From Structure to Barriers;

A Comprehensive Case Study of a Regional High-Tech, Chip-Related Cluster in Eastern Netherlands

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Abstract

Aim – This study explores the dynamic structure of a high-tech, chip-related cluster in the eastern part of the Netherlands, more precisely Twente. By gathering insights in the regional value chain, the regional value network and potential barriers in the development of the cluster a comprehensive overview has been created of the cluster.

Method – This study utilizes a qualitative research approach. A total of 15 interviews were conducted among organizations active in the cluster under research. Only decisionmakers were interviewed, thereby ensuring reliability and validity for the gathered data.

Results – This study consists of three deliverables. 1) A comprehensive description of the regional value chain and where it differentiates from the industry's conventional value chain, 2) A description of the regional value network, outlining different roles, actors and activities within the cluster, 3) Potential barriers impacting the development of the cluster. A total of 4 barriers were derived from the data, consisting of a human capital barrier: talent, the role of IP, the realisation of a new foundry and the cluster initiative.

Theoretical Implications – This study has multiple theoretical implications. Firstly, it adds a case study to the literature space. Secondly, it combines both the value chain model and the value network model. Thereby, presenting a complete and comprehensive description of the cluster under research. Moreover, this study identifies a total of 4 barrier in cluster development. Although, two barriers are lacking generalizability, likely only impacting the researched cluster, other identified barriers add to the theory by having impact on collaborations and knowledge spillovers (the role of IP), and general cluster development (cluster initiative) by identifying new variables of impact.

Practical Implications – By presenting a comprehensive overview of the structure of the cluster local policymakers, entrepreneurs and leaders can determine strong points of the regional cluster, and missing elements. Furthermore, by identifying potential barriers regional entrepreneurs and policymakers could act upon and strategize how to tackle the identified barriers. By eventually adjusting or creating policy to strengthen the cluster. Moreover, other cluster facilitators could use this study as a resource for the development of their cluster.

Keywords – Regional Clusters, Cluster Development, Cluster Initiative, Value Chain, Value Network, Barriers

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1 Introduction

1.1 Research context

In 2021, when the world experienced shortages in the supply of computer chips (Mohammad et al., 2022), it became apparent that computer chips are the core building blocks of nowadays society. Moving to an ever more digitalised, measurable, AI-supported globalised world expectations are that demand continues to grow. One of the outcomes of the global supply chain problem, back in 2021, was that governments, especially in the West realised their dependency on China and Asia. With this realisation, governments drew new policies supported by huge subsidy funds. These actions aimed to be less dependent and more self-sufficient, especially on key technologies such as semiconductors and computer chips.

Europe's Chips Act (*The European Chips Act - Regulation 2023/1781*, n.d.) and the United States CHIPS and Science Act (Rep. Ryan, 2022) made these policy decisions tangible for market players. On a national level, similar initiatives started when the Dutch government launched the Growfund (*Publieke Investeringen Vergroten Economische Groei En Toekomstige Welvaart. Kabinet Lanceert Nationaal Groeifonds | Nieuwsbericht | Rijksoverheid.Nl*, 2020), also focusing on key enabling technologies. These actions placed a lot of attention towards the industry of semiconductors and chips, both internationally and nationally pushing investments. Moreover, on a national level different consortiums and initiatives launched in order to attract the announced capital. In the rural area of Twente an initiative was launched, called Chip Tech Twente. Chip Tech Twente formalised a cluster of chip-related companies as, due to the presence of a technical university, a concentration of high-tech companies developed itself over the years.

This development can be traced back to 1962, when the Dutch government realised a knowledge institution in Twente, located in the eastern part of the Netherlands. One of the core pillars of this knowledge institution, since its realisation, was entrepreneurship and technology, this to strengthen the regional economy. This strategy resulted in many university spin-offs, in many different industries. One industry in particular developed itself over the years, that of nano- and chip-technology, yet it remained scattered and disjoined in the region.

Local actors realised that, instead of pursuing these announced subsidies individually, they would increase the chance to be allocated funds if they organised themselves as a cluster resulting in the realisation of Chip Tech Twente. Yet, much of this cluster and its dynamics remains unknown.

Scholars have researched the phenomenon of regional clusters from many perspectives, for example its impact on innovation (Asheim & Isaksen, 2007), the regional economy (Zysman, 2007), how industry clusters are related to industry lifecycles (Menzel & Fornahl, 2010), the networks that clusters are composed of (Kajikawa et al., 2012) and different case studies, for example regarding wine clusters in Chili (Giuliani, 2013) or the high tech cluster of Silicon Valley (Chandler & Saxenian, 1994; Engel, 2015; Klepper, 2010). Yet, most case studies focus on describing a cluster based on the presence or absence of certain factors, or by using different quantitative variables. Hence, there remains a scarcity in the literature space in regard to how a cluster is structured using qualitive methods, like the value network theory.
Therefore, this research aims to add a case study to the literature space by analysing the structure of the high-tech cluster in Twente using the value network theory, by also taking in account the industry characteristics. Moreover, having a qualitive research strategy (conducting semi-structured interviews), opens the opportunity to also identify potential barriers influencing the development of the cluster under research. Thereby, having another contribution to the literature space by identifying and discussing the impact of these barriers on the development of high-tech clusters.

1.2 Research objective

This study consists of multiple deliverables. To create an overview of the cluster, it is key to understand how the complex chain of the industry is structured, and which elements of the value chain are represented in the cluster. Therefore, the first deliverable is an overview of the value chain of the industry in the region. As Zamora (2016) states the value chain is a useful model to outline the different steps in the industry and where value is added. An overview of how value is created in the regional value chain is provided by having an inductive research approach. Furthermore, by having an understanding of the regional value chain, the map of the value network can be structured. This map completes the overview of the cluster and creates insight in how the cluster is built up. Third and finally, barriers were derived from the

data, identifying potential barriers influencing the development of the cluster. The following research question for this study is formulated:

How is the high-tech, chip-related cluster in the region of Twente structured and what are the potential barriers in the development of this cluster?

1.2 Contribution to the literature field

This research adds to the literature field in numerous ways. Firstly, this research has a qualitative nature which is uncommon in the field of regional cluster research. Most scholars research clusters by using quantitative data, often in terms of patent data. Also, this research combines multiple models resulting in a comprehensive overview and snapshot of the cluster. Moreover, this two-folded overview of the cluster provides a case study which on itself is an addition to the literature space. Furthermore, this research identifies potential barriers in the development of the cluster, this could be interpreted by local actors as hands-on, concrete advise with the aim of improving the cluster, but could also be researched in the future to compare data.

This paper is structured as followed; the next section is a literature overview consisting of two elements; theory on regional clusters and theory on the value chain and network. This section is followed by the methodology, which describes the research strategy, how the data is gathered and analysed. After which the results section describes the empirical, inductive results. The results section is divided into three parts, that of the value chain, the value network and the identified barriers. The discussion section follows the results section, in here the results are discussed and conclusions are drawn.

2 Theoretical background

To answer the research question of *how is the high-tech, chip-related cluster in the region of Twente structured and what are the potential barriers in the development of this cluster?*, first multiple sub-questions are discussed on forehand to create a theoretical understanding of the researched phenomena and to create a foundation for this research. This section, the theoretical background, discusses the different theories.

The research question is divided into two sections, that of how the cluster is structured and that of potential developmental barriers. Firstly, theory regarding clusters is discussed, this is done by answering the sub-question of *What is a regional cluster?* To define what a cluster entails. Furthermore, theory regarding the first part of the research question is discussed; that of how the cluster is structured. To answer this part of the research question, theory is used of the value chain and the value network. Both will be discussed by answering the following sub-questions: *What is a value chain, and where does it differ from the supply chain?* and *What is a value network, and how does it differ from the value chain?* The argument of why both models are used for this study is because the industry itself is rather complex, the value chain is a tool to create simplicity in complex matters.
Therefore, to have an understanding of what the theory of the value chain model exactly entails the sub-question of *What is a value chain, and where does it differ from the supply chain?* is formulated. Moreover, to create a more detailed overview of how the cluster is structured the model of the Value Network Analysis is used. This theory is discussed by answering the sub-question of: *What is a value network, and how does it differ from the value chain.* The value network analysis enables the researcher to create a detailed description of the cluster with its different actors, and how these actors are linked.

After providing a clear perspective on regional clusters and how the structure of the cluster is researched, factors/variables influencing the development of clusters will be discussed, this is done by answering the sub-question: *Which factors, identified by researchers, influence the development of clusters?* This sub-question creates an overview of the variables that are identified as success factors in cluster development.

By having the following sub-questions the theoretical fundament is paved to understand what a cluster entails, how this is researched in this study and which factors influence the development of regional clusters.

- *What is a regional cluster?*
- *What is a value chain, and where does it differ from the supply chain?*
- *What is a value network, and how does it differ from the value chain?*
- *Which factors, identified by scholars, influence the development of clusters?*

The above sub-questions therefore help to answer the main research question of *how is the high-tech, chip-related cluster in the region of Twente structured and what are the potential barriers in the development of this cluster?*

2.1 What is a regional cluster?

The phenomenon of regional clusters is not something new. Alfred Marshall was one of the first researchers who realised certain industries tend to be concentrated in particular regions (Marshall, 1920). Marshall realised that location proximity of firms, active in a similar industry generate certain benefits. He stated that by being in close proximity economical agglomeration for firms occurs, which leads into three key benefits he identified: that of having access to skilled (and specialised) labour, access to specialised suppliers and knowledge spillovers from competing firms. Resulting in a strong economic regional performance.

The work of Alfred Marshall dates back to the 1920's, but when Michael Porter re-introduced the topic of regional clusters in the early 1990's, it popularized and started to find its way to more scholars and even policymakers. Resulting in a surge of publications ever since. Porter introduced a more detailed perspective on the role of clusters in the regional economy, which became a broadly accepted definition by others.

Porter defines clusters as: "*critical masses (in one place) of unusual competitive success in particular fields"*, more specifically *"clusters are geographic concentrations of interconnected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities important to competition […] Clusters also often extend*

downstream to channels and customers and laterally to manufacturers of complementary products and to companies in industries related by skills, technologies, or common inputs. Finally, many clusters include governmental and other institutions (such as universities, standard-setting agencies, think tanks, vocational training providers, and trade associations) that provide specialized training, education, information, research and technical support" (Porter, 1998, para. 8).

The last decade another perspective gained traction in the literature space, that of entrepreneurial ecosystems. Between the two phenomena is much overlap. Ecosystems are a conceptual umbrella for resources and benefits that are produced by collaborating, often in a regional community of entrepreneurs and their supporters. The ecosystem perspective is broader than the cluster perspective, still this phenomenon is worth discussing since there are overlapping elements. Erik Stam (2015) structures the entrepreneurial ecosystem into 10 elements. As Stam states: "*the systemic conditions are the heart of the ecosystem: networks of entrepreneurs, leadership, finance, knowledge, and support services. The presence of these elements and the interaction between them predominantly determine the success of the ecosystem*" (Stam, 2015, p. 1766). Next to these systematic conditions, entrepreneurial ecosystems have framework conditions, consisting of formal institutions, culture, physical infrastructure, and demand.

Where the perspective of Stam is more systemic, taking in account the basic elements of any entrepreneurial fundament (leadership, finance, knowledge) and framework conditions (institutions, culture, physical infrastructure), is the perspective of Porter more holistic, describing how certain goods and services flow through the cluster. The overlapping theme in both perspectives, as well as Marshall's perspective, is the concentration of firms and the collaboration between firms. All agree, as they include it their definitions, that "the interaction between them" (referring to the actors in the ecosystem) "encompass an array of linked industries and other entities important to competition". The main difference between these two phenomena is that clusters focus on a particular field/industry, whilst entrepreneurial ecosystems describe the regional ecosystem as a whole.

In conclusion, a regional cluster is an economical phenomenon where in a defined geographical area a concentration of organizations lies, active in similar, overlapping industries, thereby providing complementary goods and services. This concentration of organizations is supported by formal institutions, such as universities, think tanks and triple helices, providing support in for example talent, policies and funding. The interaction of all the different types of actors in this geographical area eventually results in a stronger economically performing region.

2.2 What is a value chain, and where does it differ from the supply chain?

By discussing what a cluster entails and how it is defined in the literature, an understanding is created for the researched phenomenon. Yet, how this phenomenon is researched in this study, and what scholars have published regarding the used models will be discussed in the upcoming sub questions. First the concept of value chain will be discussed, taking in account also the concept of the supply chain.

The concept of the Value Chain is quite ambiguous. Feller et al. (2006) explored the difference between Value Chain and Supply Chain, as they are often regarded as overspilling concepts. The supply chain focusses on the management of the flow of goods from suppliers to ultimately the end-user, the primary focus in supply chains is the costs and efficiencies of supply, and the steps of goods and materials moving from their different sources to the end customer (Feller et al., 2006). The value chain, on the other hand, has a perspective of the end-customer who 'values' the end-product and moves back in the chain through the value-adding steps, whilst the supply chain has a perspective from supplier to end-customer. Both perspectives consist of the same firms but analyse the chain in an opposing matter. In short, the supply chain has an upstream perspective, focussing on integrating suppliers and producer processes, improving efficiency, reducing waste, whilst the value chain has a downstream perspective, focussed on creating value in the eyes of the customer (Feller et al., 2006).

The value chain is a framework which models the steps of value-adding activities. Porter (1985) developed this framework when studying competitive advantages. The initial framework was mainly focused on activities within firms, describing the strategic activities deployed by organisations in order to deliver valuable products or services to the market. Over the years,

the value chain concept has been enlarged by different avenues, like the Virtual Value Chain (Rayport & Sviokla, 1995), Global Value Chain (Anderson, 2000), Added Value Chain (McPhee & Wheeler, 2006), Reverse Value Chain (Jayaraman et al., 2007), Sustainable Value Chain (Fearne et al., 2012) and others. Moving away from its initial perspective of how value is created within firms, towards how value is created in industries.

