced Manufacturing Technology,* 57**,** 421-435.
VAN DE VEN, A. H. & JOHNSON, P. E. 2006. Knowledge for theory and practice. *Academy of management review,* 31**,** 802-821.
VAN DEN BOSCH, F. A., VOLBERDA, H. W. & DE BOER, M. 1999. Coevolution of firm absorptive capacity and knowledge environment: Organizational forms and combinative capabilities. *Organization science,* 10**,** 551-568.
VARUM, C. A. & MELO, C. 2010. Directions in scenario planning literature–A review of the past decades. *Futures,* 42**,** 355-369.
VERMEULEN, F. & BARKEMA, H. 2001. Learning through acquisitions. *The academy of management journal,* 44**,** 457-476.
VICENTE, M., ABRANTES, J. L. & TEIXEIRA, M. S. 2015. Measuring innovation capability in exporting firms: the INNOVSCALE. *International Marketing Review,* 32**,** 29-51.
VOLBERDA, H. W., FOSS, N. J. & LYLES, M. A. 2010. Perspective - Absorbing the concept of absorptive capacity: How to realize its potential in the organization field. *Organization science,* 21**,** 931-951.
WACK, P. 1985. Scenarios: uncharted waters ahead. *Harvard business review,* 63**,** 72-89.
WADE, J. & HEYDARI, B. Complexity: Definition and reduction techniques. Proceedings of the poster workshop at the 2014 complex systems design & management international conference, 2014. Citeseer, 213-226.
WANG, W. Y., CHAN, H. K. & PAULEEN, D. J. 2010. Aligning business process reengineering in implementing global supply chain systems by the SCOR model. *International journal of production research,* 48**,** 5647-5669.
WATKINS, A., PAPAIOANNOU, T., MUGWAGWA, J. & KALE, D. 2015. National innovation systems and the intermediary role of industry associations in building institutional capacities for innovation in developing countries: A critical review of the literature. *Research Policy,* 44**,** 1407-1418.
WEI, H.-L. & WANG, E. T. 2010. The strategic value of supply chain visibility: increasing the ability to reconfigure. *European Journal of Information Systems,* 19**,** 238-249.
WEISSENBERGER-EIBL, M. & SCHWENK, J. 2009. "Lifeblood knowledge": dynamic relational capabilities (DRC) and knowledge for firm innovativeness and competitive advantage. *Measuring Business Excellence*.
WENDLER, R. 2012. The maturity of maturity model research: A systematic mapping study. *Information and software technology,* 54**,** 1317-1339.
WERNERFELT, B. 1984. A resource-based view of the firm. *Strategic management journal,* 5**,** 171-180.
WEST, J. & BOGERS, M. 2014. Leveraging external sources of innovation: a review of research on open innovation. *Journal of product innovation management,* 31**,** 814-831.
WEST, M. & ANDERSON, N. 1996. Innovation in top management teams. *Journal of Applied psychology,* 81**,** 680.
WILLIAMS, M. & MOSER, T. 2019. The art of coding and thematic exploration in qualitative research. *International Management Review,* 15**,** 45-55.
WOHLIN, C. Guidelines for snowballing in systematic literature studies and a replication in software engineering. Proceedings of the 18th international conference on evaluation and assessment in software engineering, 2014. 1-10.

WÓJCIK, P. 2015. Exploring links between dynamic capabilities perspective and resource-based view: A literature overview. *International Journal of Management and Economics,* 45**,** 83-107.

WONG, C. Y., BOON-ITT, S. & WONG, C. W. 2011. The contingency effects of environmental uncertainty on the relationship between supply chain integration and operational performance. *Journal of Operations management,* 29**,** 604-615.

WRIGHT, G., BRADFIELD, R. & CAIRNS, G. 2013. Does the intuitive logics method–and its recent enhancements–produce "effective" scenarios? *Technological Forecasting and Social Change,* 80**,** 631-642.

YIN, R. K. 2009. *Case study research: Design and methods*, sage.

YU, D. & HANG, C. C. 2010. A reflective review of disruptive innovation theory. *International journal of management reviews,* 12**,** 435-452.

YUNUS, E. N. 2018. Leveraging supply chain collaboration in pursuing radical innovation. *International Journal of Innovation Science*.

YUSUF, Y. Y., GUNASEKARAN, A., ADELEYE, E. O. & SIVAYOGANATHAN, K. 2004. Agile supply chain capabilities: Determinants of competitive objectives. *European journal of operational research,* 159**,** 379-392.

ZAHRA, S. A. & GEORGE, G. 2002. Absorptive capacity: A review, reconceptualization, and extension. *Academy of management review,* 27**,** 185-203.

ZENG, S. X., XIE, X. M. & TAM, C. M. 2010. Relationship between cooperation networks and innovation performance of SMEs. *Technovation,* 30**,** 181-194.

ZHANG, M., MACPHERSON, A. & JONES, O. 2006. Conceptualizing the learning process in SMEs: improving innovation through external orientation. *International Small Business Journal,* 24**,** 299-323.

ZHOU, H., BENTON JR, W., SCHILLING, D. A. & MILLIGAN, G. W. 2011. Supply chain integration and the SCOR model. *Journal of Business Logistics,* 32**,** 332-344.

ZHU, Q., KRIKKE, H. & CANIËLS, M. C. 2018. Supply chain integration: value creation through managing inter-organizational learning. *International journal of operations & production management*.

ZHU, Y., WITTMANN, X. & PENG, M. W. 2012. Institution-based barriers to innovation in SMEs in China. *Asia Pacific Journal of Management,* 29**,** 1131-1142.

ZIKMUND, W. G., BABIN, B. J., CARR, J. C. & GRIFFIN, M. 2010. Business Research Methods, South Western. *Cengage Learning*.

ZIMMERMANN, R., FERREIRA, L. M. D. & MOREIRA, A. C. 2016. The influence of supply chain on the innovation process: a systematic literature review. *Supply Chain Management: An International Journal*.

ZOTT, C. 2003. Dynamic capabilities and the emergence of intraindustry differential firm performance: insights from a simulation study. *Strategic management journal,* 24**,** 97-125.

APPENDIX

Appendix Chapter 3 – Research participant information sheet

A.C3.1 Participant information sheet for interviews (chapter 5)

Participant Information Sheet (Interviews)

Name of department: **Design, Manufacturing, and Engineering Management (DMEM)**
Title of the study: **Expected impact of Covid-19 on supply chain management and innovation activities in manufacturing**

Introduction
The department of design manufacturing and engineering management at the University of Strathclyde is conducting this research project about Covid-19 implications on innovation. Involved in the research are Prof MacBryde as innovation specialist, Dr Zante as supply chain specialist, and Mr Reckordt as PhD student. Contact details can be found below.

What is the purpose of this research?
It is likely that a number of companies will go bankrupt as a consequence of the Covid-19 implications. This can lead to a major disruption of supply chains in some industry sectors. However, one of the main drivers to overcome disruptive change, is innovation. High innovativeness as a main driver for supply chain resilience could not only help limit the economic impact of Covid-19, but it can also help Scottish manufacturing emerge from the situation stronger than it was before Covid-19. To be able to boost innovation, one first needs to know how the importance of innovation is perceived and how it has changed. To later develop targeted and tailored support it is important to know, which industry sectors will be affected more than others.

Therefore, a qualitative exploratory study shall be carried out. A set of interviews with experts from Scottish manufacturing is carried out with the following objectives:

1. To identify which manufacturing industries' supply chains are believed to be hit hardest by Covid-19 implications.
2. To identify changes in the perception of the importance of innovation and changes in innovation activities caused by Covid-19 implications.
3. To investigate how ready companies feel to deal with supply chain disruption and what kind of support they wish for.
4. To investigate if the perception of the importance of innovation changes once a stable new normal is reached. Hence, the study shall be repeated after 12 months.

The outcomes of the study shall be used as a starting point for more in depths research on how to design targeted and tailored innovation support!

Do you have to take part?
Participation is voluntary. Participants have the right to withdraw from the research without detriment at all times.

What will you do in the project?
To participate in this research project participants are interviewed either in a semi-structured or unstructured way. Interviews will be carried out online using Microsoft teams. Interviews will be recorded and transcribed for analysis. Interviews take up to one hour.

The place of useful learning

Why have you been invited to take part?
Participants of this study are required to work at a company operating in the manufacturing industry in Scotland. The participant must be able to answer questions about strategic matters and innovation. Potential participants are approached through direct email contact. This is just the case if a company or an individual has accepted to be contacted about such studies with the University of Strathclyde before. The study is also advertised online on social media through university channels.

What information is being collected in the project?
Information is collected about the participant's company regarding the industry sector, supply chain position, size, the perception of innovation during Covid-19, and perception of the Covid-19 impact on supply chains. This data is anonymised after transcription for analysis.

Who will have access to the information?
Access to data is granted just to the involved researchers Prof MacBryde, Dr Zante, and Mr Reckordt.

Where will the information be stored and how long will it be kept for?
All data are stored on secure University of Strathclyde servers. Upon transcription of the interviews, interviewee and company will be made anonymous for further analysis. Then the row data including video recordings will be deleted.

Thank you for reading this information – please ask any questions if you are unsure about what is written here.

Please also read our Privacy Notice for Research Participants

A.C3.2 Participant information sheet for focus groups and strategizing workshops (chapter 6 and chapter 8)

Participant Information Sheet (Focus groups & workshops)

Name of department: **Design, Manufacturing, and Engineering Management (DMEM)**
Title of the study: **Expected impact of Covid-19 on supply chain management and innovation activities in manufacturing**

Introduction
The department of design manufacturing and engineering management at the University of Strathclyde is conducting this research project about Covid-19 implications on innovation. Involved in the research are Prof MacBryde as innovation specialist, Dr Zante as supply chain specialist, and Mr Reckordt as PhD student. Contact details can be found below.

What is the purpose of this research?
It is likely that a number of companies will go bankrupt as a consequence of the Covid-19 implications. This can lead to a major disruption of supply chains in some industry sectors. However, one of the main drivers to overcome disruptive change, is innovation. High innovativeness as a main driver for supply chain resilience could not only help limit the economic impact of Covid-19, but it can also help Scottish manufacturing emerge from the situation stronger than it was before Covid-19. For the present study the aerospace sector has been chosen as subject of investigation. Here policy making advice is suggested to boost innovation capability along one supply chain. In detail, the objectives of this study are:

1. To identify the current state of innovation capability in a participating company as part of the supply chain that is being analysed, as well as identifying the current state of innovation capability of the supply chain itself (focus group / audit)
2. Develop improvement strategies for innovation capability based on the initial audit for participating companies and the supply chain itself (workshop / strategizing)
3. Derive policy making advice to support the successful implementation of developed improvement strategies

During the research a novel innovation capability maturity framework for supply chains is used which is also aimed at validating with the current research.

Do you have to take part?
Participation is voluntary. Participants have the right to withdraw from the research without detriment at all times.

What will you do in the project?
Analysed will be single companies of the same supply chain and the supply chain as a whole. The study consists of two parts. Part one is an audit of the current innovation capability of a company and the supply chain as focus group interviews. Part two aims at developing strategies for improvement of innovation capability either for a company or the supply chain as a whole. Based on future developments of the aerospace sector and the results of the initial audits, strategies are developed with the same participants in so called strategizing workshops. This means there are two dates necessary for each participating company and the supply chain representation group. Each date will take approximately 3 hours. Focus groups and strategizing workshops are conducted online using Microsoft Teams and Miro online note boards. Focus groups and strategizing workshops are recorded for analysis.

The place of useful learning

Why have you been invited to take part?
Participants of this study are required to work at a company operating in the aerospace industry in Scotland. The participant must be able to answer questions about strategic matters and innovation. Potential participants are approached through direct email contact. This is just the case if a company or an individual has accepted to be contacted about such studies with the University of Strathclyde before. The study is also advertised online on social media through university channels.

What information is being collected in the project?
Information is collected about the participant's company or supply chain group regarding innovation activities, leadership, organisational aspects, and strategic aspects. This data is anonymised for analysis.

Who will have access to the information?
Access to data is granted just to the involved researchers Prof MacBryde, Dr Zante, and Mr Reckordt.

Where will the information be stored and how long will it be kept for?
All data are stored on secure University of Strathclyde servers. After data collection participants and participating companies will be made anonymous. Then the row data including video recordings will be deleted.

Thank you for reading this information – please ask any questions if you are unsure about what is written here.

Please also read our Privacy Notice for Research Participants

Appendix Chapter 4 – MaSCICMAF maturity stage descriptions

C1 Organisational culture and leadership

IC Subdimension	Maturity level 1 - Reactive	Maturity level 2 - Adaptive	Maturity level 3 - Proactive
Risk acceptance and risk management	There is little awareness of risk in general. There is no formal risk management in place, but some risk management tools are used. Employees are not involved in risk assessments. In general risk is not appreciated.	There is a general awareness of risk. Formal use of risk management tools is made. However, there is no high tolerance for risk taking or for failure.	The company is highly aware of risks. Risks are manged structured using formal tools. Employees participate in risk management. Risk taking is valued and mistakes are considered as part of learning. Taken risks are managed well.
Ambition, promotion of innovation and change, openness towards change, and communication of success	Innovation and change is not important to management. There is a low level of initiative taking. Initiatives meet significant resistance from co-workers and management. Success and appreciation of ideas is usually not communicated broadly.	Innovation and change are promoted informally by innovation and change specialists or R&D personnel. These also take initiatives. Other employees are not involved in innovation and change. Some resistance to change is evident. Success of innovation and change is communicated informally and not systematically.	Strategy promotes innovation and change systematically. The organisation looks actively for opportunities to change, and employees take initiatives. Active living of innovation and change creating an intrapreneurial culture where employees are empowered to implement ideas. Success is formally and systematically communicated valuing the involved people.
Leadership practices, communication and decision making	Leadership is characterised by a directive style. Formal communication is valued within a strictly hierarchical system. Decision making needs time.	There is a directive leadership style, but initiatives are pushed informally if of interest to managers. Decision making still takes a lot of time.	Leadership is participatory. Communication and decision making are quick and informal.