Porter (1985) was the first who introduced the full range of activities, required to create a product or a service, from its concept phase, production phase, logistical phase and the final end consumer. The underlying assumption of this model is that each step in the chain adds value to the end-product (Hellin & Meijer, 2006). The Value Chain is useful for mapping out the value-adding steps in the market or industry. The model, since its introduction has been used in various ways moving beyond the study of individual firms (Zamora, 2016b). It is important to distinguish two types of value-creating activities; that within the industry (in which each company adds value to the end-product), and that within companies, with its inputs, outputs and supporting activities (Llorente et al., 2023).

In conclusion, the value chain is useful to outline the value-adding steps in an industry. The supply chain perspective, on the other hand, dives deeper into all the value-adding steps and the management of goods and services, thereby also taking in account the costs and efficiency. process. The purpose of this study is to create insight in the structure of the cluster, therefore the value chain approach, by having a more holistic nature, is more suitable as it is used in a supportive manner for the value network analysis.

2.3 What is a value network, and how does it differ from the value chain?

Scholars realised the perspective of the value chain does not cover the whole arena of value creation. Value is created in a network, hence the literature space started to move from the value chain perspective towards the value network perspective. As Ricciotti (2020) describes in his systematic literature review regarding the evolution of value chain to value network. Where in the in the early days (1985 to 1990) Porter developed the Value Chain as a tool to combine internal data with data outside the firm, regarding the competitive environment, in order the decide how to allocate certain resources within the firm. However, this model had some flaws, for example in finding the proper data.

Moving on from this firm-focussed perspective, scholars started to include the dynamic nature of doing business, considering the Value Chain together with other concepts (e.g. models for commitment under uncertainty), this was also done by Porter (1991) developing his framework further. Next this this, to optimize the Value Chain analysis, others added different factors impacting value creation, like Shapiro et al. (1993). Moreover, scholars started to introduce the network perspective mid-nineties with one of the first contributions by Achrol (1997). Others built upon this network perspective (Allee, 2000; Anderson, 2000; Bovel & Martha, 2000; Dyer & Nobeoka, 2000).

As Tsai & Ghoshal (1998) noticed; the transition from value chain to value network has strong links with globalization, and the social aspect, that of relationships, trustworthiness, vision and social interaction which helps to create value in the form of innovation (Tsai & Ghoshal, 1998). Ricciotti outlines that from the early 2000's, the role of the internet heavily influenced the value chain theory. Also, the connection between the Value Chain and Business Models started to be described (Fjeldstad & Haanœs, 2001; Schweizer, 2005). Ricciotti underscores that the attention in the literature field continued to move from individual firms to the 'Value-Creating Networks', which is formed by key firms able to create value for the end consumer.

Taking more variables in account, mid 2000, scholars started to include brand, reputation, social capital and goodwill, calling this revised model the Added Value Chain. Next to this, the Reverse Value Chain was introduced. Providing a framework from the end consumer back to the point of origin (Jayaraman et al., 2007; McPhee & Wheeler, 2006), creating insight in the sustainability of the value chain of certain industries. Additional perspectives on the Value Chain framework continued to enter the literature space like the Sustainable Value Chain Framework (Fearne et al., 2012) and connecting the Value Chain to the concept of Business Process Management, next to multiple case studies.

The study of Ricciotti provides a comprehensive overview of how the literature space developed itself, including more and more variables over time. Ricciotti identifies a couple reasons why the value chain concept has developed into a value network perspective. The author outlines that competition became global, thereby reducing boundaries and therefore creating a need to be efficient to stay competitive. Moreover, companies, nowadays need to collaborate, since they often lack all the skills needed to fulfil customer needs. Next to this, digitalization plays a major role. Value within firms has transformed from tangible assets to

intangible assets. Being in a global, digitized competitive world created the need for firms to be flexible and agile. All these reasons explain the shift from the value chain to the value network. As Ricciotti highlights from the research of Simatupang et al. (2017): "*Value Chain members should work together to align costs, risks and revenues. Companies become nodes along the supply chain; rather than looking at the single Value Chain, the Value Network is taken into consideration, then the focus is shifted from an internal to an inter-organisational perspective*". (Ricciotti, 2020, p. 205)

The key variable in the value network is understanding the dynamic of how value converts, both in tangible and intangible assets. There are many forms of conversions in networks, with many different types of networks. Such as purposeful networks (examples of this are organisations with a specific role focussed on a specific task or outcome), internal-focussed networks, e.g. the interaction between different interfirm-related roles. External-focussed networks, focussed on the interaction between suppliers, investors, customers and other partners of organisations. As Allee (2008) stated, networks engaging in both tangible and intangible value exchanges to support the achievement of specific outcomes and to generate economic and social good.

The value network can be mapped through three elements, that of roles, transactions and deliverables. Roles consists of participants in the network who provide contributions and carry out functions. These participants can be individuals, teams, business units, organisations, industry groups of even nation states. Transactions, also known as activities, consists of the interaction between two participants of the network. Deliverables are the actual things that move from one to another (Allee, 2008).

The figure below (Figure 1) outlines the network of an external value network focussing on market innovation for a technology company and serves as an example. It displays the different roles within the network, the transactions (who has a relationship with who) and the deliverables. For example, resellers (role) have a transaction with Technology provider (Role), and the resellers deliver market insights for the technology provider. But as in any network, ties between different roles are often complex, and not 'just' transactional. (Allee, 2008)

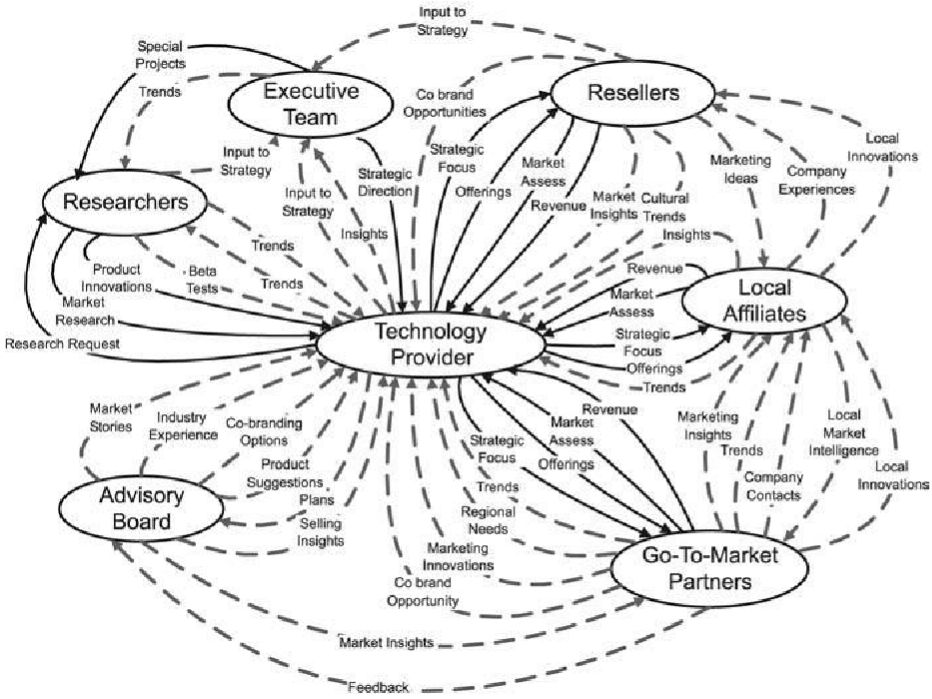


Figure 3.
An external value network focusing on market innovation for a technology company

Figure 1 Example of a value network (Allee, 2008)

In conclusion, the literature space developed itself over the years by taking a network perspective. To analyse a value network three variables are taken in account: that of roles, transactions and deliverables. Transactions are mapped out by using an arrow in the map and occur between two roles. Each transaction then is illustrated by the deliverable. The different roles are outlined in a table, in which the role is generalized and explained, and all the relevant actors are displayed. This study utilizes this approach as well, as it illustrates the structure of the cluster in a detailed matter.

2.4 Which factors, identified by researchers, influence the development of clusters?

The reason of why a regional cluster grows into a success and others not, has been a question scholars tried to answer. Over the years literature studies have been published outlining and summarizing the results of multiple case studies. The research of Gagné et al., 2010; Klofsten et al., 2015; Tavassoli & Tsagdis, 2014 provide variables impacting the development of regional clusters.

Tavassoli & Tsagdis (2014) conducted a systematic literature review regarding empirical evidence of critical success factors for clusters, on which they build a model outlining how the different factors are related and how different actors are involved in the cluster. Tavassoli &

Tsagdis (2014) identified fifteen critical success factors. As the authors identified in the literature, it all starts with (1) the *right vision* and (2) *trust* of the support organisation, also known as the cluster facilitator or cluster initiative (Coletti & Di Maria, 2015; Klofsten et al., 2015). (3) *Geographical proximity* of firms, both in terms of industry firms and other actors is also identified as a critical success factor. (4) *Pre-existing knowledge*, consisting of educational programmes in the region provided by knowledge institutions.

Moreover, (5) *brand name* is also identified as a critical success factor. A brand name is not only useful for branding purposes of the cluster, but also helps to define the geographical boundaries of the cluster. Additionally, the presence of (6) *strong actor* is important for the cluster. This can be a leading industry firm, or a higher educational institute (Klofsten et al., 1999).

(7) *Networking* is identified as well as a critical success factor. For example, between universities and small medium enterprises, but this can also be between firms as well. Tavassoli & Tsagdis (2014) also emphasises that studies mention the importance of (8) *physical infrastructure*. This can be seen as infrastructure in the broad sense, as in roads and the presence of public transport, but also in the form of technology parks, research institutes, laboratories and support facilities for firms.

(9) *Finance*, and access to finance is also a factor which is key in the success of a cluster. There are multiple ways in which finance is accessible, this can be in the form of government funded projects or alternative financing, like universities or specially dedicated (private) funds. (10) *Innovation* capacity of firms is also regarded by scholars as key in the development of clusters, since innovation is linked to growth (Lyons, 2000). Bridging the factor of innovation is (11) *entrepreneurship* at its different levels (individual, organisational, collective).

Tavassoli & Tsagdis (2014) found that a number of studies also mention the necessity of a (12) *growing company base* for cluster success, where both start-ups and established firms play important roles in the cluster. Linked to a growing company base is (13) *staff attraction* from outside the cluster. The attractiveness of the region is linked to the cluster's successful firms which portray the region to the 'outside world' as an attractive place to live and the provided quality of life in the region. Outside cluster relations have also been identified as critical success factors, which can be summarized as (14) *external links*. Finally, the role of (15) *support organisations* has been underpinned by numerous scholars (Coletti & Di Maria, 2015; Gagné

et al., 2010; Ingstrup, 2010; Klofsten et al., 2015; Tavassoli & Tsagdis, 2014) as critical in the success of cluster, since they bring many elements of the success factors together.

The figure below (Figure 2) outlines the different factors and visualises how these are linked.

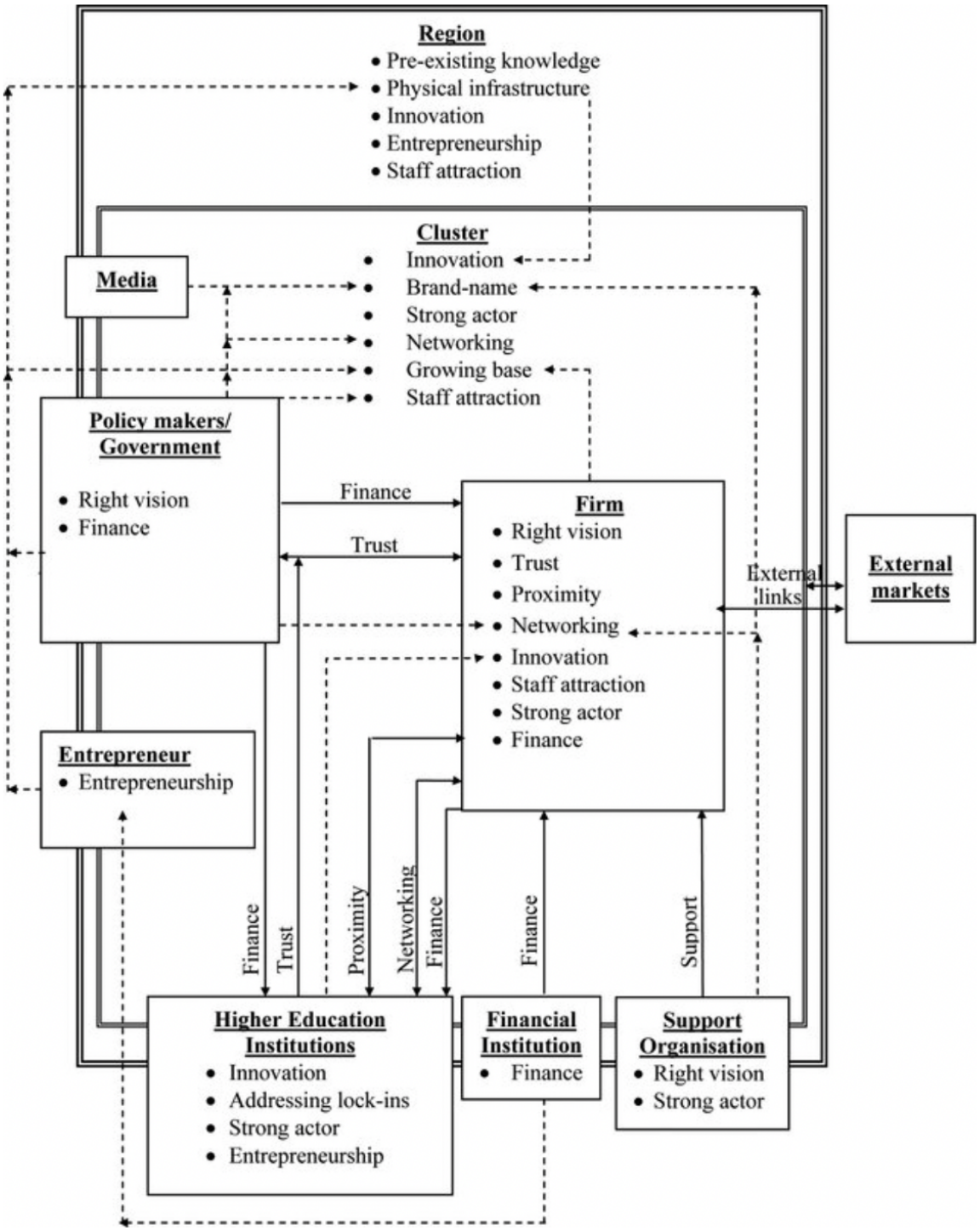


Figure 2 Conceptual Model of Success Factors (Tavassoli & Tsagdis, 2014)

The study of Gagné et al. (2010) has a different origin compared to the research of Tavassoli & Tsagdis (2014). Gagné et al. (2010) focusses on technology clusters in industrialised countries and underpins that they have been researched by a considerable number of researchers and policymakers, resulting in many reports and research studies of these clusters. The literature study of Gagne identified twelve factors divided into four capital categories: Human Capital, Social Capital, Physical Capital and Investment Capital. Gagne identified two factors for human capital. (1) *Skilled Workforce* and (2) *Innovative Technology and Technological Transfer*. Access to highly skilled workforce, as Gagné et al. (2010) states, is consistently regarded as one of the most important factors supporting the growth of a cluster. This factor is strongly linked to the innovative technology and technological transfer since workers interact with each other, thereby exchanging knowledge, leading to innovations.

Regarding social capital Gagne identified 5 factors. (3) *Networking*, (4) *External Knowledge Sources*, (5) *Cluster Animators* (6) *Leadership* and (7) *Cluster Brand*. Gagné et al. (2010) states that the ability of cluster stakeholders to form linkages with others and maintaining these collaborations is key in the formation and growth of the cluster. Networking between clusters that focus on similar industries is also identified as an important factor for knowledge-sharing and could serve as an exhilarator for a cluster. As Gagne (2010) states, successful clusters have a commonality in the form that they are able to create relationships and collaborations with parties outside the cluster. This external linkage is important in the successful development of the cluster.

Next to these external linkages, the role of the cluster animator is indispensable, which is emphasized by many researchers. The cluster animator acts as a linking pin in bringing organisations together and push networking and collaboration. Cluster animators are also distinguished as cluster facilitators or cluster initiatives. Gagne states that there is a difference between leadership and cluster animators. Where cluster animators focus on the establishment and maintenance of networks, is the focus of leadership on providing direction and driving strategic orientation and overall development of the cluster. Completing the social capital category is the cluster brand. Gagne (2010) underlines, that a clear brand of the cluster is critical in strengthening and market the cluster. A cluster brand not only acts as a marketing tool but could also serve as an ability of the cluster to attract investments, capital and workers.

The category of physical capital consists of two factors. (8) *Specialised Training* and (9) *Educational Infrastructure*. With the presence of specialised training and educational programs an infrastructure is created which provides a supply of talented and qualified workers to firms in the cluster, thereby contributing to the growth of the cluster (Gagné et al., 2010a).

The category of investment capital consists of three factors. That of (10) *Government Support*, (11) *Business Support Services* and (12) *Risk Capital*. As Gagné et al. (2010) states, public sector organisations play a variety of roles in developing clusters. The most crucial role for government in cluster development is to develop an integrated strategy that includes elements of regional development, science, regulations and competition (Gagné et al., 2010). The presence of business support services is also vital in the development of clusters. These organisations provide services ranging from grant assistance to marketing, and from networking to business advice. Last but not least, access to risk capital. As Gagne states, the availability of risk capital to support R&D investments is also documented as an essential element in cluster development (Gagné et al., 2010).

Gagne (2010) emphasizes also the role of anchor organizations, also referred to as cluster initiative or cluster facilitator. This also is identified in the literature as a core element. "*Anchor firms serve to attract both allies and competitors, as well as give rise to the creation of new companies. [...] They also serve to incite the emergence of industry-specific value chains by spinning off related technology firms, suppliers, and consultants. Further, they support the long-term development of networks through relationships established and maintained among employees and business associates*."(Gagné et al., 2010, p. 89). An anchor organisation is not necessarily a firm. Public organisations, universities or governmental agencies could also take on the role of an anchor organisation. The anchor organization and its role in a cluster has also been researched by scholars, where again success factors were identified. Klofsten et al. (2015) outlined these success factors in their research.

As anchor organisations or cluster initiatives are often at the centre of the cluster, bringing together all the parties and acting as a linking pin, they are also bound to factors influencing

their success. Klofsten et al. (2015) identified 5 key factors in the management of these cluster initiatives. Consisting of (1) *Idea*, (2) *Driving forces and commitment*, (3) *Activities*, (4) *Critical Mass*, and (5) *Organization*.

Having a clear *idea* helps to identify what the needs are that the cluster initiative is fulfilling for the cluster. Klofsten et al. (2015) point out that several studies emphasize the presence of a viable cluster idea as a linchpin of success. Having a clear idea of what the cluster entails, what it needs and which resources it needs helps to pave the fundament for the actors within the cluster. This collection of wants and needs is conducted and managed by the cluster initiative.

Driving forces and commitment entail committed members who help to create enthusiasm and the necessary energy for carrying out activities among the cluster members and initiating change. The cluster initiative is often responsible for managing the network of actors and keeping everybody motivated and committed.

Activities are needed to be organised to make it advantageous to be a member of the cluster. These activities can differ from networking events to presentations of what the different cluster members do, to training and educational programmes for entrepreneurs. Important to take into account with this factor is that activities should deliver unique value for cluster members.

Critical mass is important since there is a need for a certain number of motivated actors in the cluster. Critical mass constitutes both in number of organisations and in the diversity of organisations. By having a sufficient amount of members in the cluster meaningful and valuable exchange can occur.

Organisation focuses on the coordinating role of managing the network, organising the activities. This is often managed by the dedicated cluster initiative, and not by a firm active in the cluster. Cluster initiatives often comprise of only a handful of workers, these workers have a strong network within the cluster. As Klofsten et al. (2015b point out, it is important to define various roles within clusters to prevent misunderstandings among the cluster actors.

In conclusion, taking in account the discussed literature studies on success factors for cluster development a total of 32 factors are identified. However, many factors of the studies show overlaps in terms of capitals, as is highlighted in the table below.

Table 1 Overview of Identified Success Factors

Category	Gagné et al., 2010	Klofsten et al., 2015	**Tavassoli & Tsagdis, 2014**
Human Capital	(1) *Skilled Workforce* (2) *Innovative Technology and Technological Transfer*		(4) *pre-existing knowledge* (11) *entrepreneurship* (13) *staff attraction* (10) *Innovation* *(7) Networking*
Social Capital	(3) *Networking* (4) *External Knowledge Sources*		(7) *Networking* (14) *external links* (15) Geographical Proximity
Physical Capital	(8) *Specialised Training* (9) *Educational Infrastructure*		(3) *Geographical proximity* (8) *physical infrastructure* (12) *growing company base* *(4) pre-existing knowledge* *(10) Innovation* (11) Entrepreneurship
Financial Capital	(11) *Business Support Services* (12) *Risk Capital*		(9) *Finance* *(15) Support Organisation* (7) Networking

Anchor Organisation	5) *Cluster Animators* (6) *Leadership* (7) *Cluster Brand*	(1) *Idea* (2) *Driving forces and commitment* (3) *Activities* (4) *Critical Mass* (5) *Organization*	(1) the *right vision* (2) *trust* (5) *Brand name* (6) *strong actor* *(15) Support Organisation*

To answer the sub-question of which factors, identified by researchers, influence the development of clusters. Where the research of Klofsten focusses on the Anchor Organisation, or cluster initiative, i.e. the leading organisation of the cluster, is the work of both Gagne and Tavasalli more applicable to the cluster as a whole. Summarizing all the discussed variables in the following categories:

1. Access to human capital (talent, pre-existing knowledge transfer, skilled workforce and innovation & R&D capacity)
2. Access to investment capital (Government support, risk capital, and Business Support Organisations)
3. Access to physical capital (physical infrastructure, geographical proximity, growing company base)
4. Access to social capital (networking, personal proximity, entrepreneurship and external links/knowledge sources)
5. The role of the cluster initiative/facilitator. (idea, driving forces and commitment, activities, critical mass, organisation)

3 Methodology section

The following section discusses the set-up of this study. Firstly, the research design is discussed, followed by the used research instruments. Thirdly, concerns regarding the reliability and validity are discussed, followed by the selection of participants. Ending the methodology section with an outline of how the data is analysed.

3.1 Research Design

The aim of this research is to create an understanding of the structure of the cluster. Moreover, this research aims to identify how cluster actors perceive factors associated with cluster growth and development. To gather these insights, a qualitative approach is considered as the most suitable approach. Qualitative research is known for its rich, in-depth data collection (Gehman et al., 2018). Providing opportunities for the researcher to dive deeper into given answers and gain a deeper understanding of the researched phenomena.

Moreover, since this study focusses on a specific cluster (with clear geographical boundaries), a qualitative research approach in the form of a case study captures the research goals best. As multiple authors state (Gehman et al., 2018; Stake, 1995; Yin, 1981), case studies provided a holistic view of the researched phenomenon. Cases are unique, and complex entities that cannot be reduced to one variable or perspective. Stake (1995) advocates the naturalistic inquiry of case studies, which involves studying the case in their natural setting, capturing real-life experiences. Stake (1995) argues also that researchers should aim for in-depth, contextually rich descriptions of the case. Next to this, Stake (1995) argues that multiple perspectives should be explored when conducting a case study. Understanding the diversity of perspectives could contribute to a comprehensive analysis of the cluster.

As Gehman et al (2018) discuss in their paper, building theory from case studies relies on inductive grounded theory building. *"Theory building from cases is centered on theory that is testable, generalizable, logically coherent, and empirically valid. Its particularly useful for answering "how" questions, may be either normative or descriptive, and either process (i.e., focused on similarity) or variance based" […] "Researchers basically walk in the door and don't have a preconception of what relationships they-re going to see. They may have a guess about*

the construct but are fundamentally going in open-minded" […] "A case study is a rich empirical instance of some phenomenon, typically using multiple data sources. A case can be about a group or an organization." (Gehman et al., 2018, p. 287).

3.2 Research Instruments

To gather data, semi-structured interviews were chosen to be the most suitable choice. Semi-structured interviews are specifically useful in certain research situations. More specifically, open-ended questions and independent thoughts of individuals in a specific group are needed to gain insights (Adams, 2015). Exactly this strategy was required to gain insight into the researched phenomena.

The process selection of interviewees was also important (Adams, 2015). Interviewees needed to fulfil two selection criteria. Firstly, the organisation needed to be a known member of the cluster initiative or needed to be located within the geographical boundaries of the cluster and active in the respected industry.
Secondly, the interviewee needed to be familiar with the cluster and industry. CEO's and managerial directors often have a clear view of the meso-environment of the organisation, in this case, the cluster and other organisations in the geographical proximity of the organisation. Therefore, only decision-makers in the organisation were contacted and interviewed.

The formulated research questions are based on the work of Gagné et al. (2010); Klofsten et al. (2015); Peppard & Rylander (2006); Tavassoli & Tsagdis (2014). Consisting of the five formulated categories regarding the factors, next to questions aimed at creating insight in the value network (see TB). Appendix 1 consists of the interview guide.
The interview was structured in the following matter. First, the researcher introduced himself and provided background information on the topic and the reason for the research, whilst also emphasizing the anonymity of the respondent was secured. Ending the introduction with a formal request for recording. After this consent, the recording was started after which the interviewee was asked to introduce him- or herself, the role in the organisation and a general introduction of the organisation, its service/product and markets. This gave an insight into where the organisation could be placed in the value chain, and in the value network. Following

this part of the interview, the success factors were discussed divided over five categories (Human Capital, Social Capital, Physical Capital Financial Capital and the Cluster Initiative).

Given the semi-structured nature of the interviews, interview topics were discussed in various ways. A respondent could for example bring up the topic of talent, after which the interview moved towards the human capital element of the cluster. Meanwhile, in the interview guide it could be the case that this topic was structured for later in the interview.
Having this interview strategy, allowed the researcher to gather sufficient data through a semi-structured manner. Interviews lasted approximately 45 to 60 minutes.

3.3 Reliability and Validity

The reliability of the data was ensured with a background check of the interviewees. These needed to fulfil the selection criteria. Given their positions within their respected firms, interviewees were able to provide the researcher with reliable data.
Validity was ensured by discussing the same topics with each interviewee. Given the semi-structured nature of the interviews, interviews might have followed a different structure, but the researcher made sure that all topics were addressed. By having multiple perspectives on the same subject validity of the research is ensured.
As, Corbin and Strawn (1990) state in their article there is no fixed number of participants when conducting qualitative research. Saturation is a phenomenon where no new data is collected, and participants start to give information which is already familiar with the researcher. For this research, the number of interviews was not fixed. Yet, the researcher realised after fifteen (15) interviews that data saturation occurred, after which the data collection phase ended.