C2 Entrepreneurship and strategy

IC Subdimension	***Maturity level 1 - Reactive***	***Maturity level 2 - Adaptive***	***Maturity level 3 - Proactive***
Strategic renewal and flexibility (Change management)	Company has informal change management processes in place without a formal change management team. Change is dealt with on an ad hoc basis if need arises. Strategy itself is not frequently reviewed or adapted.	Systematic change management processes and formal change team are in place. Processes can be repeated. Strategy itself is monitored constantly.	Systematic change management process including improvement is in place with a formal change management team. Focus lays on learning from change mistakes in the past. The strategy itself is reviewed and adapted frequently.
Organisational flexibility and agility	Understanding of the need for flexibility and how to measure it as part of systems performance. Reactive use of available flexibility is made to maintain system performance.	Company is at a state of being able to plan and control the available flexibility to sustain system' s performance. The focus is on management i.e., planning the available flexibility as well as the control of exploitable flexibility.	Company emphasizes the proactive management of flexibility towards agility. It plans and controls both external and internal environments to proactively influence the flexibility requirement as well as to bridge the gaps between the required, available, and exploited flexibility. The idea is not only to cure the symptom but also the cause.
Entrepreneurial capability	Company builds on exiting business model and customers. Low initiative for business development and network building.	Company explores new business models systematically. Adopting new business models and building new partnerships happen occasionally but not systematically.	Entrepreneurial mindset with capability to develop the business constantly, using new business models, attracting new customers, and building new networks.
Supply chain resilience	Company looks for suppliers when a need arises. No defined processes are in place for supplier selection. Supply is considered an exchange of goods or services. No long-term connection or supplier development is intended.	Supply base is scanned frequently for new supplier opportunities. Processes are in place for supplier selection. Collaboration is order and bulk based. No supplier development or supplier retainment programmes. OR supply base is not scanned frequently even though processes for supply selection and retention are in place	Company has supply base scanning processes in place. Defined and fast processes are in place for suppler selection. Processes are in place to retain suppliers and develop them.
Accessing of innovation support and funding	Company occasionally comes across public funding options and non-financial support industry support options. There is little understanding of application processes. Applications are rarely submitted.	Company scans public funding and available industry support frequently. The scanning is however, based on personal interest and not on structured company processes. Applications are submitted occasionally.	Company has processes and resources in place to monitor public funding and availability of non-financial support from industry support organisations. Processes are in place for funding applications and access to industry support. Both is accessed frequently
Diversity of products / services and diversity of customers	Single product or service business in a highly specialised industry with few customers. No thriving for diversification and no experience in market positioning	Diverse product and service portfolio for diversification but just a narrow customer base. Or broad customer base but single product or service business. Little experience in market positioning.	Diverse product and service portfolio. Addressing serving broad customer basis in different markets with diversity being part of the company strategy. High level of experience in market positioning.

C3 Knowledge management and technology adoption

IC Subdimension	*Maturity level 1 - Reactive*	*Maturity level 2 - Adaptive*	*Maturity level 3 - Proactive*
Knowledge management, idea management, and knowledge sharing	Communication of initiatives is mainly informal. Commitment is based solely on friendships or reputation. There is a low level of monitoring with limited sharing of facilities. Knowledge and information are informally shared but limited in a team or there is no sharing at all.	Centralized reporting of ideas is in place with regular meetings and open facilities. On demand budget for meeting commitments is available. Occasional inter-department knowledge sharing takes place. Digital systems are in place for easy knowledge sharing and communication.	Initiatives and ideas are linked. Communication via intranet with start-up shared facilities. Everyone can easily contribute with ideas. Idea sharing is encouraged. Knowledge is stored separately from knowledge holder and easily accessible and understandable for everyone. There is a structural budget in place for knowledge and idea sharing.
Technology adoption strategy and processes (e.g., digitalisation)	New technologies are introduced just on individual initiatives, but the company is broadly unaware of technological developments or ignores them. There are no systemised processes of introducing new technology. Trial and error mentality.	Technology is identified and introduced frequently. However, the introduction of new technology is considered responsibility of individual departments. Cross departmental initiatives are rare and there is no coordination on company scoring model to synchronise activities and define global processes.	There are defined strategies in place to continuously monitor and introduce new technologies on a company level. Strategic investments are made to build needed qualifications to use new technology. When preparing to introduce new technologies frameworks like readiness assessments are systematically used. Once a decision is made company is committed to introducing the new technology. Before the introduction a good understanding of the new technology is generated, its implications and benefits and threats are evaluated. Partners along the value chain are included in the introduction where applicable.

C4 Innovation strategy, communication, and open innovation

IC Subdimension	*Maturity level 1 - Reactive*	*Maturity level 2 - Adaptive*	*Maturity level 3 - Proactive*
clear innovation strategy aligned with company strategy and innovation measurement and adequate recourse allocation	Innovation is not promoted by the competitive strategy. Innovation activities are sporadic and not coordinated. If innovation is measured it is usually just financially. Resources need to be fought for every single innovation project.	There is an innovation strategy in place inline with the competitive strategy. Innovation activities are planned and measured. Measures include financial aspects and patents. Recourse allocation is subjective.	The competitive strategy promotes innovation. In line with this there is a separate clearly defined innovation strategy and innovation processes. Innovation goals are set and constantly measured. Measures go beyond finance and patents (like this maturity model). Enough financial, personnel, equipment resources are allocated to innovation projects. This is also constantly measured. Based on these measures' strategy, goals, resource allocation and processes are optimised.
Cooperation with suppliers, customers, public institutions, and openness to share information and to adopt new outside knowledge	Innovation cooperation and new partnerships are based on individual initiative. Low levels of informal standards for collaboration are in place.	Formal but low intense innovation cooperation. Partnerships are usually short and based on partial formal standardisation. Corporations usually take place with trusted previous partners and networks.	Partnerships are focussed on intensity and endurance to create joint innovation. Partnering tools used and management actively encourages satisfaction of partners and measures it; Communication is broadly standardised and ownership rules are clear. Active diversification of innovation partners and network expansion with private and public organisations. Partner selection is a defined process in line with the competitive strategy. Partnership opportunities are explored regularly.

C5 Organisational learning and absorptive capacity

IC Subdimension	*Maturity level 1 - Reactive*	*Maturity level 2 - Adaptive*	*Maturity level 3 - Proactive*
New knowledge and skills identification and acquisition (acquisition)	External knowledge and skills identification happens just sporadically and is mostly limited to direct competitors.	Knowledge and skills are identified frequently. The source of information is mainly the own industry. OR knowledge and skills are identified infrequently but the source of information is broad ideas, concepts, new information, and skills are shared across departments but not frequently. Cross departmental teams are rather an exception. Ideas, concepts, new information, and skills are shared across departments but not frequently. Cross departmental teams are rather an exception.	A continuous broad identification of information takes place as well in the own industry as in other industries. Outside the box thinking is highly promoted. There is a clear search strategy.
New knowledge and skills integration (assimilation)	Ideas, concepts, new information, and skills remain in the department where they are generated. Cross departmental exchange happens sporadically.	Ideas, concepts, new information, and skills are shared across departments but not frequently. Cross departmental teams are rather an exception.	Ideas, concepts, new information, and skills are communicated quickly across departments. Cross functional problem solving is the norm. Frequent meetings to exchange information, developments, and problems.
Application of knowledge and skills (transformation)	New knowledge and skills are barely integrated into daily operations	A number of employees include new knowledge and skills in their operations and drive the use of it. However, it is not companywide. Innovation methods are used sporadically.	Employees are able to absorb new information and include new knowledge and skills in daily operations linking existing and new knowledge and skills. Innovation methods are used frequently.
Exploitation of knowledge and skills (exploitation)	New knowledge and skills are usually not exploited. New products and services are rare, new business models and organisational change is not considered	New products or services are considered and introduced infrequently using new knowledge and skills. Sometimes organisational changes and new business models are considered.	Frequently new ways of exploiting new knowledge, skills, and new technology are considered. The company embraces new business models and new organisational constructs to exploit new information and technology.

C6 Individual creativity, skills and learning

IC Subdimension	*Maturity level 1 - Reactive*	*Maturity level 2 - Adaptive*	*Maturity level 3 - Proactive*
Individual skills in one's field of knowledge	Most employees have superficial knowledge and skills needed for their daily work. Workforce is rather generalist than specialised.	Some employees hold deep knowledge and skills in some areas of work. These people function as lead people.	Almost every employee holds deep individual knowledge and skills which is needed for their job.
Individual knowledge and skills about innovation	Employees hold superficial knowledge and skills about innovation. They are not aware or sure about importance of innovation for the business. Additional guidance from outside organisations is needed for innovation projects.	There is a general awareness that innovation is important for company success. Some innovation knowledge and skills are available and smaller innovation projects can be carried out without outside help.	Some employees hold deep individual knowledge and skills about innovation. These employees can teach others. There is a companywide high awareness of importance of innovation and its application for company success.
Individual continuous will for learning	Employees do not take initiatives and are resistant to learning.	Employees usually do not take the initiative of learning but are generally very open to personal development.	Employees take initiatives for further learning.
Availability of options for individual learning	Employees have to take initiatives to get support for individual learning.	Company offers some support for individual development. Development must be of benefit for company.	Company offers broad options for individual development. It does not have to be for direct company benefit. Systems are in place for control of what knowledge is gained.

SC1 Supply Chain Structure and Governance

IC Subdimension	Maturity level 1 - Reactive	Maturity level 2 - Adaptive	Maturity level 3 - Proactive
Nature of collaboration, fairness, use of power, and responsibility	There are no standards agreed on for collaboration or standards are dictated by larger members abusing their market power. Smaller members are not heard and there is no way to promote innovation for all members. Collaborations are designed to be transactions.	Standards are agreed on to run everyday supply relationship and set responsibilities. There are no standards for activities beyond everyday supply chain activities. In case of further collaboration bilateral individual agreements are used. Opportunities to promote innovations for all members are limited to promote innovation to the supply chain. Collaborations are mainly transactions with a few exceptions of deeper collaborations.	There is a committee representing all supply chain members. This committee allows everyone to be heard. Standards and responsibilities for everyday supply relationship and extraordinary collaborations are agreed on mutually and ensure a fair treatment for everyone. Governance provides options to promote innovations. No supply chain member abuses its market power. Collaborations are designed to be long lasting and to the benefit of all members.
Communication	There is little communication along the supply chain. Communication is rather reactive.	Communication takes place within different parts of the supply chain. However, these different parts do not communicate well with each	Communication takes place between most parts of the supply chain. Communication is considered useful, and companies proactively approach other supply chain mem-
Reliability and trust	Collaboration is characterised by general mistrust; reliability of members is limited but there are also no standards in place to protect intellectual property. Just transactional data is shared.	Careful approach to data sharing. Data beyond transaction is just shared with few trusted partners.	Collaboration is characterised by mutual trust and reliability. Collaborations are built on agreed standards especially for intellectual property. A wide range of data including innovation activities is shared.
Regulation	Supply chain is highly regulated either by legal requirements or quality requirements making innovations highly complex and expensive because approval or certification is required	Supply chain is regulated by quality standards. However, certification processes are uncomplicated and not expensive.	Supply chain is not very regulated. In general, to get an innovation on the market no expensive permissions or certifications are needed.
Change and risk attitude	Low general initiative taking. Initiatives meet resistance from supply chain members. Risk and change is generally avoided. Supply chain just changes reactively if there is a real threat	Some members take initiatives, but general atmosphere is change avers and huge efforts are needed to convince supply chain members of change and risk taking.	Supply chain members actively look for opportunities to change and promote them to their up and down stream supply chains which are generally willing to change and seize new opportunities
Supply chain structure	Supply chain is characterised by many TIER levels making innovation time consuming to	Parts of the supply chain have many TIER levels others have just few making innovation easier	Supply chain is flat meaning there are not many TIER levels making innovation rather easy to realise
Supply chain visibility	There is little supply chain visibility. Products and their parts can generally not be tracked back through the supply chain to the raw material.	Supply chain visibility is given for some supply that is actively tracked back through the supply chain to the raw material. Industry 4 technology is not widely used throughout the supply chain for more visibility.	There is high supply chain visibility. Products and their parts are usually tracked back through the supply chain to the raw material. Industry 4 technology is used for real-time visibility.
Joint value capturing with supply chain members and public support organisations	There is little or no joint innovation activity and developments.	Joint innovation activities take place between some members which have a history of collaboration and mutual trust. General openness towards new joint innovation activities is limited.	Collaboration in development is the norm. Collaborations take place in different parts of the supply chain. New collaborations are actively encouraged. Special innovation hubs (either physical or virtual) are used. Joint value capturing mechanisms are in place

SC2 Supply Base

IC Subdimension	*Maturity level 1 - Reactive*	*Maturity level 2 - Adaptive*	*Maturity level 3 - Proactive*
Supply base resilience	The supply base is narrow. Few or single suppliers of crucial products or services generating bottle necks. Supply chain is highly specialised. Crucial suppliers very timely and costly to replace. Supply base is generally untransparent.	The supply base is broad but has some significant bottle necks with a few crucial suppliers. Even though the suppliers would be difficult to replace it is unlikely that they break away. Especially these suppliers are transparent.	The supply base is broad. There are no or just few bottle necks. Even though suppliers are specialised they can easily change their operations if there is demand for new products or services. Replacing suppliers' capabilities and capacities is relatively quickly and cheap possible. Supply base is generally transparent.
Technology adoption capability	Generally new technology is not constantly adopted in the supply base. Adoption only takes place when there is a serious need. There are no formal processes in place to monitor technological opportunities. Related skills for technology adoption are just developed when needed. Reactive behaviour.	Technological developments are monitored frequently but there are no formal processes. Technology is adopted if it is widely accepted in the industry. Related required kills are developed just when needed. Adaptive behaviour	Companies of the supply base usually have processes in place to constantly monitor technological developments and to make decisions on introductions. Required related skills are continuously developed. Generally, adoption of new technology is embraced in the supply base. Proactive behaviour

SC3 Public Supply Chain Support

IC Subdimension	*Maturity level 1 - Reactive*	*Maturity level 2 - Adaptive*	*Maturity level 3 - Proactive*
Availability of public funding for supply chain and supply base development	Public funding is very limited and just covers very few specialised or call related topics. In general, accessing public funding is complex and time consuming. General will to access public funding is limited.	Public funding for innovative ideas is available but either it does not cover r and d or commercialisation, access is complex and time consuming, or general will for access is limited	Public funding for innovative ideas is available and easily accessible including funding for r and d and commercialisation to specifically develop supply base capabilities. Companies access funding frequently.
Availability of public support organisations for supply chain and supply base development	Public and private industry support is not or just very limited available. No coordination of supply base development	General public and private industry support and innovation support is available to a limited extend. Special support for supply chain and supply base development is limited. Generally, support is just occasionally used.	Private and public industry support organisations are available and are frequently used. Special innovation support for supply base development and capability transparency. Special support for supply chain development is also available.