3.4 Participants

As mentioned, participants were selected based on 2 selection criteria. Two online sources were addressed to identify potential participants: a member overview from HighTechNL and ChipTech Twente. HightechNL is a Dutch nationwide initiative bringing together multiple business clusters over 4 different high-tech industries, that of Robotics, Semiconductors, Life Sciences and Energy, it acts as a network organisation and aims to strengthening the position of these industries in the Netherlands and Europe (*Ledenlijst | High Tech NL*, 2024). As a

selection criterion, only companies located in the region of Twente and members of the Semiconductor cluster were contacted. ChipTech Twente, is known as the cluster initiative for the cluster under research. All companies who are a member of ChipTech Twente, therefore fit the selection criteria and where contacted. Through LinkedIn and company websites CEO's and managing directors were identified and contacted via either LinkedIn or mail. To ensure the anonymity of the participants a unique identifier is connected to the corresponding transcript after the completion of the interview. Table 2, shows relevant information of the participant. ChipTech Twente divides the cluster into four categories: Chip Design, Chip Applications, Research Organisations, and Support Organisations. The researcher chose to interview participants active in all four categories to create broad perspective on the cluster, with the aim to lower the chance of potential biases.

Table 1 Overview of participants

Company Category	Company Name	Role of interviewee	Identifier
Chip Design	QBayLogic	CEO	CD-1
Chip Design	Bruco Integraded	Senior Business Dev.	CD-2
Chip Design	Epiphany	CEO	CD-3
Support Organisation	ChipTech Twente	Program manager	SO-1
Support Organisation	OostNL	Business Dev. Tech, Photonics Business Dev. Semicon	SO-2
Support Organisation	New Origin	CEO	SO-3
Support Organisation	Novel-T	Finance Expert	SO-4
Support Organisation	UT Holding	Senior lawyer	SO-5
Chip Application	MedSpray	CEO	CA-1
Chip Application	QMicro	Managing Director	CA-2
Chip Application	SuperLight Photonics	CEO	CA-3

Chip Application	PHIX	CEO	CA-4
Chip Application	Eurofins/Maser	COO	CA-5
Research Organisation	MESA+	Scientific Director	RO-1
Research Organisation	MESA+	Business Director	RO-2

As discussed, data was collected through semi-structured interviews, therefore providing primary data. Having this inductive approach is also bound to several biases. Participants could be biased because of a certain role they have within a company or more specifically the cluster. Also, conformation bias, known for the search for a conformation of already known information is something the researcher took into account. This was specifically important during data collection to take in account. The researcher tried to overcome these possible biases by keeping an open-minded attitude during the interviews and a continuous realisation of the role the participant has within the cluster and organisation.

3.5 Data Analysis

To collect and analyse the data the grounded theory was used. This theory allowed the researcher to already start analysing collected data after the first interview (Corbin & Strauss, 1990). Throughout the coding process, new data was continually compared to existing codes and categories. The outcome of Grounded Theory research is the development of a theoretical framework that explains the phenomenon under study. Grounded theory is useful for exploring and explaining complex social phenomena because it allows researchers to build theories directly from empirical data rather than relying on preconceived notions or established theories (Corbin & Strauss, 1990).

Collected data was analysed through the Gioia-method. This method consists of multiple steps. Firstly, out of the data first-order codes are retrieved. These first-order codes were transferred into second-order themes, these second-order themes were categorized into aggregated dimensions. (Gioia et al., 2013).

First-order codes are the initial codes that researchers assign to segments of the collected texts in the transcripts. They serve the label and describe specific content within the text. First-order

codes are typically descriptive and represent the most basic level of analysis. First-order codes are used to identify and categorize elements of the text that are relevant to the research question and objectives (Gioia et al., 2013).
Second-order themes, also known as axial codes or second-level codes, are used to create a more structured and systematic way of organising the first-order codes into broader categories or themes. In essence, the second-order themes help to provide a conceptual framework for understanding the data by grouping related first-order codes together. Themes are more abstract and theoretical and therefore contribute to the explanation of the researched phenomena. (Gioia et al., 2013).

To analyse the data software was used. The usages of software provided multiple advantages for the researcher. The software-package (ATLASS.ti) enabled the researcher to analyse transcripts faster and more structured. Transcripts are uploaded into the software-program, after which the software was able to detect patterns in the data. Using software provided a more structured way of analysing data, also preventing the researcher from making mistakes when analysing data manually. However, during data analysis the researcher made the decision to also include Excel when analysing the data. Excel eventually was the foundation of the created Gioia-structures, as the software package allowed the researcher to 'easily' copy the codes out of the transcripts. Atlass.ti was used as a first step in the analysis to identify common quotes within the fifteen transcripts.

The following section, consisting of the results, contains the three deliverables. Firstly, the regional value chain will be described. Providing an understanding of how the regional value chain is build up. Secondly, the value network is described. Here, the three variables of the value network are described and mapped out. Moreover, strong points and missing elements within the network were derived from the data and are described as well. Third, and finally potential barriers are discussed, potentially influencing the development of the cluster. Thereby providing the findings to answer the main research question of *how is the high-tech, chip-related cluster in the region of Twente structured and what are the potential barriers in the development of this cluster?*

4 Results

The following section outlines the results regarding the research question of *how is the high-tech, chip-related cluster in the region of Twente structured and what are the potential barriers in the development of this cluster?* and consists of three elements; 1) the regional value chain, 2) the value network of the cluster and 3) identified barriers regarding cluster development. The first two elements are intertwined so that, to create a better understanding of how the regional value network is built up, the regional value chain is described first. Both elements help to create an overview of how the cluster is structured. Lastly, the third part of this section describes 4 barriers identified during data collection influencing the development of the cluster, thereby providing results for the second part of the research question.

4.1 Deliverable 1: The Regional Value Chain

The value chain of semiconductors, or microchips, is one of the most complex chains in the world. As a participant stated: *"Whether it's the Netherlands with the ASML machine or the cobalt from an illegal mine in Ghana. If you add it all up, you're at 60 national borders, 800 process steps. It is a utopia that you can do this autonomously in one way or another. I think the crux of the matter is that you have to make sure that you are an indispensable player in the whole thing. If that interdependence exists, then there is nothing to worry about." (RO-1)* This statement describes the complex nature of the industry's value chain. Nevertheless, given this complex nature, the data showed that the regional value chain is rather uniquely structured.

Two aggregated dimensions were retrieved from the data, one outlining the conventional value chain and one outlining unique regional characteristics. The figure below outlines the first order codes that were derived from the data, leading to second order themes, that of the different verticals in the value chain and the aggregated dimension of the conventional value chain.

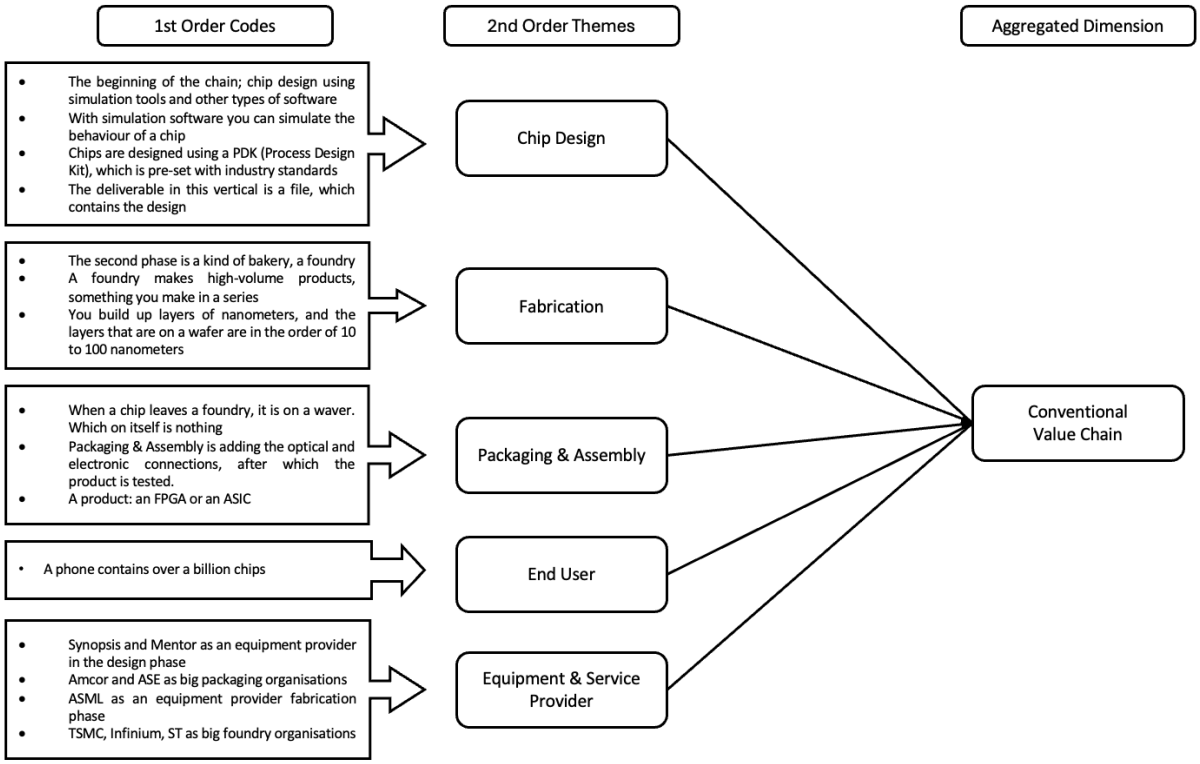


Figure 3 Aggregated Dimension of the Conventional Value Chain

The regional value chain on the other hand differs in a couple of aspects from the general industry's value chain. Participants provided a clear overview, each from their perspective and organisational background. Where the general value chain of the industry often is described in four (4) phases (design, fabrication, packaging & assembly, end user), does the regional value chain of Twente consist of six (6) phases (research, design, testing & prototyping, fabrication, packaging & assembly, end user). This finding is based on an aggregated dimension where regional characteristics impact the regional value chain. The following data structure outlines this finding.

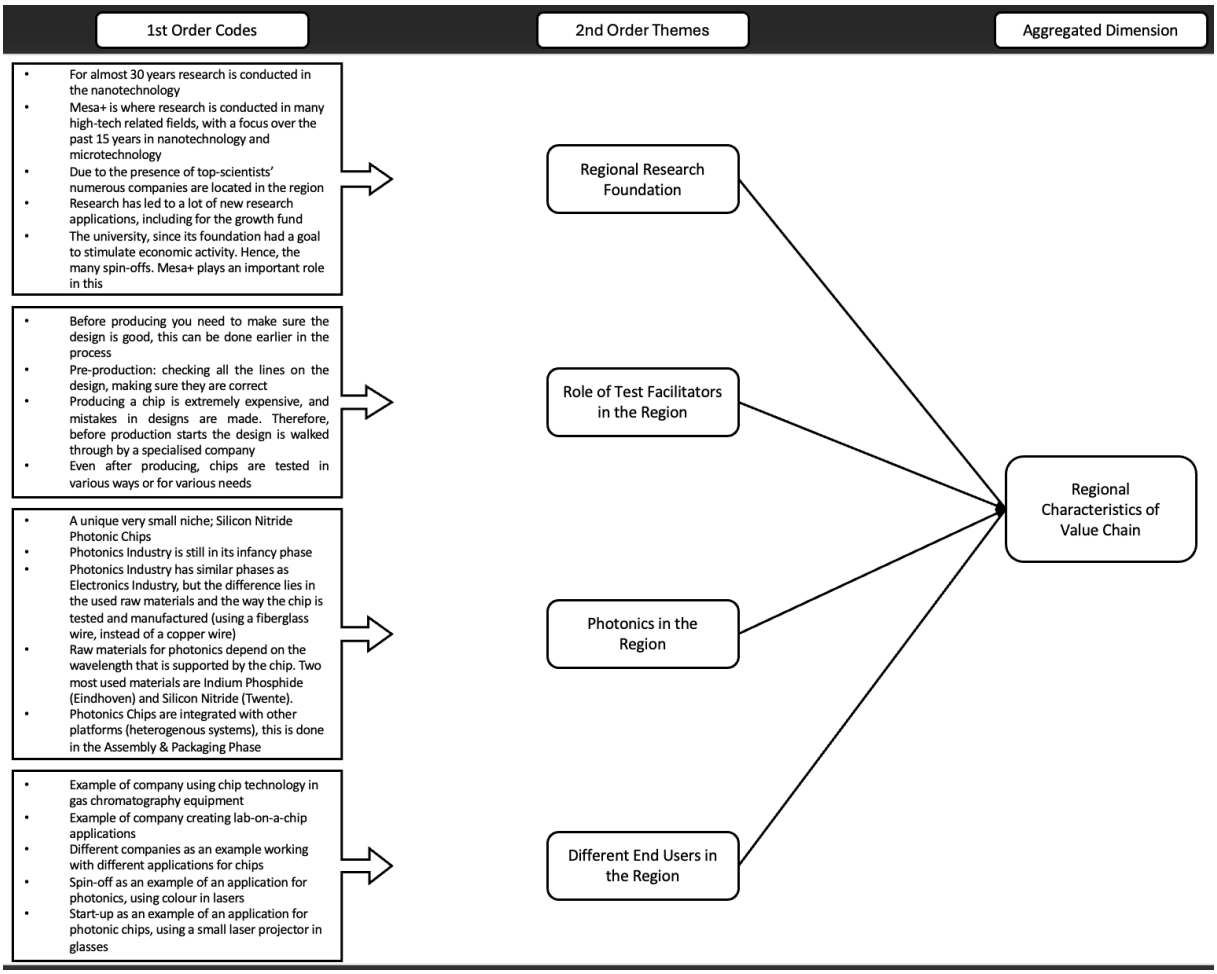
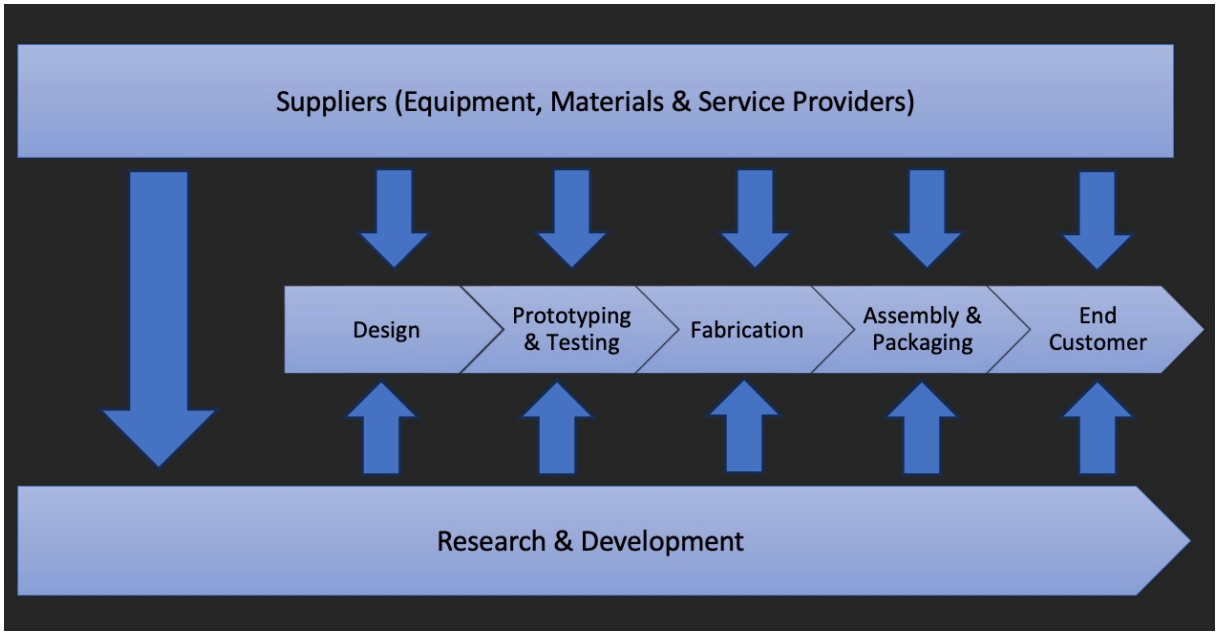


Figure 4 Aggregated Dimension of Regional Characteristics of Value Chain

The difference in the regional value chain, compared to the conventional chain is due to the role of the university, where there is a strong fundament of high valued and respected researchers. This vertical in the value chain has influenced the development of the regional value network severely. Since many organisations (start-ups/spin-offs) find their origin within one of the research groups active at the university. Next to this, by having a strong representation of researchers, organisations choose to locate themselves in the geographical proximity of the university, more specifically some test facilitators. The figure (Figure 5) below outlines the regional value chain. Moreover, due to the presence of the university a niche within the industry developed itself, that of photonics. Also, by the presence of test facilitators a new, regional, vertical occurred where chips can be tested prior to the fabrication phase. This all, led to the following figure in which the regional value chain is portrayed.

Figure 5 Regional Value Chain Twente based on data analysis



4.1.1 Research & Development

The cluster finds its origin at the university. As one participant stated regarding the emergence of the cluster: *"You can see that we are very well known in the Netherlands and abroad in areas mainly about new materials, new nanotechnology for those areas that I have just mentioned: quantum, photonics, batteries, and so on. Well, a by-catch is that for almost 30 years, but certainly in the last 20 years, a lot of IP and know-how has emerged from that research. This has also led to the creation of small businesses. Consider, for example, Micronit, which is a larger company, Lionix, but there are dozens more. These companies first produced in the same research environment. So, they hired that cleanroom equipment for their small-scale production." (RO-1)* Many spin-offs active in the sector are still located in the region and some developed themselves into established organisations, yet the scale of these organisations remains SME (Small Medium Enterprises). The vertical of R&D in the value chain has linkages throughout the complete chain, from design to end users.

The regional expertise has developed over the years towards a particular platform for a specific type of chip called photonic chips, the expertise concentrates on the usage of a specific raw material called silicium nitride. Especially within this niche the region is strong and continues to develop itself. Resulting in spin-offs active in multiple verticals of the value chain and even a vertically integrated spin-off (active across the whole value chain), using the technology.

It is important to distinguish this niche from the conventional electronic semiconductor industry, since it is still rather small scale compared to the electronic chip sector, moreover the production differs as well. Yet, the value chain of photonics in terms of verticals remains similar to that of electronics.

4.1.2 Electronics versus Photonics

Regarding photonic chips and the difference compared to conventional, electronic chips, one participant explained: *"Photonic chips, that's a bit of a new lead on the tree because photonic chips, they are 'baked' in a slightly different way. We need slightly different raw materials for that. Assembly and test as well, if you attach copper wire to it, it's just somewhat different than attaching a fibre optic to it. It's a little bit different when you have to test electronics. You test it slightly differently than photonics. But the whole process and also the underlying ideas in the technology that goes with it, that's pretty similar and it's still a bit like the 4 steps." (CA-3)* When the industry of microchips and semiconductors is discussed, many then refer to electronic chips. These are the conventional chips. Over the years different ways of producing chips and types of chips have been researched, where the region of Twente developed an expertise in the field of photonic chips and different applications with the technology.

The biggest difference between electronic chips and photonic chips is the way data is transferred. In essence to only function of a chip is to transfer data. Electronic chips use a little copper wire to transfer data, whilst photonic chips use a little fibreglass wire. Electronic chips transfer data through an electronic signal, contrarily photonic chips use light to transfer data. The upside of this method is that more data can be transferred in a more energy-efficient way. The downside is that it is more expensive to produce a photonic chip, since the industry at this stage is still in its infancy. There are two main avenues within the photonics industry referring to the used raw materials: Silicium Nitride and Indium Phosphide.

The Netherlands in general has a lot of expertise on both avenues, yet this is not concentrated in one region alone. The region of Twente has expertise regarding Silicium Nitride, whilst the region of Eindhoven has expertise regarding Indium Phosphide. These two different raw materials are used for two different applications within industries and require different platforms. As one participant explained: "So *light has different colours, and the colours you can make with indium phosphide are more suitable for telecom and datacom. So, everything*

that is in a data centre, goes as light on a fibre. And the nitride, which is a bit wider, also supports/sends coarser wavelengths/colours of light. For example, it can be used for sensing, or for microfluidics, it can be used in medical sensors, and next to this also for AR (Augmented Reality). So, for visible light" (CD-3) So, the expertise of Twente, Silicium Nitride more suitable for medical applications, microfluidics or AR, to name a few examples.

Where the semiconductor industry developed itself into one of the most efficient industries of the world, is the avenue of photonics still in its infancy. One participant viewed the industry as followed: *"I actually think it's more like an offshoot of the industry and I have to say, like that whole industry is now. Right now, it's pretty artisanal. Actually, it reminds me of how the chip industry was say 30 years ago. The atmosphere is also very friendly. Companies help each other out and move forward. Everybody knows everybody knows. An awful lot of money goes into it, without there being any real, real understanding of how that is commercially justifiable. Brussels is also one culprit in this, they just pump a lot of money into it and then we'll see where we end up. Well that doesn't quite do it justice though. (CA-3)* The specific stage of photonics in the industry's life cycle therefore needs to be taken in account carefully, when discussing the value chain and network. As many firms active in this niche remain small and given its complex nature it could take years to grow into a mature industry niche.

Moreover, since the main actors in the global value chain are industry giants who invest billions of euros into production processes, it will take time to see a change in their business model. This explains why the photonics industry remains rather small scale in the global context. Currently, these giants (mainly Intel, Samsung, TSMC) are investing in the next generation of electronic chips who are even smaller (5 to 7 nanometres). Therefore, severe investments by industry for the photonics industry will not occur in the near future. Yet, this offspring remains important for the region.

4.1.3 Chip Design

R&D is the foundation for every product, yet the first stage of chip production starts with the design phase. These chip designers design chips using industry-standardized software packages called PDKs (Process Design Kits). In essence, they draw the lines and simulate how the chip behaves. Chip designers are service providers, often working for ODM's (Original

Device Manufacturer), OEM's (Original Equipment Manufacturer) or other types of end users, for example Apple or Google. As a product, they deliver a file which contains the design of the chip. One interviewee, active in the design vertical described the niche as follows: *"What we also do is complete IC (Integrated Circuit) designs, we do that for IDMs too. So, for example, an NXP or an Nexperia asks if we can develop a chip for them, because they don't have enough man-capacity, but that actually means that we do the design in the customer's particular process and we actually do the design file, which is just a, yes is just a file. It's not hardware, but it's actually software. We then deliver these as deliverables to our customers, because they can produce large or high volumes themselves, they often also do the Fab processing or the Assembly test themselves. Everything that is the backend, they do it all themselves". (CD-2)*
The region contains a concentration of chip designers, around 15 companies in the region are active in this vertical. Yet, every chip design house has its own expertise. Some design ASICS, some design MEMS and some design FPGA. Each representing a different type of chip, and all require different techniques and expertise.

4.1.4 Testing & Prototyping

The second step in the 'regular' value chain is fabrication. Yet, in the region different test houses are located. From the interviews it was clear that a unique vertical in the regional value chain occurred, the one related to testing between design and fabrication.
A participant who is active in the testing niche stated: *"We are in the service business, we don't make anything, we only provide services. We also got into the ChipTech cluster because we play a role in the ecosystem, both pre-production (because before you can make a wafer to produce a chip, you have to be sure that the design is good; we can test that in advance). Before 10 million are produced, or maybe in Enschede 50 or 60 thousand, then you already have starting capital before you can start (in large numbers it is 1 or 2 million, and here in Enschede you have to think about half a million). Then you've invested half a million to make 10,000 exactly the same chips, but if there's a mistake in it, you can throw away the chip and you've thrown away half a million. That's a waste of money and it's really happening. That they do it and then they find out that they have made a mistake, that they have forgotten a line somewhere. And really, then they can throw it away and they can start over. So in the ecosystem, we are also important in advance, and we now think that it is wise for companies to start testing much earlier in the process and that how we can test can be taken into*

account." (CA-5) By having these possibilities in the region a 'new' vertical in the regional value chain is created, since its facilities and opportunities are there to test between design and fabrication. A unique characteristic to this region.

4.1.5 Fabrication

The next phase in the value chain is production. When a design is approved, it is sent to a foundry. Explained by an interviewee, referring to the traditional value chain: "*The second phase is a kind of bakery, a foundry. I think the most famous chip producer of this world is TSMC, but also Intel and Samsung make a lot of chips. Well, these are very complicated processes, also very complicated ovens and ASML is kind of the only one that can build those ovens. Well, not the ovens, but speaking in parallel." (CA-3)* In a foundry, the design is etched on a silicon wafer. This wafer consists of billions of transistors.

To give a perspective on the scale, one participant explained: *"What you do is you build up layers of a few nanometers. Well, what is a nanometer? If you pull a hair out of your head, you have the thickness of a hair. That's as much as 30,000 nanometers. So, 30,000 nanometers go into one hair. And the layers that are on such a wafer are, in the order of 10 to 100 nanometers. So, you can put a lot of layers on top of each other." (RO-2)* When the wafer leaves the foundry, it is transported to Assembly and Packaging companies who create a working product out of the wafer.

In the region there are a few foundries, yet these are rather small-scale plants or exclusive to certain organisations. One organisation, linked to the university manages the biggest fabrication plant in the region. This facility, known as the Nanolab, is used for both R&D and small-scale production, which creates a tension field between researchers linked to the university and companies who are reliable on certain standards and are using the facility for their own needs. An interviewee explained the role of the Nanolab as followed: *"Actually, what you do in the NanoLab is fundamental research. The moment you think you have something that you can bring to a product, then you start making a prototype, then you need a pilot line to see if you can scale it up, and if you really start production, then you're working on commercial things. That commercial business doesn't really belong to a research facility at the university. Only we have a number of companies that started in this way from fundamental*

research and that have grown. They also came into being. They are now running production on that same line within the research institute and that's where it bottlenecks because then you get that research and commerce are on the same line and that conflicts. In addition, the demand became so high that it is at the expense of research opportunities, so there has to be a commercial production facility to normalize the process and also for the companies to be able to grow and produce." (SO-1) So although a research and production facility is located in the region, therefore being present as a vertical in the regional value chain, conflicts of interests occur in the same physical environment.

4.1.6 Assembly & Packaging

Assembly & Packaging, also known as Assembly and Testing (ASAT) in the 'regular' value chain or Packaging and Testing, is the phase in which transistors on the wafer are transformed into a working chip. As one interviewee explained: *"The so-called Packaging Companies, they make a chip. They make the chip that has connections on it. Let me put it this way, because when a chip comes from the factory, a foundry. Is it a flat thing without any wires or fibres attached, and then you can't really do anything with that. It would be very fragile, wouldn't it? A packaging company puts it in a 'box'. The next phase is the so-called test phase and the last two, they are sometimes taken together then they are called ASAT (assembly and test)." (CA-3)* This phase often entails prototyping, so small batches are produced, assembled and tested before the chips are turned into mass production. In the region there is an assembly & packaging company which focusses on photonic chips. This company was a spin-off of another company in the region, also focussing on photonic chips.

4.1.7 End User

When the chip is assembled and packaged, it is incorporated into a working product. In today's world chips are integrated into almost every product, ranging from bread toasters and fridges to cars and smartphones to 5G connectivity to F-35's fighter jets. However, end users in the region are active in very ranging industries, from mobile gas analysers to spray nozzles and from needles to lab-on-a-chip applications. Even though these are end users, they remain relatively small scale, and SME. In recent years, some promising spin-offs (perceived by regional actors as high potentials) initiated, yet as with any start-up, its success remains rather uncertain.