Appendix Chapter 5 – Expert interviews

A.C5.1 Questionnaire for semi-structured interviews - Round 1

1) How has Covid affected your business?
2) How has it affected your customers?
3) How has it affected your suppliers?
4) In relation to the supply chains, you are part of…
    a. Are there full supply chains from raw material production to OEMs in the UK?
    b. Are there significant gaps in skills and capacity in the UK?
    c. Are there industry support organisations?
5) How is the economic situation in supply chain / industry sector and how was it before Covid-19?
    a. Were there many bankruptcies?
    b. Were there many job losses?
    c. Is the perception of the situation rather negative or positive?
    d. Which opportunities and threats do supply chain / industry sector members see in the current situation?
6) Do you think you are talking about innovation and doing things differently more or less than before?
7) What about action in terms of innovation? Do you have examples of doing things differently?
8) How are innovation and change seen in the supply chain / industry sector?
    a. Is change embraced?
    b. Is there active development of innovation?
    c. How is the adaptability of new technology?
    d. How well are players connected along the supply chain / industry sector and how well do they collaborate to develop innovations?
    e. How much collaboration is there with other supply chains / industry sector?
    f. What role do universities and public innovation support play in the supply chain / industry sector?
    g. Which are common innovation barriers in this supply chain / industry sector?
9) What support does the supply chain / industry sector need to be better prepared to seize opportunities and fight threats?
10) Have you accessed any government support during covid?

A.C5.2 Questionnaire for semi-structured interviews - Round 2

1) How has your business developed during the last 12 months since our last interview?
2) How have planned innovation activities developed and are there new activities planned?
3) How has the supply chain situation developed?
4) What impact did the end of furlough have for your business and the supply chain you operate in?
5) Which changes made to your business during the pandemic will last and which will you change back to a before Covid-19 state? (e.g., remote vs office-based work)
6) Are you rather positive or negative about the future?

Appendix Chapter 6 – Innovation capability assessment

A.C6.1 Questionnaire company scoring model

1. Organisational culture and leadership

Please select the options that describe your company the best for the following categories (multiple answers possible)

1 Risk management and risk attitude

- ☐ High awareness of risk (of current operations, of investments, of innovation and R&D activities, …)
- ☐ Formal risk management is carried out and risk is managed
- ☐ Risk taking is not appreciated
- ☐ There is a low tolerance for failure

2 Ambition, openness towards change, and promotion of innovation

- ☐ Innovation and change initiatives are usually met with significant resistance of co-workers and management
- ☐ Success of innovation and change is communicated systematically throughout the company
- ☐ Employees take initiatives for innovation and change projects
- ☐ Active living of change and innovation culture in which most employees participate

3 Leadership and decision making

- ☐ Leadership is directive and communication is strictly hierarchical
- ☐ Initiatives are pushed informally
- ☐ Leadership is participatory and takes into account expert suggestions in decision making
- ☐ Decision making is quick

2. Entrepreneurship and strategy

Please select the options that describe your company the best for the following categories (multiple answers possible)

1 Strategic renewal

- ☐ Competitive strategy is monitored frequently and adopted to changing conditions
- ☐ There is a formal change management team or an individual responsible for change
- ☐ Processes for change are in place

- ☐ Change is constantly monitored, and lessons are learnt from past change project mistakes

2 Organizational flexibility

- ☐ Proactive creation of flexible company structures as well as resource and staff capacity
- ☐ Flexibility is managed to optimally use existing flexibility

3 Entrepreneurial capability

- ☐ Company describes itself as entrepreneurial
- ☐ Company frequently explores new cooperation, new markets, and new business models
- ☐ Company network is constantly expanded

4 Supply chain resilience

- ☐ Supply base is constantly scanned (for availability of relevant capabilities and capacities)
- ☐ Defined processes are in place for supplier selection
- ☐ Programmes are in place to retain and develop suppliers (e.g. enabling them to use new technology)

5 Accessing of innovation support and funding

- ☐ Public funding programmes and availability are monitored frequently
- ☐ Public industry support opportunities like R&D or supply chain development support hosted by e.g. NMIS / Scottish Enterprise are monitored frequently
- ☐ The company has the necessary skills and resources to apply for public funding and industry support (identifying funding calls and writing applications, …)
- ☐ Public funding and industry support is accessed frequently

6 Diversity of products, services, and customers

- ☐ Narrow product and service portfolio
- ☐ Broad customer base
- ☐ Serving different markets

3. Knowledge management and technology adoption

Please select the options that describe your company the best for the following categories (multiple answers possible)

1 Knowledge and idea management

- ☐ There is a centralised system to record ideas and initiatives which is easily accessible to all employees

- ☐ Information and knowledge is stored and available to everyone in the company
- ☐ Cross-departmental meetings for knowledge sharing and information exchange take place sporadically
- ☐ There is a special budget available for knowledge and information sharing (for infrastructure, meetings, …)

2 Technology adoption

- ☐ The company is large unaware of technological developments that could be potentially relevant
- ☐ New technology is identified and introduced frequently
- ☐ There are clear processes and strategies in place for new technology selection and adoption like technology readiness assessments or technology roadmaps
- ☐ Partners along the value chain are included in the adoption of new technology if relevant (e.g. digitalisation)
- ☐ Adoption of new technology is considered responsibility of single departments. Cross departmental initiatives are rare
- ☐ A good understanding of a new technology is generated throughout the relevant personnel before its introduction

4. Innovation strategy, communication, and open innovation

Please select the options that describe your company the best for the following categories (multiple answers possible)

1 Innovation strategy

- ☐ Innovation activities are sporadic but uncoordinated
- ☐ We have an innovation strategy
- ☐ We measure innovation using financial measures and patent output
- ☐ We measure innovation with a broad range of indicators (beyond financial indicators and patent output)
- ☐ We have enough resources allocated to carry out innovation projects (financial, personnel, equipment)
- ☐ Innovation is promoted throughout the entire company

2 Cooperation with other organisations and open innovation

- ☐ Innovation cooperation is based on individual initiatives
- ☐ Innovation cooperation is based on standardised rules and contracts
- ☐ Innovation cooperation is focussed on intensity and long lasting cocreation of value
- ☐ Ownership of intellectual property is clearly defined
- ☐ Innovation cooperation usually takes place with previous, trusted partners
- ☐ New partnership opportunities are explored regularly

5. Organisational learning and absorptive capacity

Please select the options that describe your company the best for the following categories (multiple answers possible)

1 Identification of new knowledge and skills potentially useful for the company

- ☐ New, potentially useful information and skills are usually identified within just the direct business vicinity like direct competitors or suppliers and customers
- ☐ New, potentially useful information and skills are identified frequently
- ☐ There are clear search strategies in place to identify new, potentially useful information and skills

2 Integration of new knowledge and skills into existing knowledge and skills

- ☐ New, potentially useful information is shared throughout the company across teams
- ☐ Cross-departmental and cross-team problem solving is the norm

3 Application of knowledge and skills (new and existing)

- ☐ Recently acquired information and skills are barely integrated into daily operations
- ☐ Recently acquired information and skills are used in daily operations by the departments or teams that initiated the acquisition
- ☐ Recently acquired information and skills are integrated in all relevant departments and teams throughout the company
- ☐ Innovation methods are frequently used (Design Thinking, Scenarios, TRIZ, etc)

4 Exploitation of new knowledge and skills (creating innovation)

- ☐ New products and services are considered
- ☐ New business models and new markets are considered
- ☐ New ways of making money out of the newly acquired information and skills (e.g., the above two) are considered frequently
- ☐ New ways of making money out of the newly acquired information and skills are (actually) introduced frequently

6. Individual creativity, skills and learning

Please select the options that describe your company the best for the following categories (multiple answers possible)

1 Individual skills in one's field of knowledge

- ☐ Employees hold superficial knowledge and skills they need for fulfilling their tasks. Knowledge and skills are rather generalist.

- ☐ Some people hold expert knowledge and skills in their field and function as lead people.
- ☐ Most employees hold deep expert knowledge and skills in their field

2 Individual knowledge and skills in innovation

- ☐ High awareness of importance of innovation throughout the company
- ☐ Some employees hold general innovation knowledge and skills so that smaller innovation projects can be conducted without external innovation/ project management support
- ☐ There is a specialised innovation or R&D department where employees hold specialised innovation knowledge and skills who can teach others in the company

3 Individual attitude towards learning

- ☐ Employees take the initiative for additional learning and training
- ☐ Employees are generally very open towards learning and training

4 Availability of options for individual learning

- ☐ The company offers options for training and additional learning
- ☐ The company regularly updates training and learning opportunities
- ☐ Learning and training options are not necessarily connected to direct needs of the company and its operations

A.C6.2 Questionnaire supply chain scoring model

1. Supply Chain Structure and Governance

Please select the options that describe the supply chain of interest the best for the following categories (multiple answers possible)

1 Nature of collaboration, fairness, use of power, and responsibility

- ☐ There is a committee representing most supply chain members
- ☐ Every member has a voice and is heard by this committee
- ☐ Standards and responsibilities are agreed on for everyday collaboration along the supply chain
- ☐ Standards and responsibilities are agreed on for extraordinary collaboration along the supply chain
- ☐ Supply chain governance ensures fair treatment of everyone
- ☐ Supply chain governance ensures promotion of collaboration and innovation
- ☐ Collaboration is designed to be long lasting and to the benefit all partners
- ☐ No supply chain member abuses its market power

2 Communication

- ☐ Communication takes place just between a few parts of the supply chain
- ☐ Communication takes place between most parts of the supply chain
- ☐ Supply chain members largely approach other members proactively

3 Reliability and trust

- ☐ Collaboration is characterised by mutual trust and reliability
- ☐ Collaborations are built on agreed standards especially for intellectual property
- ☐ A wide range of data including innovation activities is shared as willingness to data sharing is high

4 Regulation

- ☐ Industry is highly regulated by legal requirements
- ☐ Industry is highly regulated by quality standards and certifications
- ☐ Certification processes are not expensive and not time consuming

5 Change and risk attitude

- ☐ Most supply chain members actively look for new opportunities
- ☐ Opportunities are communicated up and down the supply chain to encourage change
- ☐ The general attitude within the industry is risk and change averse

6 Supply chain structure

- ☐ Parts of the supply chain are rather flat meaning just a few TIER stages
- ☐ The whole supply chain is rather flat meaning just a few TIER stages

7 Supply chain visibility

- ☐ Just some products and their parts are usually tracked back / can be tracked back through the supply chain to raw material
- ☐ Most products and their parts are usually tracked back / can be tracked back through the supply chain to raw material
- ☐ Industry 4 technology is used widely throughout the supply chain to ensure real time supply chain visibility

8 Joint value capturing with supply chain members and public support organisations

- ☐ Collaboration between supply chain members is the norm
- ☐ Collaboration between companies and public support organisations is the norm
- ☐ Collaboration just takes place between partners with a collaboration history
- ☐ Special innovation hubs (physical or virtual) and innovation networks are used
- ☐ Joint value capturing mechanisms are in place

2. Supply Base

Please select the options that describe your company the best for the following categories (multiple answers possible)

1 Supply base resilience

- ☐ The supply base is broad
- ☐ There are just few bottlenecks along the supply chain
- ☐ Even though suppliers are specialised they can easily change their operations if there is demand for new products or services
- ☐ Replacing suppliers' capabilities and capacities is relatively quickly and cheap possible
- ☐ Suppliers going bust is relatively unlikely
- ☐ The supply base is generally transparent

2 Technology adoption capability

- ☐ Companies of the supply base largely have processes in place constantly monitor technological developments
- ☐ Supply base largely proactively introduces new technology
- ☐ Required related skills are continuously developed before and during the introduction of new technology

3. Public Supply Chain Support

Please select the options that describe your company the best for the following categories (multiple answers possible)

1 Availability of public funding for supply chain and supply base development

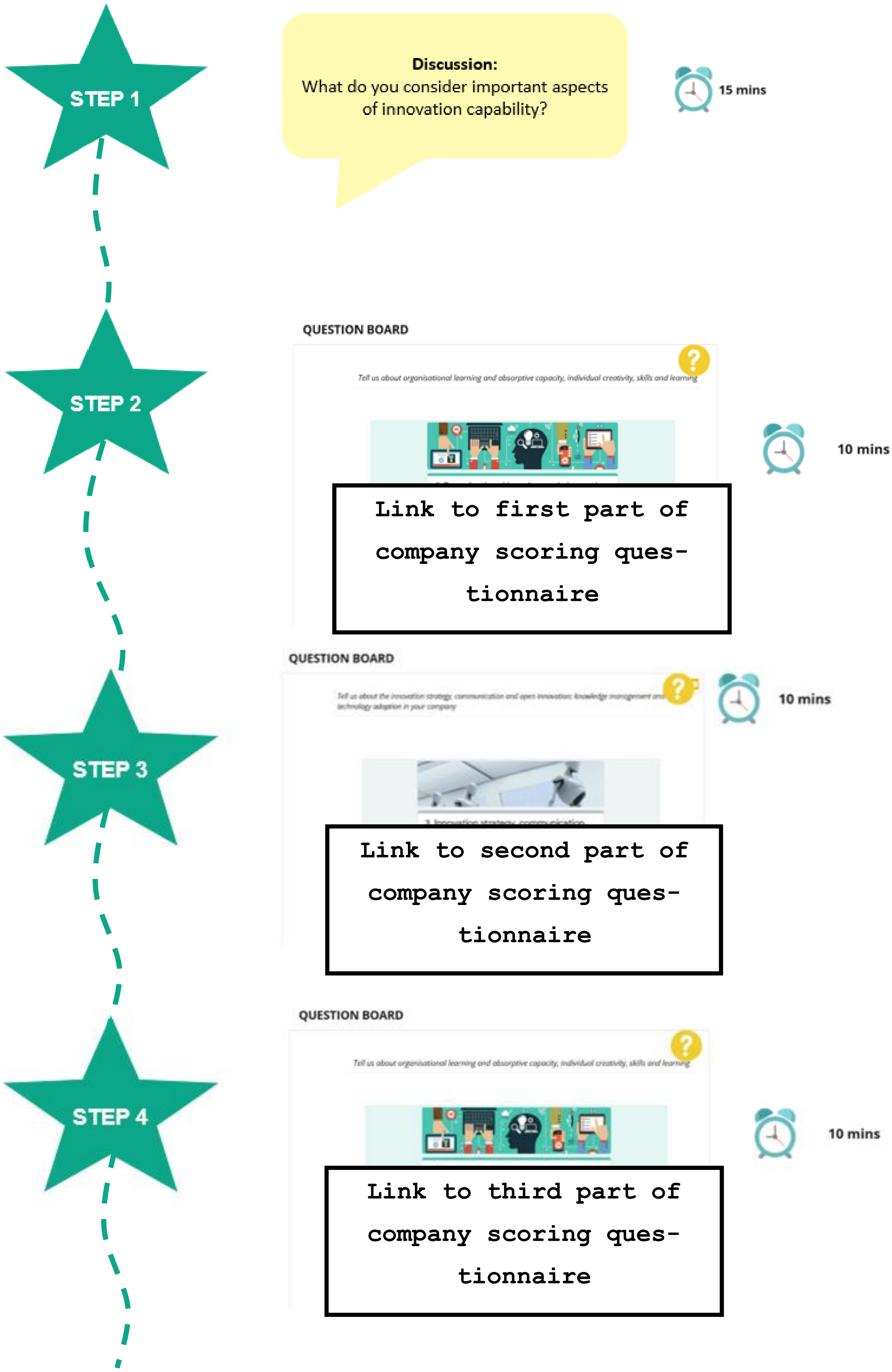
- ☐ Public funding is available for R and D projects
- ☐ Public funding is available for upscaling and commercialisation of innovative ideas
- ☐ Public funding is easily and quickly accessible
- ☐ Companies generally make good use of available public funding

2 Availability of public support organisations for supply chain and supply base development

- ☐ Public and private industry support organisations are available
- ☐ Supply base companies frequently interact with these organisations
- ☐ These organisations offer special innovation support
- ☐ These organisations support and coordinate supply chain development and rise capability transparency throughout the supply base

A.C6.3 Focus group Miro board company 1

Workshop 1 company 1



STEP 5

Task:
Based on our discussion, please list the reasons you consider impacting your innovation capability the most.

15 mins

Participant 1	Participant 2	Participant 3	Participant 4
Training workforce	Resource expertise	Lack of clear direction	Lack of dedicated resources
Management of change	Innovation culture	Lack of coordination	Different priorities across different functions
Leadership commitment	Lack of cohesion in communication		Lack of leadership support
Budget and time allocation when project planning	Lack of common basis for innovation		

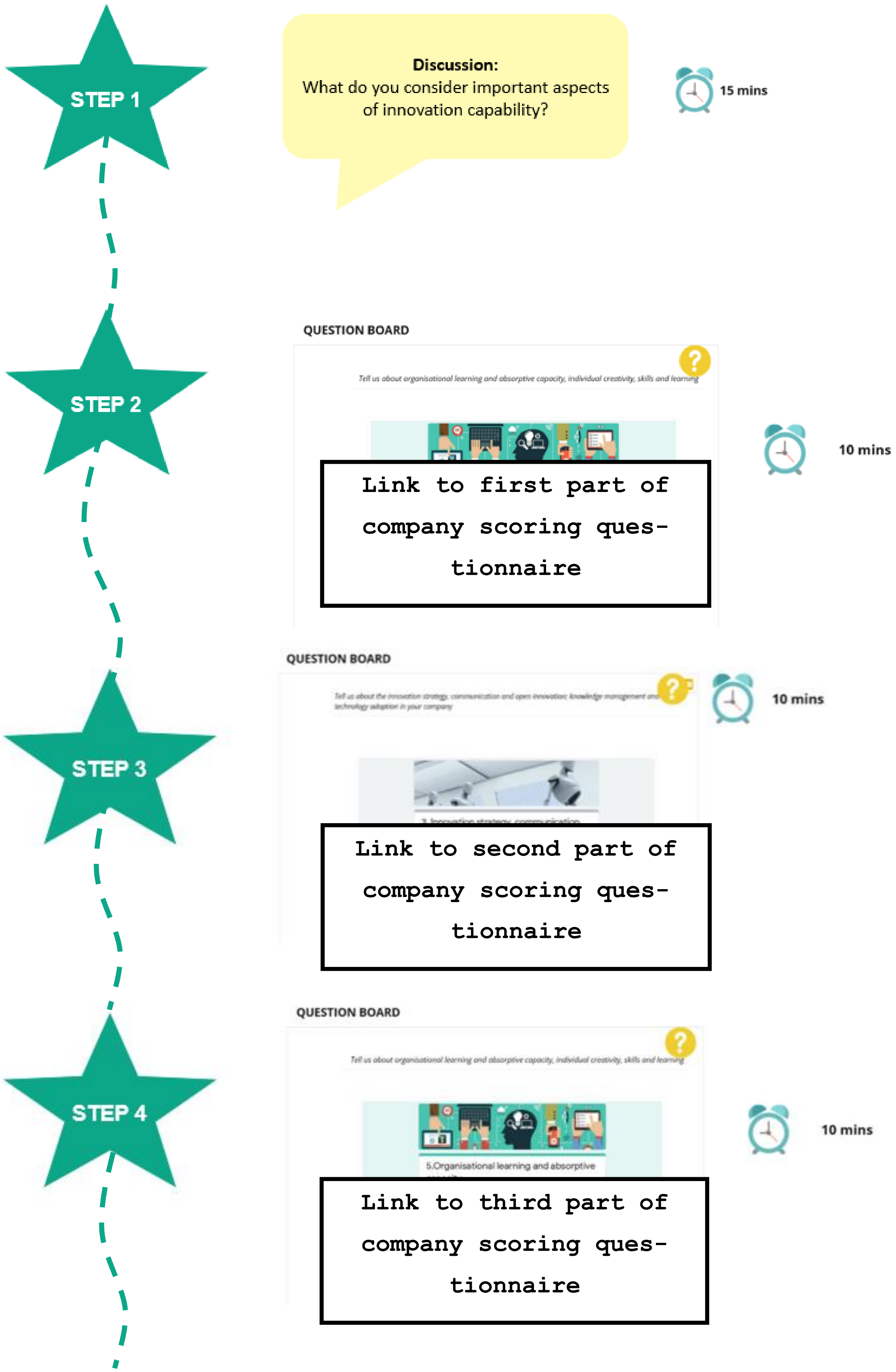
STEP 6


Feedback
Give us your feedback to improve our tool
Feedback
Link to feedback form

A.C6.4 Innovation capability scoring company 1

ICD	Subdimension	Score
ICD C1 – Organisational culture und leadership	C1.1 Risk acceptance and risk management	2 – Adaptive
	C1.2 Ambition, promotion of innovation and change, openness towards change, and communication of success	1 – Reactive
	C1.3 Leadership practices, communication and decision making	1 – Reactive
ICD C2 – Entrepreneurship and strategy	C2.1 Strategic renewal and flexibility (Change management)	2 – Adaptive
	C2.2 Organisational flexibility and agility	1 – Reactive
	C2.3 Entrepreneurial capability	2 – Adaptive
	C2.4 Supply chain resilience	2 – Adaptive
	C2.5 Accessing of innovation support and funding	3 – Proactive
	C2.6 Diversity of products / services and diversity of customers	3 – Proactive
ICD C3 – Knowledge management and technology adoption	C3.1 Knowledge management, idea management, and knowledge sharing	1 – Reactive
	C3.2 Technology adoption strategy and processes	2 – Adaptive
ICD C4 – Innovation strategy, communication, and open innovation	C4.1 Clear innovation strategy aligned with company strategy and innovation measurement and adequate recourse allocation	2 – Adaptive
	C4.2 Cooperation with suppliers, customers, public institutions, and openness to share information and to adopt new outside knowledge	2 – Adaptive
ICD C5 – Organisational learning and absorptive capacity (innovation process)	C5.1 New knowledge and skills identification and acquisition (acquisition)	2 – Adaptive
	C5.2 New knowledge and skills integration (assimilation)	3 – Proactive
	C5.3 Application of knowledge and skills (transformation)	1 – Reactive
	C5.4 Exploitation of knowledge and skills (exploitation)	2 – Adaptive
ICD C6 – Individual skills and learning	C6.1 Individual skills in one's field of knowledge	2 – Adaptive
	C6.2 Individual knowledge and skills about innovation	2 – Adaptive
	C6.3 Individual continuous will for learning	2 – Adaptive
	C6.4 Availability of options for individual learning	3 – Proactive

A.C6.5 Focus group Miro board company 2



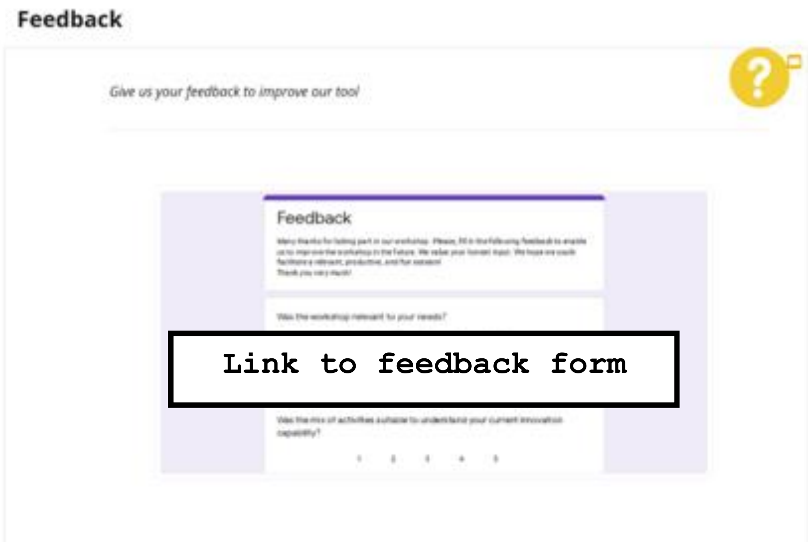
STEP 5

Task:
Based on our discussion, please list the reasons you consider impacting your innovation capability the most.

15 mins

Participant 1	Participant 2	Participant 3
Lack of openness to new ideas and change	Lack of formal innovation strategy	Lack of investment into new technology
Lack of time allocation to navigate funding landscape	Lack of dedicated time for innovation	Lack of leadership support for innovation
Lack of innovation budget		Lack of knowledge management and centrally accessible knowledge
Very limited collaboration with suppliers and customers and learning from them		


STEP 6


Feedback
Give us your feedback to improve our tool
Feedback
Link to feedback form

A.C6.6 Innovation capability scoring company 2

ICD	Subdimension	Score
ICD C1 – Organisational culture und leadership	C1.1 Risk acceptance and risk management	2 – Adaptive
	C1.2 Ambition, promotion of innovation and change, openness towards change, and communication of success	1 – Reactive
	C1.3 Leadership practices, communication and decision making	2 – Adaptive
ICD C2 – Entrepreneurship and strategy	C2.1 Strategic renewal and flexibility (Change management)	1 – Reactive
	C2.2 Organisational flexibility and agility	1 – Reactive
	C2.3 Entrepreneurial capability	2 – Adaptive
	C2.4 Supply chain resilience	2 – Adaptive
	C2.5 Accessing of innovation support and funding	2 – Adaptive
	C2.6 Diversity of products / services and diversity of customers	3 – Proactive
ICD C3 – Knowledge management and technology adoption	C3.1 Knowledge management, idea management, and knowledge sharing	1 – Reactive
	C3.2 Technology adoption strategy and processes	2 – Adaptive
ICD C4 – Innovation strategy, communication, and open innovation	C4.1 Clear innovation strategy aligned with company strategy and innovation measurement and adequate recourse allocation	1 – Reactive
	C4.2 Cooperation with suppliers, customers, public institutions, and openness to share information and to adopt new outside knowledge	2 – Adaptive
ICD C5 – Organisational learning and absorptive capacity (innovation process)	C5.1 New knowledge and skills identification and acquisition (acquisition)	2 – Adaptive
	C5.2 New knowledge and skills integration (assimilation)	2 – Adaptive
	C5.3 Application of knowledge and skills (transformation)	1 – Reactive
	C5.4 Exploitation of knowledge and skills (exploitation)	2 – Adaptive
ICD C6 – Individual skills and learning	C6.1 Individual skills in one's field of knowledge	3 – Proactive
	C6.2 Individual knowledge and skills about innovation	2 – Adaptive
	C6.3 Individual continuous will for learning	3 – Proactive
	C6.4 Availability of options for individual learning	2 – Adaptive

A.C6.7 Focus group Miro board supply chain

STEP 5

Task:
Based on our discussion, please list the reasons you consider impacting your innovation capability the most.

Fight for survival	Lack of understanding of Scottish aerospace supply chain	Lack of ability to change quickly	Not being fit for uncertain technology future e.g., electrification, hydrogen etc	Lack of funding and talent
Complicated funding landscape	Difficult to access university knowledge base	Funding schemes being withdrawn	Restrictive regulations	Lack of agility
Too focussed on making near future work, no time to think about longer strategies	Lack of skills across supply chain	Aging workforce	Massive increase of energy prices	Central decision making (outside UK)
	Lack of engagement of parts of the supply chain with each other and public institutions			

STEP 6

Feedback

Link to feedback form

A.C6.8 Innovation capability scoring supply chain

ICD	Subdimension	Score
ICD SC1 – Supply chain structure and governance	SC1.1 Nature of collaboration, fairness, use of power, and responsibility	3 – Proactive
	SC1.2 Communication	2 – Adaptive
	SC1.3 Reliability and trust	2 – Adaptive
	SC1.4 Regulation	1 – Reactive
	SC1.5 Change and risk attitude	1 – Reactive
	SC1.6 Supply chain structure	1 – Reactive
	SC1.7 Supply chain visibility	3 – Proactive
	SC1.8 Joint value capturing with supply chain members and public support organisations	2 – Adaptive
ICD SC2 – Supply base	SC2.1 Supply base resilience	1 – Reactive
	SC2.2 Technology adoption capability	2 – Adaptive
ICD SC3 – Public supply chain support	SC3.1 Availability of public funding for supply chain and supply base development	2 – Adaptive
	SC3.2 Availability of public support organisations for supply chain and supply base development	2 – Adaptive

A.C6.9 Feedback and validation questionnaire

1. Workshop design

1.1) How would you rate the quality of the workshop? (From 1 to 5 with 1 = unacceptable and 5 = outstanding)

1	2	3	4	5
☐	☐	☐	☐	☐

1.2) To what extent was the mix of activities suitable to understand your innovation capability? (1 = not suitable and 5 = very suitable)

1	2	3	4	5
☐	☐	☐	☐	☐

1.3) How relevant was the workshop to your needs? (1 = irrelevant and 5 = highly relevant)

1	2	3	4	5
☐	☐	☐	☐	☐

1.4) What suggestions do you have to improve the workshops?