Whilst the vertical of production is represented in the region, it remains rather small-scale focussed. Regional end users who do produce a product often have production elsewhere, as one explained: *"The NanoLab is of no use to us for upscaling. We cannot rely on the quality system. We have no control over the equipment. We have no control over the service. We are ISO (….) certified, which means that we do our production somewhere else. We have a foundry in Germany that produces all the chips for us, and we develop them ourselves here in NanoLab. So basically, the recipe, the Coca-Cola recipe, how you come up with a product, which in our case are all a bit different. That expertise lies with (Company Name), and it is developed locally. And then the transition to a single design, which is mass-produced, that's up to the foundry." (CA-1)*

4.1.8 Suppliers

The final node in the value chain is that of suppliers. As each vertical in the value chain relies on suppliers, these suppliers are specialised in materials, machinery and services. Well-known suppliers are for example ASML, providing machinery to print chips on wafers to foundries such as TSMC, and Synopsys the largest supplier of design software used by chip designers. The region has a couple of these suppliers. Yet, these suppliers remain rather externally focused, focussed on supplying big organisations such as ASML, NXP and BESI, often integrated into the ecosystems of these companies. As one participant stated: *"Although ASML is located in Eindhoven, Veldhoven, a large part of their technology comes from this region. Demcon is a major supplier of ASML, as is VDL ETG. ASML is interested in some technologies from some startups here. So it would be nice if such a party (like ASML) would be included in the system, I mean physically. Research groups do important research for ASML too" (SO-2)* As the quote shows, suppliers who are located in the region are not involved in the cluster, yet they are represented in the regional value chain.

4.2 Deliverable 2: Value Network of the cluster

Based on the insights gathered for the regional value chain, multiple roles were derived. Moreover, desk research helped to gather data on the regional actors in the cluster. Out of the interviews another aggregated dimension (Figure 7) was retrieved which will be presented after the map of the value network, since it outlines strong points and missing elements within the cluster.

4.2.1 The Value Network

The value network consists of three elements, that of roles, actors and activities, as explained in the theoretical background. Roles and activities are generalized; however this study is a regional representation. A total of 59 actors were derived from the desk research and interviews. These 59 actors were categorized over 10 roles, mainly based on the different verticals of deliverable 1. The table below (Table 3) outlines the regional roles, actors and activities.

Table 3 Roles, Actors & Activities of the regional cluster

Role	Actor	Activities
Knowledge Institutions	University of Twente Saxion ROC	Conducting research & providing education
Research & Production Facility	MESA+ High Tech Factory New Origin	R&D facility and small level production facility
Chip Design	Bruco Integrated QBayLogic Benchmark Epiphany (start-up) ChainIC Memsic Sencure AEMICS AxiomIC (part of Teledyne Dalsa) Axign (part of Monolithic Power Systems) IotM (part of Bosch) 3T (part of Kendrion) Dizain-Sync (part of Bruco) Dialog Semiconductors (part of Renesas) Ansem (part of Cyient LTD)	Service providers. Designing chips for different niches and applications (FPGA, MEMS, ASICs, RF, ADC). Clients are ODMs, OEMs and other end users

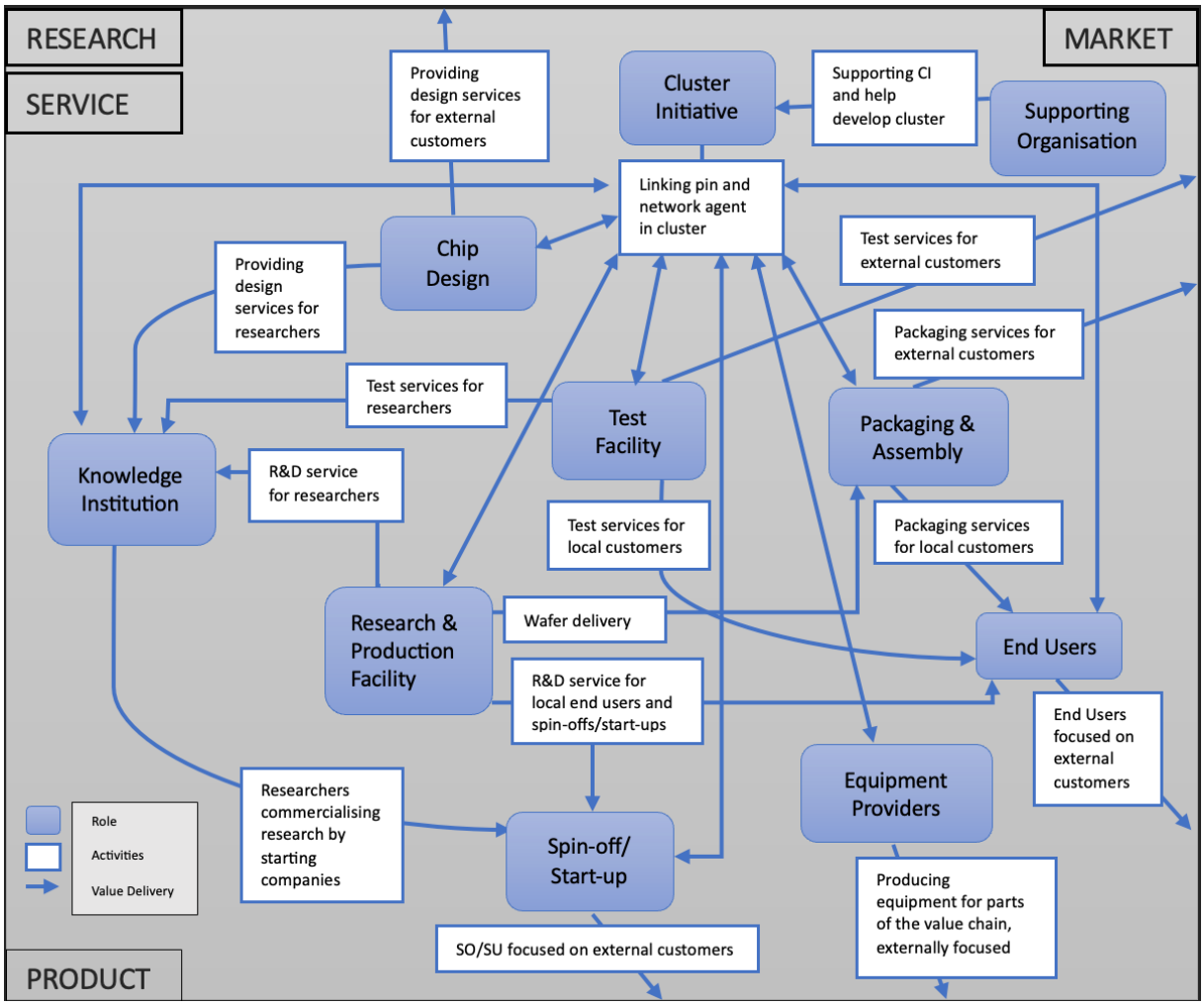
Packaging & Assembly Companies	PHIX (spin-off out of Lionix)	Service provider. Packaging and assembly of photonic chips
Testing Facilitators	Maser/Eurofins Salland Engineering NanoPhysics	Service provider. Test services (reliability, failure, analysis) for chips
End User	Medspray Uneedle Micronit Qmicro (part of Sensirion) Lionix (part of Magic Micro (South Korea) Quix (spin-off out og Lionix) Bronkhorst High-Tech Sensata Enrichtment Technology (ETC) Xsens (part of Movella) Fisic	Regional end users differ from producing photonic chips to mobile gas analysers using nanotechnology
Equipment Providers	Demcon VDL ETG Solmates (part of LAM Research) Thales IMS Hitech Power Protection (part of Air Water Inc (Japan)) SFC Energy PhoeniX (Part of Synopsys) Brookhuis	Service and equipment providers for different phases of the value chain, from design software for photonic chips to suppliers for ASML
Spin-off/Start-up	Locsense Encytos FlowBeams Smarttip IamFluidics Superlight Photonics Brilliance Aluvia Ecsens (part of OccamDX)	Spin offs out of the UT, focussing on different products and markets. Differing next-gen lasers to lab-on-a-chip applications
Cluster Initiative	ChipTech Twente	Networking agent and linking pin in the cluster
Supporting Organisations	Twente Board Kennispark OostNL Novel-T	Supporting organisations, linked to the CI. Some companies within the cluster have direct links to supporting organisations through investments

The following map showcases the value network of the cluster. The left side of the map represents the research phase, whilst the right side represents the market phase. The upper

side of the map represents service providers, whilst the lower side of the map represents product manufactures.

The line with the arrow implies how the value of the activity is delivered. As the visual shows there is a lot of interaction with the Cluster Initiative, also there is an important role in the cluster for the Knowledge Institutions and the Research and Production Facility.

Figure 6 Value Network of the regional cluster



All in all, the value map shows the different internal linkages, and external linkages.

Commercial organisations in the cluster have almost all customers outside the region, yet there are some linkages within the region. More specifically the linkages of the packaging & assembly role, with strong ties to regional end users, and the research & production facility which operates mostly for regional actors. Moreover, the figure outlines the complex

relationships of the different roles within the network, where the cluster facilitator/initiative operates as a linking pin between all different roles.

The regional value network represents all the verticals of the value chain; however most actors operate on a small-scale which needs to be taken in account. Despite the fact that most actors in the region are operating on a small scale, it is unique that so many parts of the value chain are represented regionally. As will be discussed in the two following parts, there are a few elements of the network which can be perceived as strong points, and some elements which can be perceived as missing elements. These insights were derived from the data and are presented in the following data structure (see Figure 7).

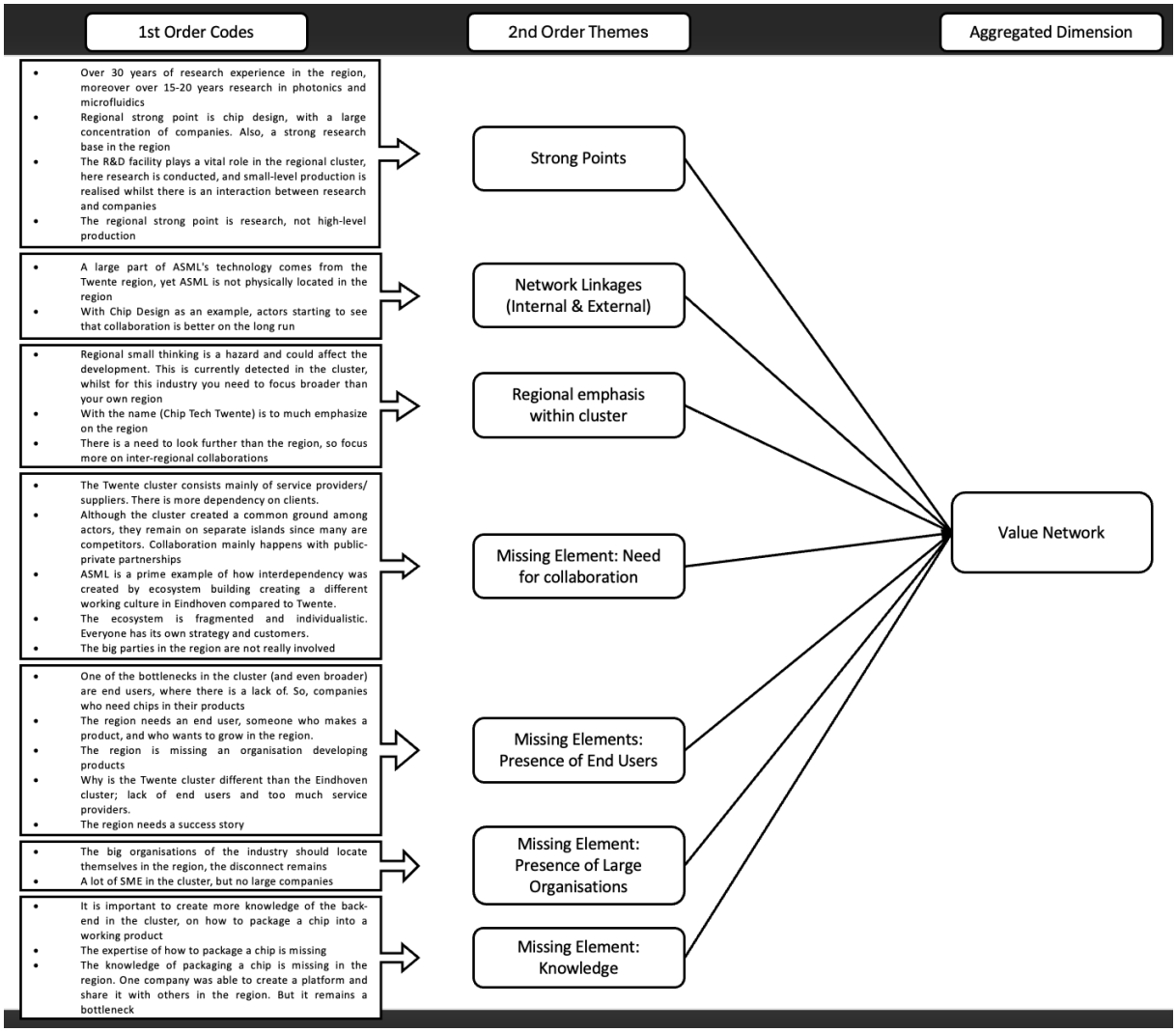


Figure 7 Aggregated Dimension of Value Network

4.2.2 Strong points of the value network

The university has a special role within the regional value network, as it is the centre of much activity. As a participant stated; *"(Name of respected professor) has been here for 30 years at this university, (Name of a respected professor) has been at this university for 30 years. We have been doing research on silicon nitride for 15 or 20 years, we have been doing research on photonics for a long time, we have been doing research in the field of microfluidics for 20 years. We have an open-access pure-play facility, and a foundry where they run production, so we have that." (RO-2*) Having this exceptional knowledge in research paved the fundament of nowadays cluster, as many spin-offs originated from the research groups. Having the necessary physical facilities to perform research and initiate small-level production also exhilarated the growing company base in the region in terms of spin-offs and start-ups and other types of companies. The best example of having this fundament in research is the concentration of chip design companies, which can be linked to one of the professors at the university who is world-renowned for his research and findings. One of his discoveries, the Nauta-switch, accelerated the developments and innovations in the industry for decades. This professor, and other renowned professors are working as a pull-factor for high-skilled talent. As was well-formulated in the following quote: *"So we're super strong in chip design. Yes, that's of course also because of (Name of the Professor), a top scientist in the field of chip design. And we have a number of companies here that do chip design, but Lionix, Micronic, Uneedle, but also a Demcon, IMS, VDL-ETG, all of which work with chip technology. That has nothing to do with chip design. Well, that's not entirely true, because Lionix is what we call a vertically integrated company, they do everything, from chip design to manufacturing. But there are definitely companies here that produce." (RO-2)* What the quote implies is that by having a top scientist present at the university, it acts as a pull factor for companies related to the field of the scientist. However, the region also consists of many other types of firms.

In conclusion, the strong research fundament at the university and the physical facilities, provided and managed by the university are unique factors in the cluster. These two factors can be perceived as major pull-factors for talent and accelerators for start-ups and spin-offs. Therefore, the university (and to a certain extent the other knowledge institutions in the region) and the research & production facility are playing a vital role in the network and influence the development of the region.

4.2.3 Missing Elements of the value network

These strong points in the network are key for the cluster, yet there are also a couple of factors who can be identified as missing elements in the network. One factor mentioned by interviewees was the lack of need for collaborations. This is explained by the fact that the majority of companies in the cluster are service providers. By being dependent on individual clients, the need to collaborate with regional actors is often perceived as not useful/needed. As one participant stated; *"It is difficult for Twente, there is no.... What, what do we have together as Twente? It's very fragmented, you have Demcon, Medical. You have 3T that works maybe half with demcon, but also his own.... They are all their own. Everyone has their own strategy and customers and that just makes it difficult, if you look at Benchmark, for example, they are not connected to the ecosystem in Twente, or to a lesser extent." (CD-2)* Moreover, participants stated that larger organisations in the region are not involved in the cluster, their collaborations with other big organisations explain this. An example of this is VDL ETG. *"If you look at how ASML has built a system, for example, then VDL ETG is responsible for all the mechanics. So they are much further down that value chain and therefore it will never be zero. So that's a whole different way of working together." (CD-2)* By not having the larger organisations in the region actively involved in the dynamics of the cluster, the tendency is that the cluster is too much SME and regionally focussed, whilst the industry has a global nature.

Another perceived missing element is the lack of end users, especially in the context of an end user being a large organisation, that could provide a vision, a leading role and work for others in the region. Contrarily, there are end users in the region nonetheless these remain relatively small-scale and inner-focussed. As one participant stated: *"That's what I think. We have a lot of SMEs here, but I don't think we have a number of very large companies here, all of which have organised their suppliers, so to speak, around them. It's automatic, and then you get a dependency. But then, people may be more willing to help each other because they both benefit from it." (RO-2)*

Not only the miss of large organisations is perceived as a missing element, more specifically the lack of end users. As stated by an interviewee; *"What we miss here in Twente is a company that has a long history of developing some products. That's kind of my analysis of the last few years and that's why it's when you hook up with a big player, you can also pull them along and you can also let them develop the roadmap and we miss that very much here in Twente, so a*

lot of initiatives have also been started by the university, for example." (CD-2) As this quote describes, a large organisation can take upon a visionary, leading role. In Twente, the larged organisation, often taking leadership and providing a vision is the university. However, this remains a knowledge institute, thereby having different priorities then regular, commercial entities.

This lack of end users can be explained by a missing element within the knowledge domain; that of how you incorporate a chip into a product. This is also known as back-end knowledge. One interviewee in particular emphasised this as a missing element in the region, he stated: *"What I've indicated is: we have a nanotechnology facility here, but no backend. And before I came here, they had the technology, which was already there. But how do you package a chip into a product that can be processed anywhere in the world. That expertise that's missing is complete here." (CA-1)* Moreover, this participant was able to help develop other companies their platform: *"I understood the whole front-end technology from my studies, so I was able to hit the nail on the head right away. Well, I've applied that a few times at companies in the area, for example (Company Name). They now produce their products on the same platform, and then I put him in hand. (Company Name), that is exactly the same. Why? Look, if you know you're going to do something with chips, then you also know that you need the expertise on how to process those chips into a scalable product. That knowledge is lacking. You should bring it here, so that anybody who has an idea can go there and say, 'How would you package that?' I could do it for anyone, I think it's a lot of fun." (CA-1)* Currently in the network there is one company who has the knowledge on how to package chips, nevertheless this company has its expertise on photonic chips, not conventional electronic chips like the interviewee pointed out.

4.2.3 Characteristics of the value network

A final remark is how many participants portrayed the regional focus of the cluster, meanwhile the industry has a global perspective. As many organisations have their customers outside the region, it is striking that the emphasis is laid on the region of Twente. As one participant stated; *“That is the Calimero thinking of Twente, which plays a very important role. Also in chip tech Twente, by all working together with companies from Twente, because then we form a base opposite of Eindhoven or something. You hear those kinds of noises and I think that's totally*

misplaced, because we need to work together much more broadly. And that's my criticism of chip tech Twente, that they are pushing forward very much with that region, while there is not a single company almost that has a customer in the region. So, you have to look much broader, but that's all that Twente Calimero thinking again, which I really detect. Of course, it is good to work together with the region, but not with the intention of building a cluster here in Twente that is independent of the rest of the world. That doesn't make sense, you have to do it on a bigger scale." (CA-4) This quote describes a regional characteristic which is not bound to this industry. Moreover, this participant was not the only one who described this regional thinking as limiting for the cluster.

4.3 Deliverable 3: Potential Barriers

As deliverable one and two outline the structure of the regional cluster, focuses the third deliverable on barriers potentially influencing the development of the cluster. Through an inductive analysis of the interviews, 4 barriers were identified. These barriers consist of talent, the role of IP, the realisation of a new foundry and the professionalisation and the cluster initiative. For each barrier variables of impact are extracted from the data. These are displayed at each barrier as an overview.

4.3.1 Barrier 1: Talent (Human Capital)

The first identified barrier focuses on a human capital issue: talent. The topic of talent was discussed by almost all respondents, and many acknowledge this as one of the biggest, and most urgent barrier to overcome. Four (4) variables of impact were retrieved from the data, with one code acknowledging the problem is generally perceived by actors.

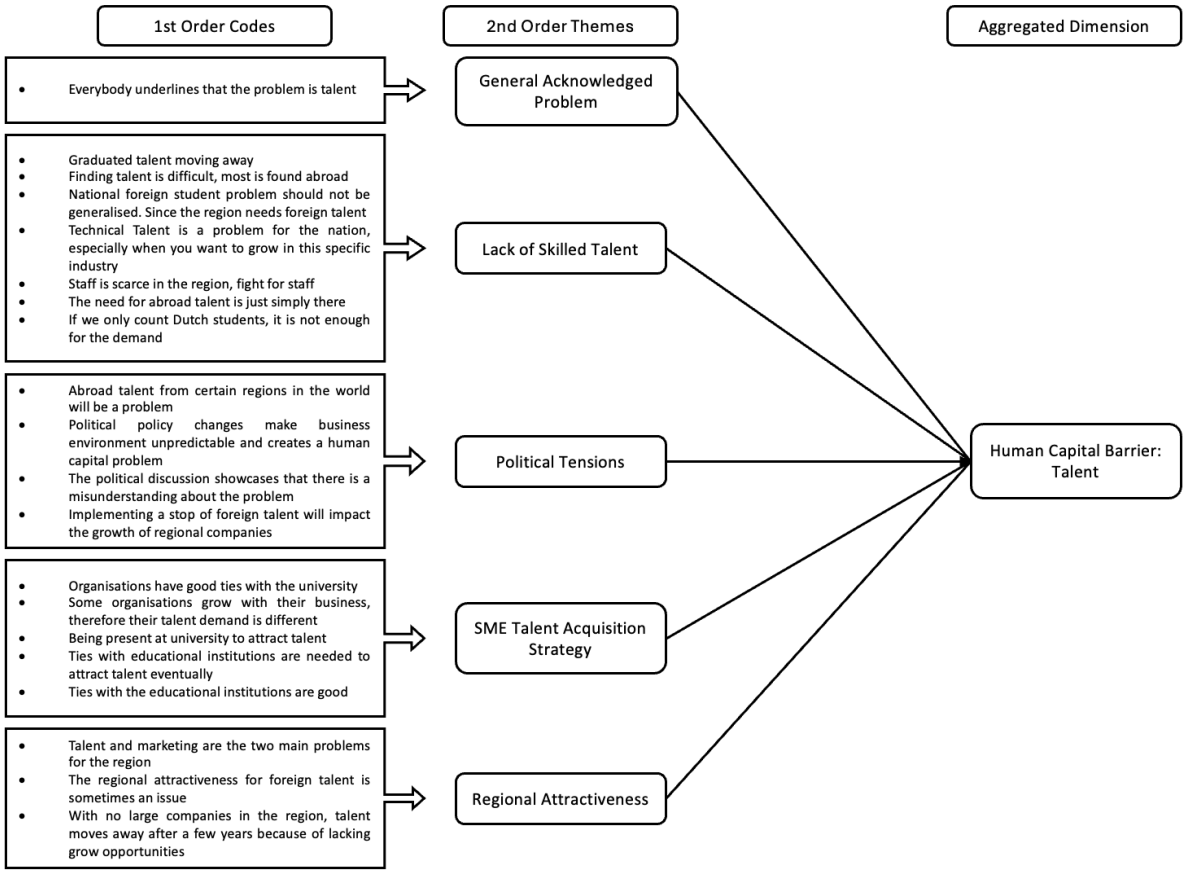


Figure 8 Aggregated Dimension of Human Capital Barrier

Human Capital is seen by most participants as the biggest barrier, both in terms of cluster development as well as firm development, as many organisations continue to grow. As a participant outlined: *"Look, I think, if you take every company you go to and ask you, what's your problem right now, everybody's going to say 'talent.'" (RO-2)* However most firms are SME, and therefore grow with their business, hiring only a handful employees each year (often graduates of the knowledge institutions), all acknowledge it is currently a fight for talent.

Some organisations, in the region with big aspirations are more outspoken on the problem since they hire more employees simultaneously. These types of organisations face major issues, for example, the amount of available talent, the competition with regional firms over the same talent and the changing attitude of the Dutch government towards foreign talent, both in terms of students as well as knowledge workers. As participants stated the human capital problem is a challenging one, since everybody wants to grow from a human capital perspective, yet the pool of people is too small. Moreover, there is uncertainty about the governmental policy towards foreign talent. As a participant stated: *"When you hear how there is discussion in the House about attracting foreign talent to the Netherlands and, for example, the abolition of the 30% ruling and all that kind of things. Then I really have the feeling that they, in the House of Representatives, don't understand how important foreign talent is for the Netherlands, because our own pool… We have to compete with companies in the United States, in China and in India. If we are only allowed to hire people from the Netherlands, then that pool is just very thin." (CA-5)* This quote highlights the current discussions in the House on downsizing the influx of foreign students and changing the 30%-tax ruling for foreign knowledge workers. For a high-tech industry, such as this industry, this potential change in policy is creating an unpredictable business environment. Resulting in organisations strategizing on potentially relocating themselves abroad. Moreover, a ban on foreign students would directly influence the development of regional organisations (and therefore the cluster). Furthermore, from an international perspective, there are certain regions and countries (e.g. Pakistan, Iran, China, India) that are not taken into account to hire/attract talent given the complicated geo-political landscape.

Besides the general lack of skilled talent and the political tensions, regional attractiveness also plays a role. Given the SME nature of the cluster and the lack of big organisations, growth

opportunities within these organisations are a paucity of. Moreover, regional attractiveness is sometimes for foreigners perceived as an issue. As a participant stated: *"Well, that's where those cultures play an important role too. Yes, and Twente is not always the region to be for a lot of foreigners. And also, that can change but then you have to have a vision of it as a region." (RO-1)* The region is perceived as rather rural, and less connected to the big cities of the country. Similarly, regional talent is moving to the West after graduation since many perceive the Randstad or the Eindhoven region as more propitious. For the regional SME this creates a challenge and during data collection it became apparent that each organisation on itself has a specific talent acquiring strategy. Which often involves building strong relationships with research departments within the university or sponsoring events for student associations.

4.3.2 Barrier 2: The role of IP

The second identified barrier focusses on the role of IP, especially in collaborating. After analysing the data, four (4) variables of impact were retrieved. These variables have a negative or a semi-negative effect on the role of IP in collaborating and are showcased in the following data structure (Figure 9).