2. Framework design

2.1) To what extend are the innovation capability dimensions presented in the framework relevant to your understanding of innovation capability (of single organisations or supply chains)? (From 1 to 5 with 1 = irrelevant and 5 = very relevant)

1	2	3	4	5
☐	☐	☐	☐	☐

2.2) To what extend do you agree with the presented maturity stages for the innovation capability dimensions? (From 1 to 5 with 1 = do not agree and 5 = fully agree)

1	2	3	4	5
☐	☐	☐	☐	☐

2.3) What suggestions do you have to improve the tool?

Appendix Chapter 7 – Future scenarios

A.C7.1 Characteristics of driving forces of future scenarios for Scottish manufacturing

Driving Force	Characteristics
DF1 Innovation and diffusion	▪ The level of basic research activity ▪ The ability to produce new technologies (e.g. fuel cells for H2) ▪ The ability to commercialise and take value from innovation ▪ The level of R&D activities between academia and industry ▪ The ability to adopt new technologies from outside the UK/Scotland ▪ The ability to gather data and use them to drive changes ▪ The ability to implement new technologies ▪ The ability to anchor the technologies at a supply base level
DF2 International trade and relation-ships	▪ Change in global partnerships in the supply chain ▪ The change in level of globalisation ▪ The impact of Brexit on exports and imports of goods ▪ Impact of international competition on the manufacturing industry ▪ The impact of relationships between UK and EU ▪ Ability to buy goods from outside the UK at a good price ▪ Availability of goods to be delivered in the UK ▪ Change in tariffs with Brexit ▪ Ability to create trade deals with the EU ▪ Ability to create trade deals with the rest of the world ▪ If leaving the UK, ability to create trade deals with the UK ▪ Changes to trading and trade deals ▪ The cost of transport and changes to such costs ▪ The level of UK trade tariffs for imports and exports ▪ The impact of UK/Scot government approach to state aid ▪ The extent to which ecosystems' appropriation regimes benefit Scotland ▪ The impact of exchange rate on final price of goods ▪ The level of the impact of cost base competition ▪ The level of trade protection measures in UK ▪ The degree of state intervention ▪ The ability to create a great place for international business (inward invest-ment) ▪ The perceptions about "made in Scotland"
DF3 Workforce and capabilities	▪ The levels of manufacturing firms' dynamic capability ▪ The level of attractiveness of living and working in Scotland ▪ Salary expectations of Scottish workforce ▪ The cost of living

	▪ Level of immigration barriers ▪ The salary level in manufacturing ▪ The availability of international skills (e.g. people coming in the UK to work) ▪ The impact of changing population ▪ The impact of relationship with trade unions ▪ The level of attractiveness of manufacturing as a career choice ▪ Level of availability of skilled workforce for manufacturing. ▪ Availability of human resources in Scotland/UK: birth rate/immigration ▪ The level of people aiming to work in manufacturing ▪ Level of technological expertise for emerging sectors (e.g. electric) ▪ The extent to which ecosystems' capability configurations benefit Scotland ▪ The level of STEM graduates in UK ▪ The level of STEM apprenticeships numbers ▪ The level of government investment in STEM ▪ The level to which manufacturing education happens at all levels (school, apprentice, university, college) ▪ The effectiveness of RTO and universities in supporting manufacturing ▪ The level of peer-to-peer learning knowledge sharing ▪ The levels of skills in the workforce ▪ The levels of unemployment in Scotland ▪ The level of strategic management capability ▪ The diversity and inclusion of the workforce in manufacturing ▪ The levels of automation in manufacturing companies ▪ Levels of redundancy in manufacturing ▪ Level or resistance to change ▪ Levels of training up-skilling and re-skilling ▪ Impact of the levels of business travel and commuting ▪ Changes in remote work in manufacturing
DF4 Availability of Finance	▪ The impact of financial institutions arrangements ▪ The instability financial market ▪ The sophistication of financial arrangements ▪ The affordability challenge in manufacturing ▪ The extent to which ecosystems 'governance arrangements benefit Scotland ▪ Impact of varying inflation rates ▪ The levels of manufacturing firms' shareholders value ▪ The impact of the interest rate on activity ▪ The variation in tax rates ▪ The level of corporation tax ▪ The impact of carbon tax

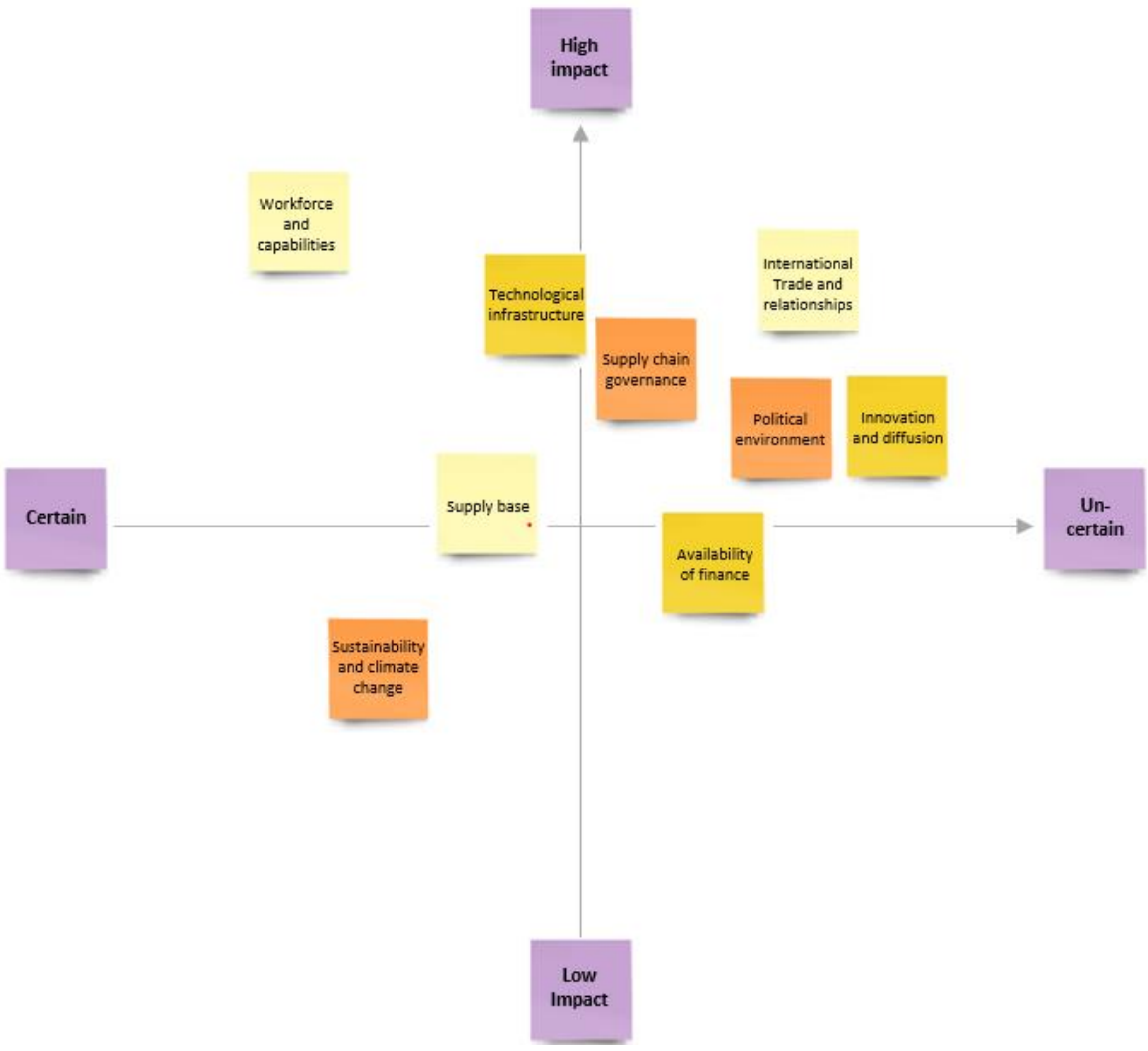
	▪ The impact of UK/Scot gov approach to state aid ▪ Level of financial and technical risk accepted by public bodies for supporting manufacturing ventures ▪ Level of private investment in Scottish manufacturing (national and international) ▪ The variation in exchange rates ▪ Levels of investments in innovation in Scotland
DF5 Political environment	▪ Impact of a referendum to leave the UK ▪ If leaving the UK: ability to integrate the EU ▪ Impact of tension between China and US ▪ The impact of global gunboat diplomacy ▪ Levels of political stability ▪ The extent of the accumulation of human suffering ▪ The degree of institutional pressure ▪ The level of interest in remanufacturing ▪ The level of interest in circular economy ▪ The impact of levelling up ▪ The impact of sectarianism ▪ Level of entrepreneurial spirit in Scotland ▪ The level of consumer sensitivity to labour exploitation in the supply chain ▪ The degree of socialism ▪ The impact of institutional entrepreneurship initiatives ▪ Level of global nationalism (populist driven politics) ▪ The extent to which ecosystems appropriation regimes benefit Scotland ▪ Level of governmental commitment to local public procurement ▪ The ability of Scotland to transition from declining to growing industries
DF6 Technological infrastructure	▪ The impact of technologically enabled infrastructure ▪ The quality of the communications infrastructure ▪ The ability to link suppliers using technology ▪ Level to which technology is able to solve society's challenges such as carbon emissions ▪ Level to which advanced manufacturing technology can compensate for high labour cost in Scotland ▪ Level of impact on supply base if manufacturing service platforms emerge (e.g. Airbnb & Uber) ▪ Level of uncertainty over which technologies will be adopted on a large scale (e.g. hydrogen economy) ▪ The level of investment in existing nationally significant manufacturing facilities to ensure continued competitiveness

DF7 Supply Base	▪ The ability of suitable suppliers ▪ The levels of manufacturing firm's core capabilities ▪ The availability of service providers (e.g. legal services) ▪ The level of effectiveness for logistics (transport time) ▪ Availability of materials and minerals for production ▪ The transport infrastructure and ability to move goods ▪ Levels of resilience in the supply base ▪ Ability to produce locally ▪ The impact of natural events affecting the supply base and chains ▪ The level of companies' size and distribution
DF8 Supply chain governance	▪ The nature of firm ownership ▪ Level of domestic primes (i.e. major companies driving supply chain decisions) ▪ The levels of servitisation in manufacturing ▪ Levels of impact on supply base if manufacturing service platforms emerge. e.g. Airbnb/Uber ▪ The level of participation in the sharing economy (e.g. shared manufacturing resources) ▪ The extent to which ecosystems governance arrangements benefit Scotland
DF9 Sustainability and climate change	▪ The COVID-19 impact on customer behaviour ▪ The level of customer interest in sustainability ▪ Changes to stakeholder salience ▪ Impact of changing customer wants and needs ▪ The level of company's interest in sustainability ▪ The impact of carbon tax ▪ The impact of carbon labelling ▪ The impact of the green agenda ▪ The impact of climate legislation for energy generation and use ▪ The impact of other pandemics ▪ The impact of natural events affecting the supply base and chains ▪ Availability of unique natural resources ▪ Impact of the move towards a circular economy ▪ The impact of Scotland brand (e.g. sustainable "green" country)

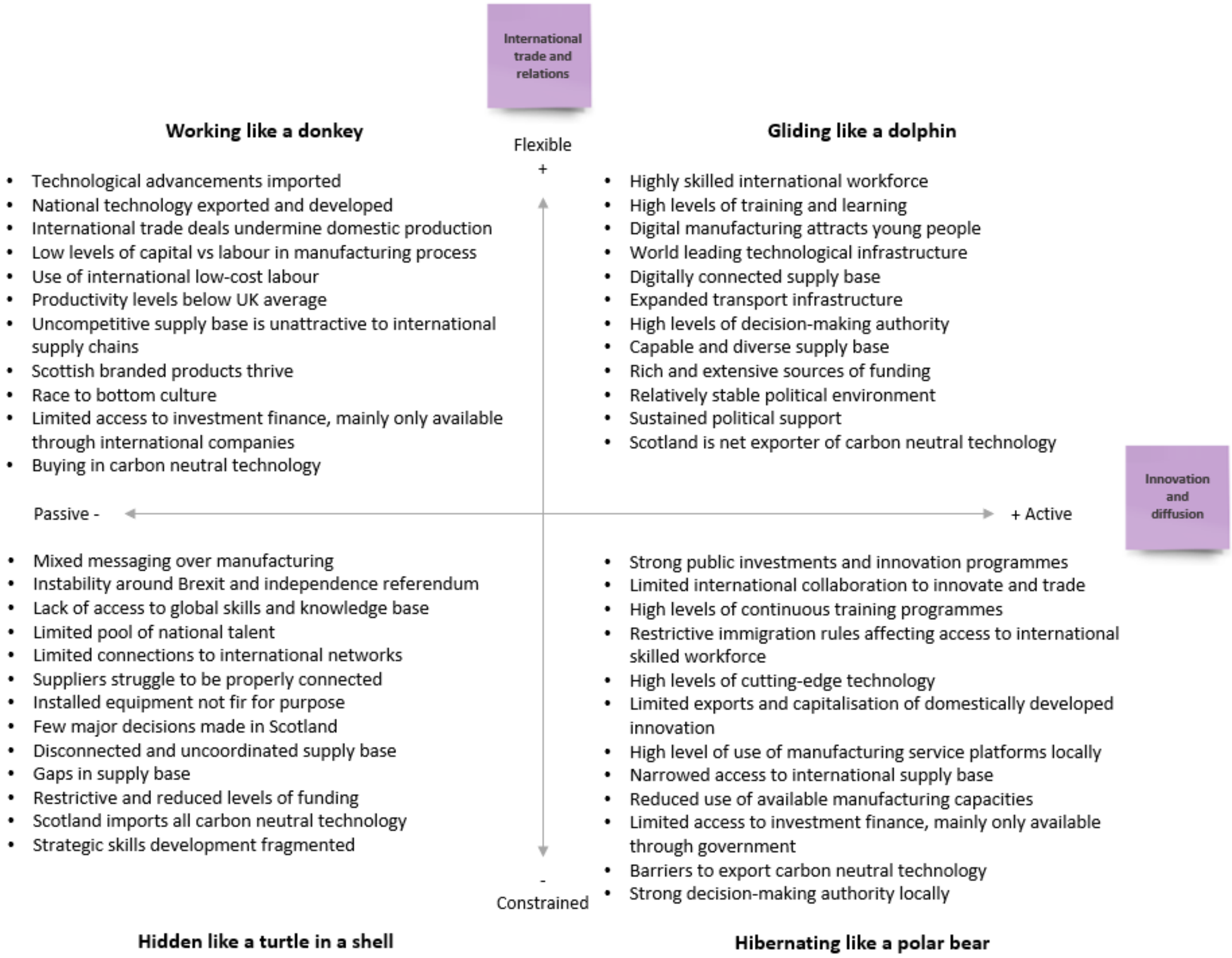
A.C7.2 Driving forces ranking for impact and uncertainty

Clusters	Impact	Uncertainty
DF1 Innovation and diffusion	6	6
DF2 International trade and relationships	5	6
DF3 Workforce and capabilities	3.8	5
DF4 Availability of Finance	6.5	5
DF5 Political environment	6	6
DF6 Technological infrastructure	7.1	4
DF7 Supply Base	7	4
DF8 Supply chain governance	5.5	4.5
DF9 Sustainability and climate change	8.5	4

A.C7.3 Driving forces mapped in the impact uncertainty matrix



A.C7.4 Future scenarios first bullet point version



A.C7.5 Future Scenarios (complete narratives)

Scenario 1: Hidden like a turtle in a shell

(Constrained international trade and relationships & passive innovation and diffusion)

Environmental deterioration is at an all-time high in 2036. Climate change is 2 degrees above pre-industrial levels, having shot up 1 degree in just 15 years. Water levels have risen as predicted with parts of Ayrshire seeing significant land being reclaimed by the river Clyde and the areas around Glasgow airport, Partick, Govan, Aberdeen, Braehead and Dumbarton being badly affected by flooding and causing disruption to transport. Extreme weather events such as flooding, landslides, drought, heatwaves, and wetted winters with more intense rainfall events have pressured public sector budgets in health care and infrastructure repair. Furthermore, the climate changes have caused zoonotic diseases to be riskier to humans with expanding global populations intruding on wildlife habitats. Poor health conditions and low incomes continue to exacerbate inequalities worldwide.

More than half of Amazon was lost by 2030 causing the extinction of many species. In Scotland, for example, increasing acidification of the oceans is affecting shellfish industries. Cold water species like the white-beaked dolphin was lost from Scottish waters. The salmon rivers lost more fish as water temperatures raised and summer water levels declined. This is affecting the Scottish fish farms production. Demand for food has increased by 35% over the last 15 years, with the subsequent production contributing to wastage of energy and water. Globally, demand for water increased by 40% and for energy by 50% in 2030. China and US continue fighting to extract and exploit natural reserves for production. For example, companies from these countries are extensively investing and locating geo-strategically in countries with abundance of fuel minerals. Multinational companies including those from India, Brazil and Indonesia have expanded abroad through mergers and acquisitions to ensure supply of scarce resources. Scottish companies did not follow this expansion. As such, Scotland has a shortage of critical raw materials and minerals that are affecting economic growth and prosperity.

The turbulence in politics has been increasing over the last 15 years in Scotland. With no independence referendum, the country is deeply divided between pro-independence and pro-union with the UK. Although there is an EU-UK Trade and Cooperation Agreement, Scottish manufacturers, such as Tennent's and Walkers, struggle to compete with the prices of producers in other European countries. Experts claim that this is Brexit's legacy to the food and drink sector after 2021.Manufacturers are concerned about decreasing foreign direct investment to Scottish businesses. The UK government has tightened restrictions on Scottish acquisitions by investors from the EU. This has delayed the upgrade of the technological infrastructure in the manufacturing sector.

Internal fights in the SNP have impacted the investment strategy for Scotland. The manufacturing industry has lost its importance on the political agenda, leaving companies in 'limbo'. Manufacturers and the whole Scottish supply base struggle with digital connectivity which has disrupted the building of digital manufacturing platforms. The current equipment used by many Scottish manufacturers is outmoded. While in other industrialised countries - such as South Korea, Germany and Japan, artificial intelligence, data infrastructure and new digital business models are utilised extensively. Worryingly, the Scottish Investment plan is not conducive to innovation, and this has caused negative effects in the competitiveness of companies such as Life Technologies (US), GSK (UK), and Omega Diagnostics (UK) which rely heavily on research. The supply base in Scotland is consequently slowly shrinking, making the country less attractive for foreign direct investment.

With several recessionary measures, the Scottish government has limited funds for supporting manufacturing and its supply chain. Firms and institutions such as Spirit Aerospace (USA), BAE Systems (UK), Thales (French), Babcock (UK) find it tough to convince global manufacturers to produce locally, leading to delays in the supply chains and a lack of cooperation to develop technological solutions and networks. Spirit AeroSystems is seriously considering pulling out of its Scottish base. Moreover, there is a competitive environment to access critical materials involved in the production of technologies and electric cars such as lithium, neodymium, dysprosium, magnesium. As a result, technological products made in Scotland are expensive for customers. At the same time the Scottish government has failed to create clear strategies for Scottish manufacturers which can attract new industries and new business start-ups. There is less entrepreneurial activity now than at any time in Scotland’s history.

Immigration decreased significantly during the fifteen years following Brexit in 2021. The Manufacturing Skills Institute’s (MSI) mitigation plan is not delivering employer demands. Scotland's population is ageing. Additionally, strict immigration policies, poor living standards, high taxes, and low salary levels have made Scotland a less desirable place for attracting international students and workforce. This has brought negative consequences for industrial cities such as Glasgow and Dundee, which have a shortfall of talent in manufacturing. There is no national plan to build a solid skill base that embraces the development of technology and new capabilities.

Lastly, China realised their plan to create super-regions of production clusters and dominate the world’s economy through research, innovation, manufacturing technologies, supply chains and raw material sources. Chinese espionage and surveillance programmes in the West have extracted data from the major innovation centres in Scotland. This has affected trade between China and the UK. Scotland is mainly importing products from trusted sources like Germany and the Netherlands. Although the SNP and other parties consistently agree on fighting climate change and the net zero agenda, Scotland hides in its shell.

Scenario 2: Hibernating like a polar bear

(Constrained international trade and relationships & active innovation and diffusion)

Scotland has made significant advancements in research, higher education, and technology. The Government is committed to continue with the development of a dynamic national innovation system and move towards a more advanced knowledge and innovation-based economy. Innovation and decarbonisation remain the top-line in the national agenda. Scientific research and publishing, higher education, and ICT infrastructure are well-recognised. Manufacturing companies are digitalised and use data to connect with the local supply chain. However, international collaboration to innovate and trade is limited. The SNP led referendum to leave the UK back in the mid 2020s failed. After Brexit, inflexible immigration rules affected Scotland's access to an international skilled workforce forcing Scotland to train its own talent and tackling the shortage of STEM skills has become one of the main objectives. The Scottish Government provides funding to high level education institutions to design and offer continuous training programmes to upskill the available workforce. The manufacturing ecosystem provides good conditions and salaries to attract young people to choose manufacturing as a career. A pool of young, educated, and skilled labour and a growing research capacity, characterises the Scottish manufacturing sector.

The Scottish Government has supported the Glasgow City Innovation District to use technology and research to mitigate against future crises. CivTech Challenge addresses problems for SMEs to decarbonise through the Low Carbon Manufacturing fund. Given the high level of entrepreneurial spirit and national engagement with the climate agenda in the country, companies develop high levels of cutting-edge technology to achieve the carbon neutral targets. However, Scotland has a lack of free trade agreements and appropriate partners to exchange products and services. Despite the active production of domestic innovative products, exports are not competitive. Products in Scotland have high tariffs and taxes which limit access to international markets and cause manufactures to have excess production capacity. The impact of varying inflation and high exchange rates fails to attract foreign direct investors.

The adoption of high technology enables the quality of communications and local infrastructure which improves the ability to link local suppliers using technology. However, the connectivity with international suppliers is difficult. It is as though Scotland is working in a polar desert with a high level of local manufacturing services platforms, but a narrowed access to the international supply base. This isolation is exacerbated by the political tensions between the United States and China, created by China's involvement in digital disruption efforts to interfere with western democracies. Following Brexit, the United Kingdom needed to intensify its relationship with the US, putting pressure on the country to align with US policies. This diminished its relationships with China. The UK continues to limit Chinese access to British financial markets and research infrastructure as tension between the two countries remains high due to the UK's rebuttal of anti-democratic agreement in Hong Kong and the subsequent migration of talented Hong Kong engineers to the UK. Since China overtook the United States as the world's largest economy in 2028, they have been imposing high tariffs for importing their technological products to western countries that trade with the US. As the UK has a strong relationship with the US, there are negative consequences for importing material and minerals from China for production in Scotland.

By reducing waste, materials are recovered and regenerated which encourages Scottish manufacturers to strengthen the development of reprocessing infrastructure and the circular economy. This reduces their carbon tax exposure. Additionally, the strict climate legislation for "energy generation and use" boosts the sales of zero emissions heavy duty vehicles in the UK. However, the current tariffs on imported products and the international transport freight charges are expensive. Despite technology advancements in Scotland, the lack of connectivity of the supply chain affects the levels of resilience in the supply base. Food & Drink companies in Scotland such as AG Barr, Willian Grant & Sons, Edrington, Diageo, Borders Biscuits, are worried due to poor international trade and conditions for working in partnership with international allies. They regularly have meetings with the UK Trade Association, Food and Drink Federation, Chambers of Commerce and Scottish Development International to raise their concerns and find solutions to the constraints for trading. Moreover, the levels of advanced manufacturing technology compensate for high labour cost in Scotland. However, the lack of availability of some products is increasing the cost of living in the country. This situation is not new, after Brexit manufacturers continued to register a faster rise in input prices than service providers due to the increase of raw material costs.

Nowadays, citizens are aware of inequality, labour exploitation and sustainability issues. Customers pay more attention to the impact of carbon labelling. Manufacturers are digitalised and are on the path of sustainability to fulfil the green expectations of their stakeholders. Scotland is producing carbon neutral solutions. Although the country exports to US, it still has strong restrictions and barriers to export carbon neutral technology to its most important trade partners like the Netherlands and Germany. As companies have barriers to hunt opportunities internationally, Scotland is in a "hibernation" stage.

Scenario 3: Working like a donkey

(Flexible international trade and relationships & passive innovation and diffusion)

The world is density populated and the air is polluted with high levels of carbon dioxide pouring into the atmosphere. The polar ice is melting which is causing high temperatures in Scotland during the summer. Low lying areas in Scotland have frequent and more severe problems with flooding. People are not as healthy as they used to be and the quality-of-life is decreasing in Scotland. After the Lambda string pandemic, people are suffering from worse chronic fatigue and lung diseases than was caused by COVID-19. There are high unemployment rates and low salaries in the country. The UK government is pursuing opportunities to attract talent from across the world. A reduced workforce and low-income in Scotland are triggering the immigration campaigns to fill these gaps. Universities and manufacturing centres are trying to attract STEM graduates from BRICS countries (Brazil, Russia, India, China and South Africa). The EU only have 4% of global STEM skilled labour to work in the manufacturing industry. Moreover, education budget cuts have exacerbated over the last decade compromising universities' performance, outputs, and wider contribution to Scotland. The shortage of funding is affecting the development of capabilities in maths, digital and technical engineering. The gender gap in STEM subjects continue to be high as it is difficult to attract women into technical careers.

The independence campaign for Scotland is on hold. A flexible approach in international relations is leading changes in the Scottish government. There is now a coalition between the SNP and the Greens to pursue additional trade agreements. The UK government is pressured to foster a vision of a global Britain in which many different trade agreements are currently in effect with single markets such as Canada, India and Australia. The relations between the UK and the EU are settling and there is now a higher trust. Scotland is exporting to the US and other trade partners, but Scotland's balance of trade is in deficit. Manufacturers are importing technology, innovative components, and materials from South Korea, Canada, Japan, and others. Some multinational original equipment manufacturers (OEM) are opening subsidiaries in Scotland. They are taking advantage of the current free trade agreements, low international trade barriers and low production costs. Merger and Acquisitions (M&A) between companies from the EU and the UK are ensuring market access and distribution channels located in both regions. This is helping manufacturers to avoid border controls, customs declarations, and differing legislation. However, the important decisions shaping the Scottish manufacturing industry and domestic supply chains are made by the bigger international players. These are influenced by European owners of M&A formed in the UK in the 2020's.

Innovation activities have drastically decreased over the last 15 years. This is due to a shortage of new innovative companies, a reduced pool of talent, and a lack of investment in research and development. Scottish manufacturers still struggle with digitalisation. Some parts of the supply base are disconnected domestically and internationally. For example, companies such as Brewdog and Borders Biscuits have lost competitiveness in international markets due to supply chain disruptions and lack of resilience. The level of investment and funds for research in Scottish universities continues being lower compared to competitors in Asia and the US. There is a failure to exploit the educational infrastructure and capacity of the university system to innovate. The innovation activities that are conducted in Scotland strongly rely on international investment. NMIS is struggling to unify manufacturing support and turn Scotland into an innovative country.

The green agenda is not achieving the net zero targets in Scotland. Manufacturing companies are still paying taxes for producing emissions in the environment. They need to upgrade their equipment to green technology. For instance, the fish industry continues using old fashioned techniques that are unsustainable over time. The fishing pressures are triggering the extinction of some marine species in Scotland. Scottish fish producers cannot compete with Norway. Fish farming experts needs to find some synthetic edible options to feed the population. Additionally, the implementation of hydrogen technologies is slow. Alexander Dennis Limited is struggling to execute its electric public transport plan in the UK; SubSea 7's offshore projects and services are delayed.

Free trade and low immigration barriers allow Scottish manufacturing to compete on price. However, technology is not cutting-edge in Scotland. The lack of robotisation and service models supported by virtual reality (VR) and augmented reality (AR) are also affecting competitiveness in the country. Definitely, "Scotland cannot make a racehorse out of a donkey".

Scenario 4: Gliding like a dolphin

(Flexible international trade and relationships & active innovation and diffusion)

Both manufacturers and society are on the path to a regenerative world. The Scottish people are aware of the limitations of resources and prefer to consume eco-friendly products. Heightened consumer awareness of health and wellness is strengthening the trend towards healthier consumption. The production of "natural" food and beverage is now a trend for manufacturers in Scotland. Furthermore, assessments of full life cycles and ecological resources are compulsory for all new products. Companies are focused towards social and environmental values. The green agenda is a priority for Scotland and manufacturers are pressured by the customers and carbon taxes to transform their production processes. The impact of climate legislation for energy generation and use is having a positive effect. Scottish manufacturers are remanufacturing and reusing systematically throughout a product's life cycle. There is a net material cost-saving for adopting a more restorative approach using less resource extraction. This means less waste, more profits, and satisfied customers.

After Scotland's independence, there are political and economic tensions with the UK. A possible trade agreement, conditions for travelling and currency between them are being negotiated. However, Scotland has more political control to create trade deals and relationships with the European Union. This also enables the progressive reduction of tariffs and greater flexibility for trading between Scotland and the EU. This not only facilitates overseas businesses and strengthens Scottish exports, but it also improves domestic production capacities of agriculture, fishery products and food. Scotland's brand as a "sustainable green country" creates a great place for international business and inward investment.

In the same way as we saw people trained in lean and six sigma in the 1990s, Scotland leads the way with a "green practitioner" army. The Advanced Manufacturing Innovation District Scotland (AMIDS) is driven by cooperation and co-funding collaborative projects between industry and higher education institutions locally and internationally. The Scottish government has been working in collaboration with different institutions such as NMIS and the University of Strathclyde to support the manufacturers ecosystem. These institutions have been implementing programmes to trigger innovation in a sustainable way. For example, the Scottish Institute for Remanufacture stays at the cutting-edge helping businesses to grow and innovate. Advancements from the life sciences and AI enable accurate predictions to anticipate patient's needs and discover new treatments for chronic disease such as cancer. Pharmaco-vigilance allows tracking effects and adverse events in real time. These achievements are attributed to sustained government support helping manufacturers to digitalise and to develop innovative capabilities which started in the early 2020's.

The UK hydrogen ambition for delivering 5GW of low carbon hydrogen production capacity was achieved by 2030. There is a full range of end users demand in place across sectors and location across Scotland. Hydrogen networks have been included through pipeline and non-pipeline channels which ensures hydrogen can be reached for a full range of end users to reduce carbon emissions. The modern transport infrastructure allows digital connectivity and energy efficiency. With the country progressing well towards net zero emissions, the use of electric cars is dominant. Hydrogen vehicle uptake is dramatically increasing, and this is the dominant type of fuel for public transport.

Millennials are driven by social values, rather than by more stable positions or higher salaries. The Fair Work Commission have been assisting employees and employers to maintain fair and productive workplaces through the adoption of digital technologies that support the needs of the worker. The National Transition Training Fund also supports the workforce across Scotland to upskill them in design, visualisation, robotics, automation, and programming. Skills Development Scotland, through its Skills Investment Plans, works with a range of institutions to deliver education programmes that encourage capabilities in science, technology, engineering, and mathematics (STEM) from an early age. Upskilling of socially disadvantaged people is also included in this programme.

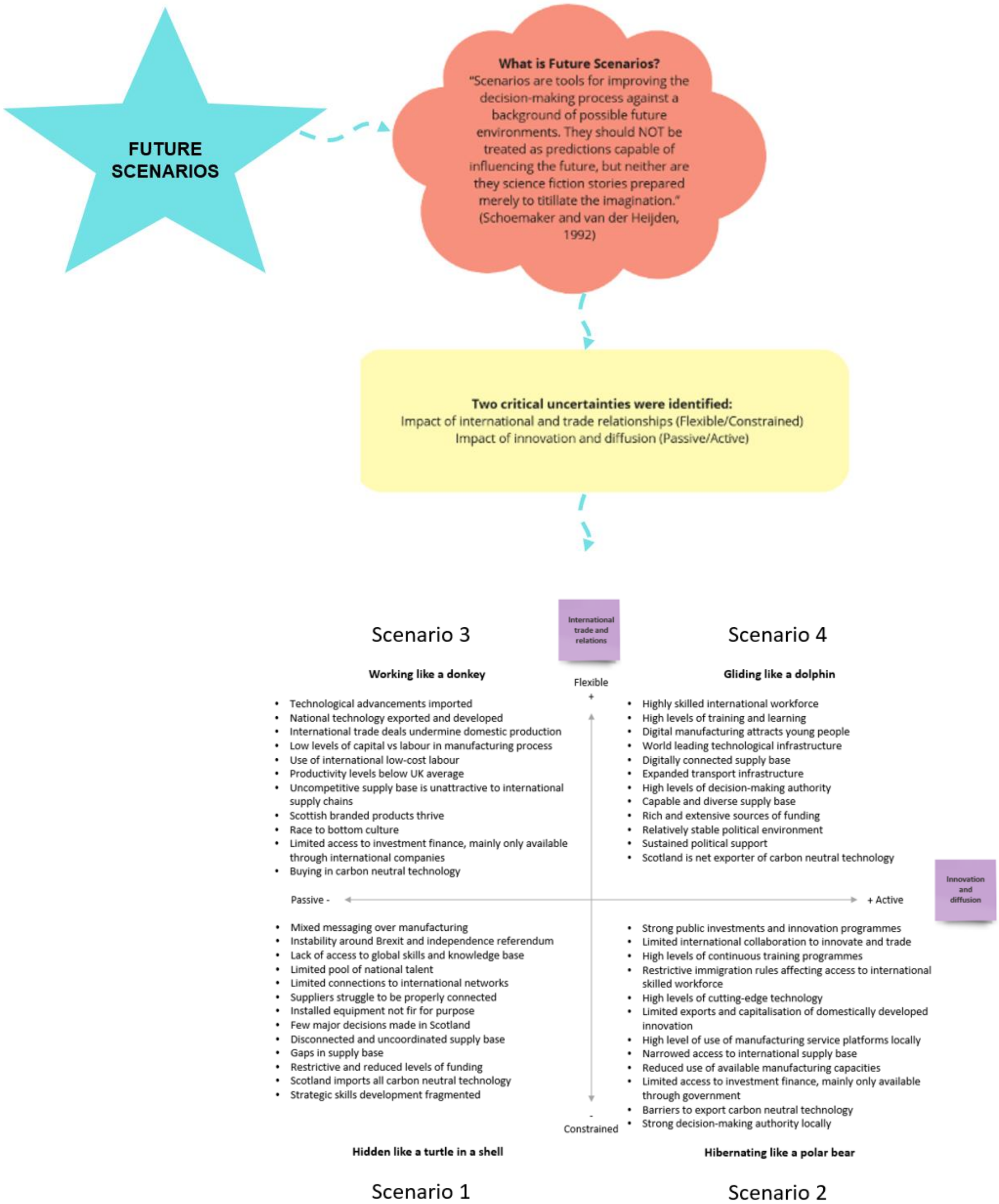
Employers are continuously training workers in how to use the new technology and Universities offer blended programmes for lifelong learning journeys to mature students locally and internationally. However, there is still a lack of well-trained workers in Scotland due to a lack of young students' motivation to pursue careers in engineering. Manufacturing companies try to fill this gap with special apps and software that enable international talent to work remotely from other countries. Manufacturers are also encouraging a more diverse and inclusive model providing technical training to minorities. Furthermore, the Scottish government has strengthened their special visas programme for retaining and attracting extraordinary talent for living and working in Scotland the last decade. These conditions and the innovative digital manufacturing industry attract young people to the country. There is a migration of an international workforce with expertise in manufacturing processes to Scotland coming from BRIC (Brazil, Russia, India, and China) countries.

In companies serving volume markets, the production is more widely focused on human–machine interaction than 15 years ago. Extensive Robotic process automation (RPA) eliminates monotonous and repetitive tasks enabling the workforce to focus on activities that add higher value such as R&D and innovation. Manufacturers can utilise the capabilities of AI to increase their speed and efficiency. Manufacturing technologies connect companies through flows of data across the value chain from design to use, servicing and potentially reuse. The ability to link suppliers using remote technologies also increases the levels of resilience of the supply base in Scotland. Manufacturers are more prepared for natural disasters and disruptions. This is due to Scotland is having a capable and diverse supply base with stable service providers. Furthermore, big data is being used for predictive analytics which prepares the manufacturers for changes or disruptions in the market. The Internet of Things (IoT) is well stablished and enables predictability and stabilisation of supply chain operations. Therefore, autonomous supply chains react to disruption without significant manual effort and makes event response much more streamlined. For example, blockchain enables transparency and real-time collaboration across various tiers of the supply chain.

Manufacturing companies and policy stakeholders in Scotland are working together following a coordinated approach to tackle the climate change plan. Scotland's emission reduction targets and the green recovery are having positive results. For instance, Scotland has achieved the 2036 target of reducing 84% of carbon emissions (from the 1990/1995 baseline). Now, Scotland is gliding to reach net zero, close to 100% by 2045.

Appendix Chapter 8 – Strategizing

A.C8.1 Miro board company 1



STEP 1

Discussion:

- What does each scenario mean for aerospace in Scotland and your organisation?
- What critical aspects are not covered in the scenarios but could happen in the future?

STEP 2

Set a focus:

- Decide which innovation capability dimension you want to focus on
- Decide which future scenario you believe is the most likely to happen

Innovation capability focus	Scenario focus
C4 Innovation strategy, communication, and open innovation	Scenario 1 Working like a donkey

STEP 3

Strategizing for the future:

1. Identify strategic actions that improve the chosen innovation capability dimension to either seize an opportunity or mitigate a risk posed by your chosen scenario
2. Identify other scenarios where developed strategic actions could be useful

STEP 4

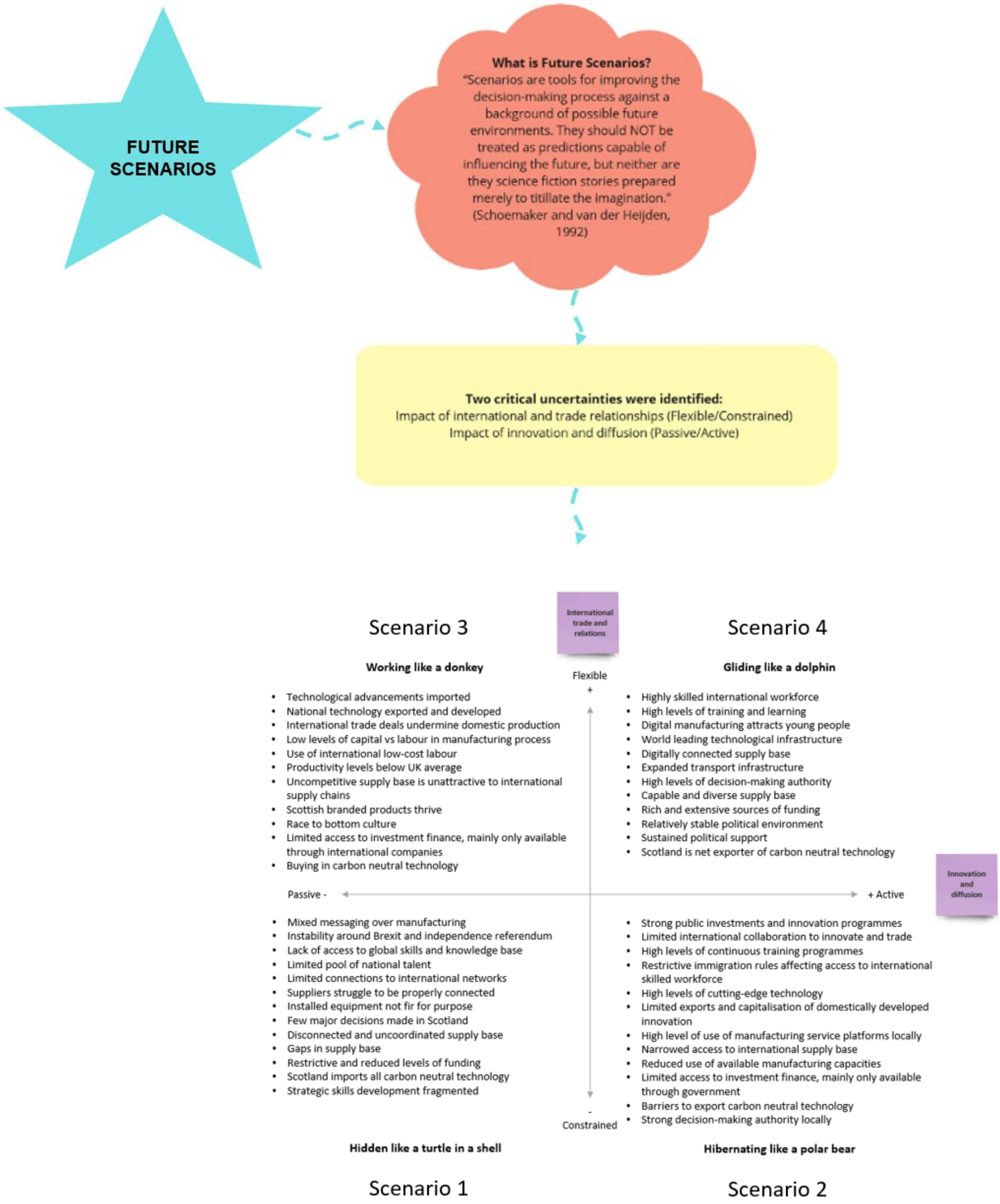
Final discussion

STEP 5

Feedback

Link to feedback form

A.C8.2 Miro board company 2



STEP 1

Discussion:

- What does each scenario mean for aerospace in Scotland and your organisation?
- What critical aspects are not covered in the scenarios but could happen in the future?

STEP 2

Set a focus:

- Decide which innovation capability dimension you want to focus on
- Decide which future scenario you believe is the most likely to happen

Innovation capability focus	**Scenario focus**
C4 Innovation strategy, communication, and open innovation	Scenario 2 Hibernating like a polar bear

STEP 3

Strategizing for the future:

1. Identify strategic actions that improve the chosen innovation capability dimension to either seize an opportunity or mitigate a risk posed by your chosen scenario
2. Identify other scenarios where developed strategic actions could be useful

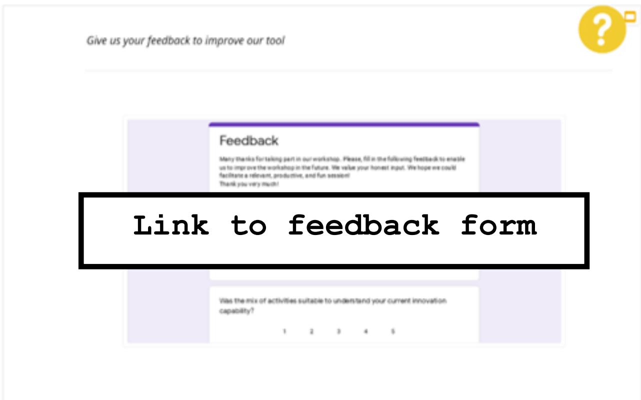

1. Strategic actions
2. Useful for which other scenario
Improve supply chain resilience - Improve links with local suppliers and other companies in politically aligned countries.
-
Pursue cooperation with government organisations
1,3
Market research and develop opportunities in the US - supply chain and customer base for existing and new products
-
Organisational Flexibility: investigate and implement processes that are relevant to emerging British industries
1,3,4
Work with government organisations to identify current capabilities and workforce experience that could be used in other industries
Only 1,3
Look at training programmes / internal development to up-skill and retain staff
Only 1,3
Review employment practices and modernise to offer more appealing positions and attract skilled labour
Only 1,3
Put a high priority on digitalisation of current manufacturing processes to improve workshop capacity
Only 1,3
Use advanced technology/processes to develop niche, high-end product
Only 1,3
1. Strategic actions
2. Useful for which other scenario
Develop relationships within our supply chain & manufacturing base network (eg: NMIS). Meet more people in our space
1,3,4
Updating hardware to allow full integration of digitalisation
Only 1,3
Training workforce to enable the whole organisation to work together digitally
Only 1,3
Use data to assess and aid decision making
1,3,4
Implement meetings to review evolving operations from a technological perspective to identify what can be done better / identify constraints & possible solutions (requiring investment)
Only 1,3
Manage more difficult contracts through communication – engage stakeholders and make them "allies". This could be addressed through digitalisation
1,3,4
Develop sustainability strategy through appreciation of our key industries challenges.
1,3,4
Improving communication and means of communication to generate trust with customers
1,3,4
Try to speak the same language as customers (common issues & expertise by industry) / build trust / be transparent in regular communications
1,3,4
1. Strategic actions
2. Useful for which other scenario
Employ someone (or outsource) who deals directly with government bodies to apply successfully for grants available for SMEs
-
Co-investment and cooperation to prototype and apply for funding
Only 1,3
Develop network and contacts within government organisations so that funding opportunities are highlighted to us early
Only 1,3
Review current raw material recycling processes to improve our % wastage
1,3,4
Speak to local companies and see if any recycling efforts can be collaborated on
1,3,4
Review company energy usage. Could this be supplemented with Solar panel with energy storage system?
1,3,4
Promote "green" credentials - customers increasingly aware and pushing towards low carbon solutions
1,3,4
Develop sustainability strategy through appreciation of our key industries challenges.
1,3,4

STEP 4

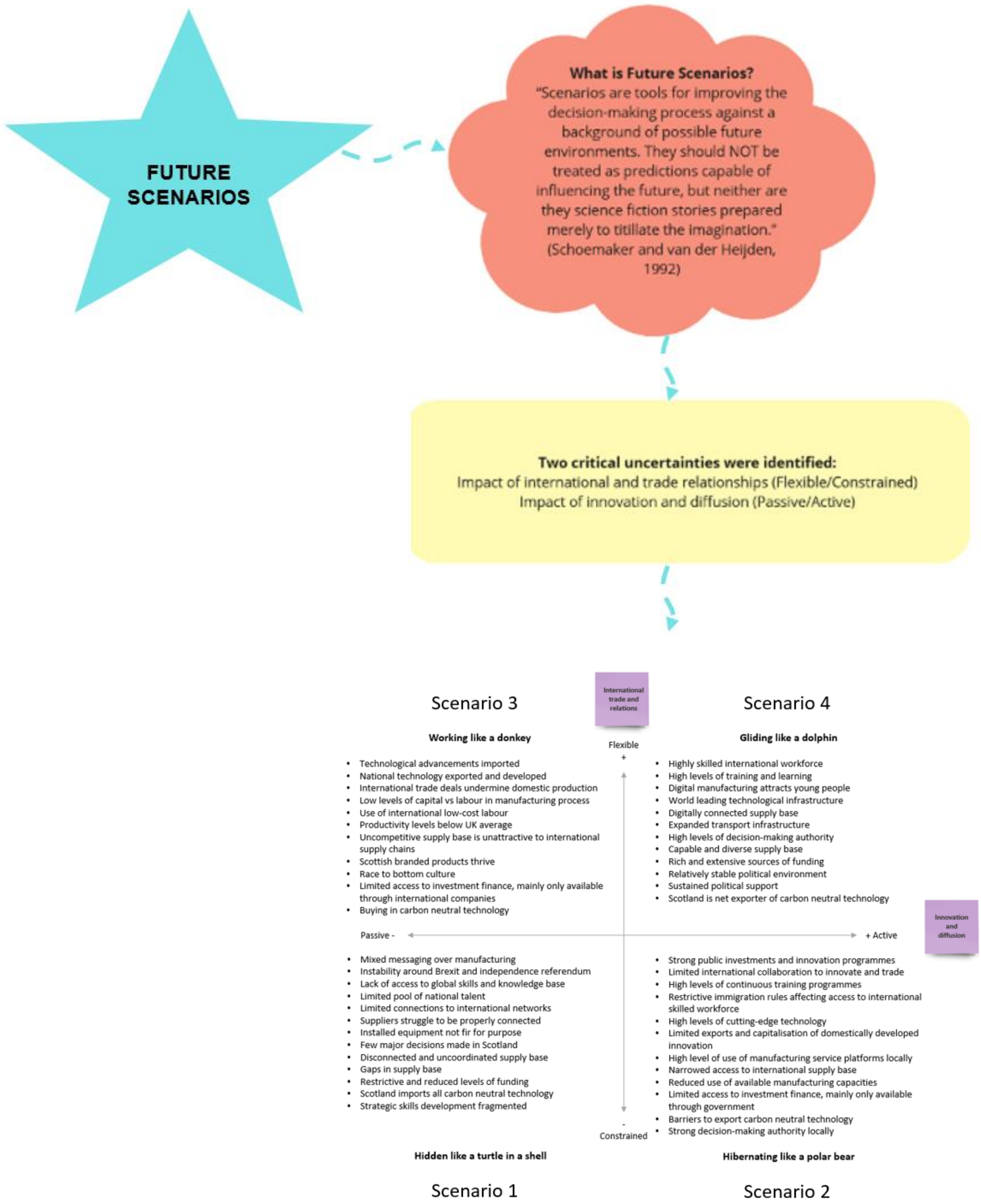
Final discussion

STEP 5

Feedback



A.C8.3 Miro board supply chain



STEP 1

Discussion:

- What does each scenario mean for aerospace in Scotland?
- What critical aspects are not covered in the scenarios but could happen in the future?

STEP 2

Set a focus:

- Decide which innovation capability dimension you want to focus on
- Decide which future scenario you believe is the most likely to happen

Innovation capability focus

Scenario focus

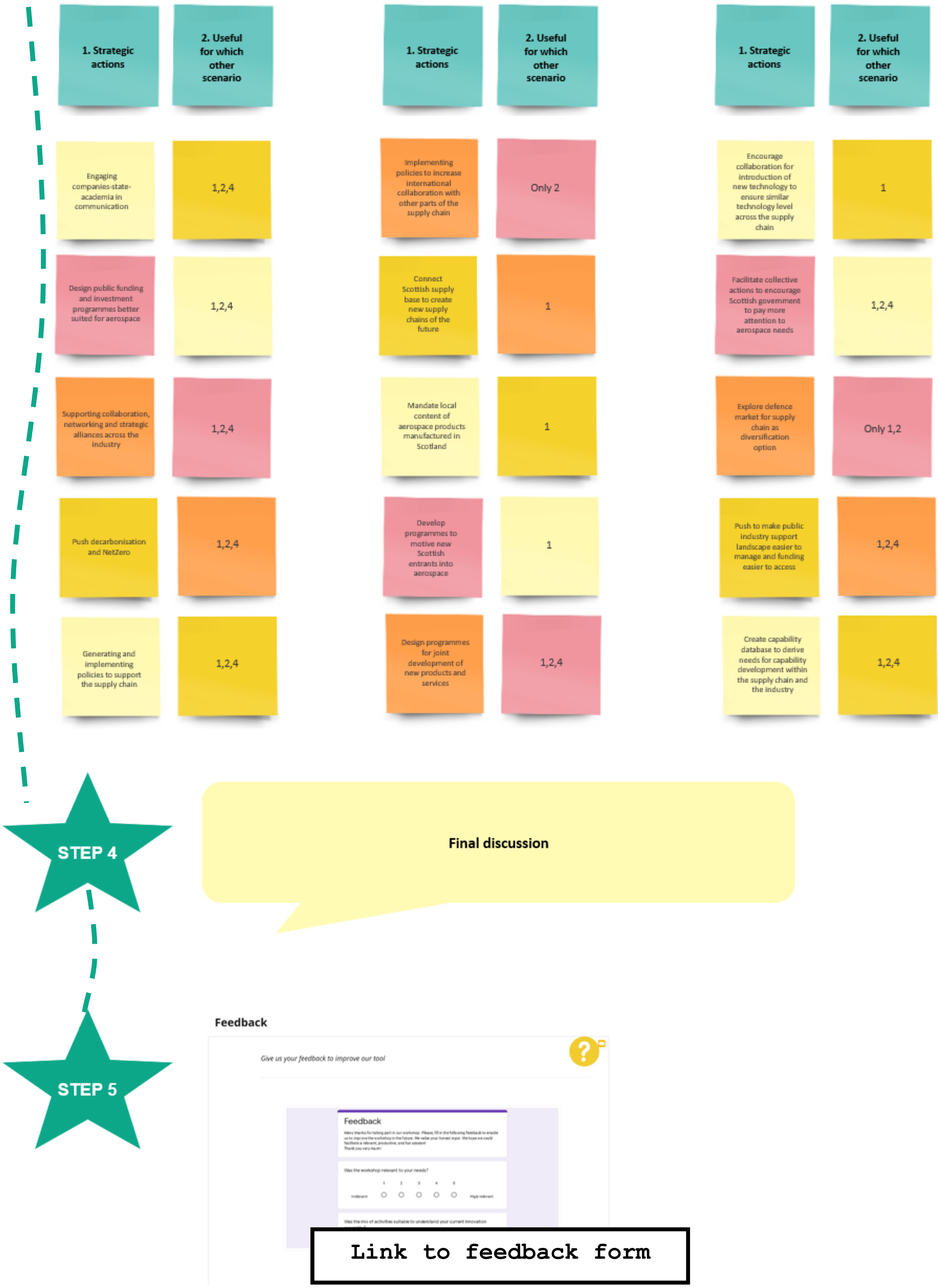
SC1 Supply chain structure and governance

Scenario 3 working like a donkey

STEP 3

Strategizing for the future:

1. Identify strategic actions that improve the chosen innovation capability dimension to either seize an opportunity or mitigate a risk posed by your chosen scenario
2. Identify other scenarios where developed strategic actions could be useful


1. Strategic actions
2. Useful for which other scenario
Engaging companies-state-academia in communication
1,2,4
Design public funding and investment programmes better suited for aerospace
1,2,4
Supporting collaboration, networking and strategic alliances across the industry
1,2,4
Push decarbonisation and NetZero
1,2,4
Generating and implementing policies to support the supply chain
1,2,4
1. Strategic actions
2. Useful for which other scenario
Implementing policies to increase international collaboration with other parts of the supply chain
Only 2
Connect Scottish supply base to create new supply chains of the future
1
Mandate local content of aerospace products manufactured in Scotland
1
Develop programmes to motive new Scottish entrants into aerospace
1
Design programmes for joint development of new products and services
1,2,4
1. Strategic actions
2. Useful for which other scenario
Encourage collaboration for introduction of new technology to ensure similar technology level across the supply chain
1
Facilitate collective actions to encourage Scottish government to pay more attention to aerospace needs
1,2,4
Explore defence market for supply chain as diversification option
Only 1,2
Push to make public industry support landscape easier to manage and funding easier to access
1,2,4
Create capability database to derive needs for capability development within the supply chain and the industry
1,2,4
STEP 4
Final discussion
STEP 5
Feedback
Give us your feedback to improve our tool
Feedback
Link to feedback form

A.C8.4 Feedback and validation questionnaire

1) How would you rate the quality of the workshop? (From 1 to 5 with 1 = unacceptable and 5 = outstanding)

1	2	3	4	5
☐	☐	☐	☐	☐

2) To what extent was the mix of activities suitable to understand your innovation capability? (From 1 to 5 with 1 = unsuitable and 5 = fully suitable)

1	2	3	4	5
☐	☐	☐	☐	☐

3) To what extent was the use of scenarios helpful to when creating innovation capability development strategies? (From 1 to 5 with 1 = not helpful and 5 = very helpful)

1	2	3	4	5
☐	☐	☐	☐	☐

4) To what extent was the use of the framework helpful when creating innovation capability development strategies? (From 1 to 5 with 1 = not helpful and 5 = very helpful)

1	2	3	4	5
☐	☐	☐	☐	☐

5) How relevant was the workshop to your needs? (1 = irrelevant and 5 = highly relevant)

1	2	3	4	5
☐	☐	☐	☐	☐

6) What suggestions do you have to improve the workshops?

University of
Strathclyde
Glasgow