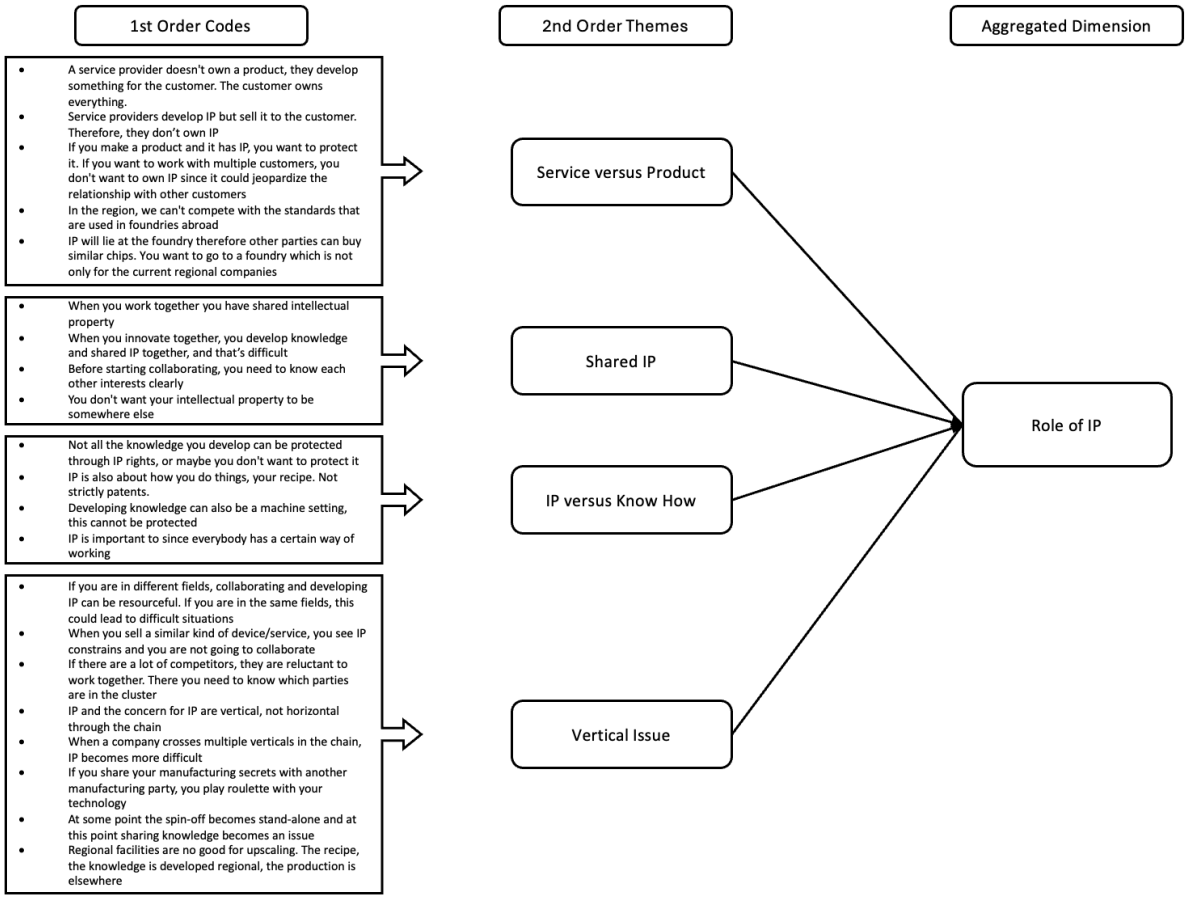


Figure 9 Aggregated Dimension of IP Barrier

IP is a key element in the industry, for many organisations IP is their 'bread and butter'. IP stands for Intellectual Property. Throughout the value chain IP is developed, yet there needs to be a distinction made between the service providers and the product developers. Service providers offer a service to the customer and want to have the possibility to work with multiple clients. Therefore, (almost) all developed IP will be owned by the client, otherwise this could jeopardise future business for the service provider. This distinction is an important factor when it comes to IP. Product developers want to own the IP on a product, whereas service providers want to sell their knowledge in terms of service. As an interviewee stated: *"We don't have our*

own products. So we have not developed something that we're going to market ourselves. We develop for a client an ASIC. That's a specific product for a customer. So that's all covered with contracts and IP clauses. And if you do that business, it automatically means that everything you develop becomes the property of the end customer. So we don't have IP." (CD-2) Regarding the cluster there is a concentration of service providers, especially in the chip design vertical. Although many have their own niche, there is still a certain reluctancy to work together.

Another important factor, and distinction needs to be made; that of IP versus Know How. As an interviewee stated: *"What is IP broadly speaking, because another category that you have, that is knowledge and there is also knowledge that you may not be able to protect. At least in intellectual property law, you rightly mention the word recipe. Not all the knowledge you develop can be protected through intellectual property rights or maybe you don't even want to protect it." (SO-5)* Especially, within the service and production industry this is the case. Many operate based on experience, by developing a modus operandi over the years. For production this could be a specific way of programming the machinery, for designing this could be a certain step-by-step guide. Undoubtedly, this has consequences for potential collaborations in the cluster. It is important to understand the playing field, and types of actors in the region. As the table of value network shows, there is a concentration of certain verticals of the chain. Moreover, SME is more reluctant to collaborate in comparison to big organisations, considering the fact that SME is more protective of their product or service.

Having a concentration of similar companies, basically competitors, in the region creates an issue. IP and the development of IP raises issues in the vertical of the value chain. A chip design company with certain unique knowledge will not collaborate with another chip design company, who is in the same vertical since there is a certain anxiety that the other party may take advantage of the other, and vice versa. This ‘vertical issue’ is across the chain. For example, regional end users who have a product are scared to work with other regional end users. As one interviewee stated: *"I just don't like working with others. I've had a few questions, for example from (Company Name), whether they could take over part of the production for us. Because they're looking for capacity. I'm just very hesitant about that. Because the moment I share my manufacturing secrets with a manufacturing party, and they come from this region, and its land grabbing instead of acknowledging and recognizing each*

other's interests. Then you just play roulette with your technology. You shouldn't do that. So I've always turned it down." (CA-1) As this statement makes clear, there is anxiety around the role of IP which complicates collaborations, and even partnerships.

Moreover, when an organisation does collaborate with another organisation, they develop shared IP. This development of shared IP often takes place in public-private partnerships when organisations work with grants. Public-private partnerships are sharply formulated therefore all parties know who owns which piece of the pie. When private organisations solely collaborate, the development of IP suddenly becomes a grey area, since it becomes unclear who discovered what, and who is entitled to what. One interviewee stated the following: *“Innovating together is indeed difficult, because I am a company. We have our own intellectual property. When I do it together, it's actually shared intellectual property, and that's difficult." (CA-2)* Therefore, in collaborations (especially on an SME scale) there remains a certain hesitancy to develop knowledge together.

The role of IP is complex. Furthermore, the characteristics of the cluster are also a complicating factor (e.g. concentration of similar, SME companies). Yet, the role of IP needs to be addressed and overcome to facilitate collaborations and enhance the development of the cluster in general. Taking the next barrier into account, the role of IP is even more underscored and urgent to tackle.

4.3.3 Barrier 3: Realisation of new Foundry

The third identified barrier is the realisation of a new foundry, focussed on photonic chips. During data collection it became clear that regional actors have the ambition to realise a new foundry. Many challenges were discussed, yet for this barrier four (4) variables of impact were derived from the data. These variables have a significant impact on the identified barrier.

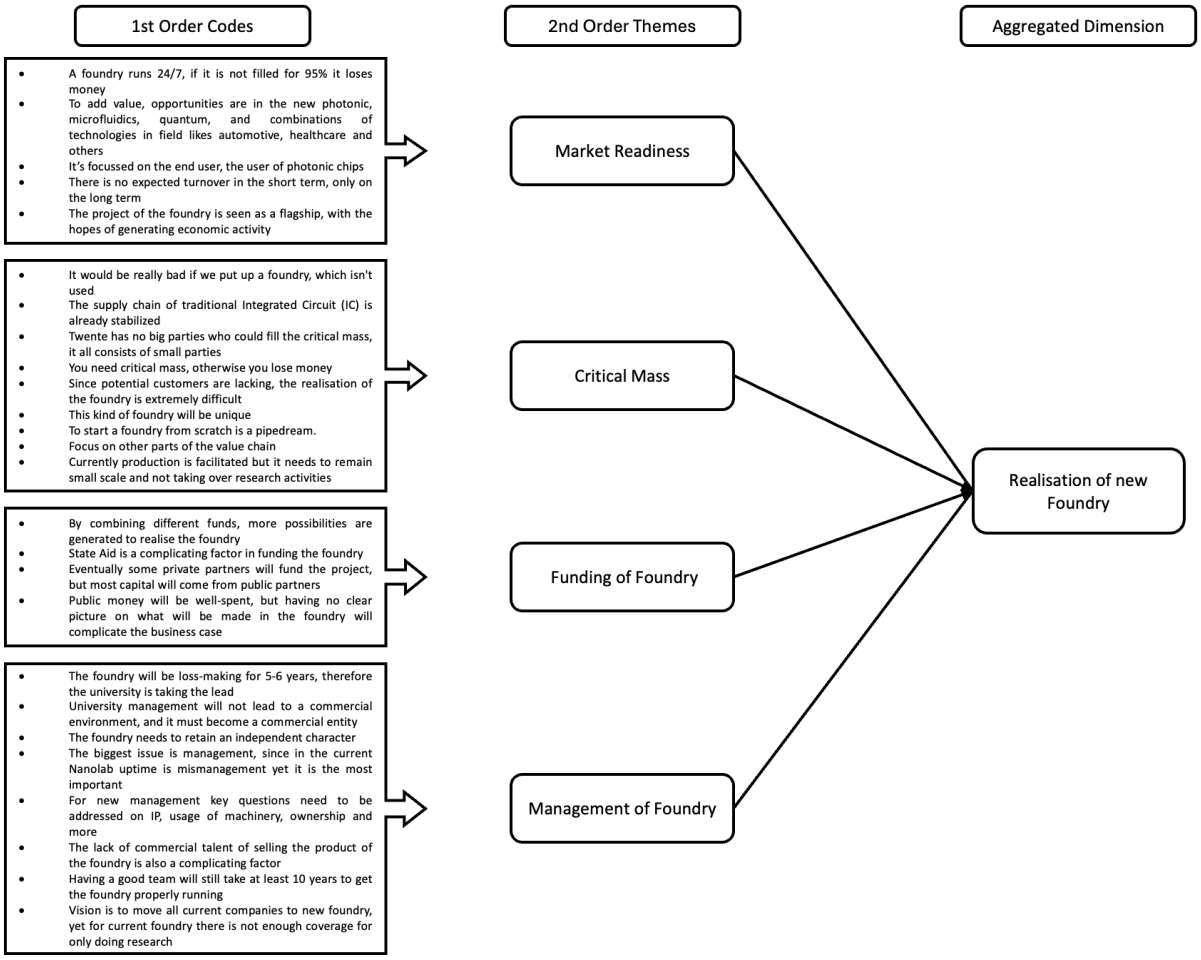


Figure 10 Aggregated Dimension of new Foundry Barrier

The call to build a new facility in the region is pushed by national (Growth-fund) and European initiatives (Chips Act). During data collection it became apparent that the topic of the new foundry, and its potential role in the cluster is a hot item. Many question the feasibility of the project. Namely companies, who pointed out that the niche that the foundry is focussing on, that of photonics, is still in its infancy phase. Moreover, interviewees acknowledged that critical mass is needed for a foundry and regional organisations are incapable of delivering this critical mass. In comparison to Germany, where in the region of Dresden currently a foundry is built by Intel and where big organisations are involved in the process. One interviewee

stated, related to the Germany foundry: *"Then parties do participate. Parties such as Bosch, which therefore form a certain guarantee for purchase. Yes, so then it's a whole ecosystem that is responsible for that and, I don't see that happening in Twente, we're just too small for that." (CA-5)*. Not having the critical mass needed to fill the foundry could have enormous impact on the project.

The university instigates on realising the foundry, meanwhile participants emphasised that this foundry should be commercially driven. A complicating factor is that the university was successful in attracting public grants, through the Growthfund. This capital needs to be spent on critical infrastructure, i.e. the current nanolab. Moreover, the current facility is managed by university-linked management. As a participant stated: *"If you let that foundry develop under the direction of the university, you won't get a commercial environment." (SO-3)*. This creates a paradox, whilst the foundry should be managed by commercial management, is the key stakeholder the university, a public entity. Moreover, even finding the proper talent is a huge challenge, given the fact that there is a small number of experts in the world who know how to manage a foundry. One participant formulated this in the following quote: *"I don't think it's very wise. And a real foundry costs a billion. And, we just don't have enough commercial talent to understand how to sell that?" (CA-5)*.

Even though, the university was successful in attracting grants, resulting in +/- 80 million in funding, building a foundry is more expensive. Given the fact that the ambition is that the foundry is commercially managed, another complicating factor is the role of state aid. Next to this, attracting private capital is challenging since the market is not there yet. A participant involved in the process stated: *"We have also laid lines and are in the process with parties that could possibly finance. But that's where it gets complicated. Before that, we first need to talk about state aid." (SO-3)*. Creating a solid business case is rather difficult, therefore, to realise this foundry first these three main barriers need to be overcome.

Key is to understand the reasoning behind the foundry. Actors reckon that the foundry could play a vital role in the cluster and ecosystem, attracting new companies. Furthermore, building infrastructure for the next generation chips could lead in the future to enormous economic growth in the region, if the technology is used on a wide scale.

The realisation of the foundry is a real barrier for the development of the cluster. Given the outspoken ambition that the facility should be commercially managed, yet the project is funded by public capital, and even for the next 5-7 years estimations are that the market is not there. On the one hand, funding to a certain extent is there, and needs to be spent. As one interviewee stated regarding the raised capital and the business case: *"If it's vague, then it's impossible, if you don't have a very clear goal with something like that, then you won't get there. But from the chiptech cluster you don't have to… if that doesn't happen, it doesn't happen, that money will end up well, eventually it will, in a certain way, flow into the chiptech, or it will flow into the nanolab. And with new machines that you say, it's not a foundry, but it's an extension of the nanolab, you can see it that way, so that's going to be fine, but you especially need people who say, how are we going to expand that chip technology here in the region. And yes, you can say that you have a new foundry, but then you also have to have a product that is going to be made in that foundry. If you don't have a high-volume product, if you don't make that, I don't know, for example that microphone chip for the iPhone here, then you don't need the organization, you don't need the building, you don't need that factory, so to speak." (CA-2)*.

In all, as the quote describes, is this barrier rather complex. Although some funding is there, ambitions are paradoxical. And by having no clear vision on the project, feasibility is in question. Yet, when this barrier is overcome. It could open up many opportunities for the industry and cluster.

4.3.4 Barrier 4: Cluster Initiative

The fourth, and final barrier derived from the data is the role of the cluster initiative. This barrier is probably the most impactful, when not overcome. During the analysis of the data, it became apparent that the role of the cluster initiative is crucial in the development of this specific cluster however there are factors potentially impacting the cluster initiative and therefore the development of the cluster. Five (5) variables of impact were derived from the data.

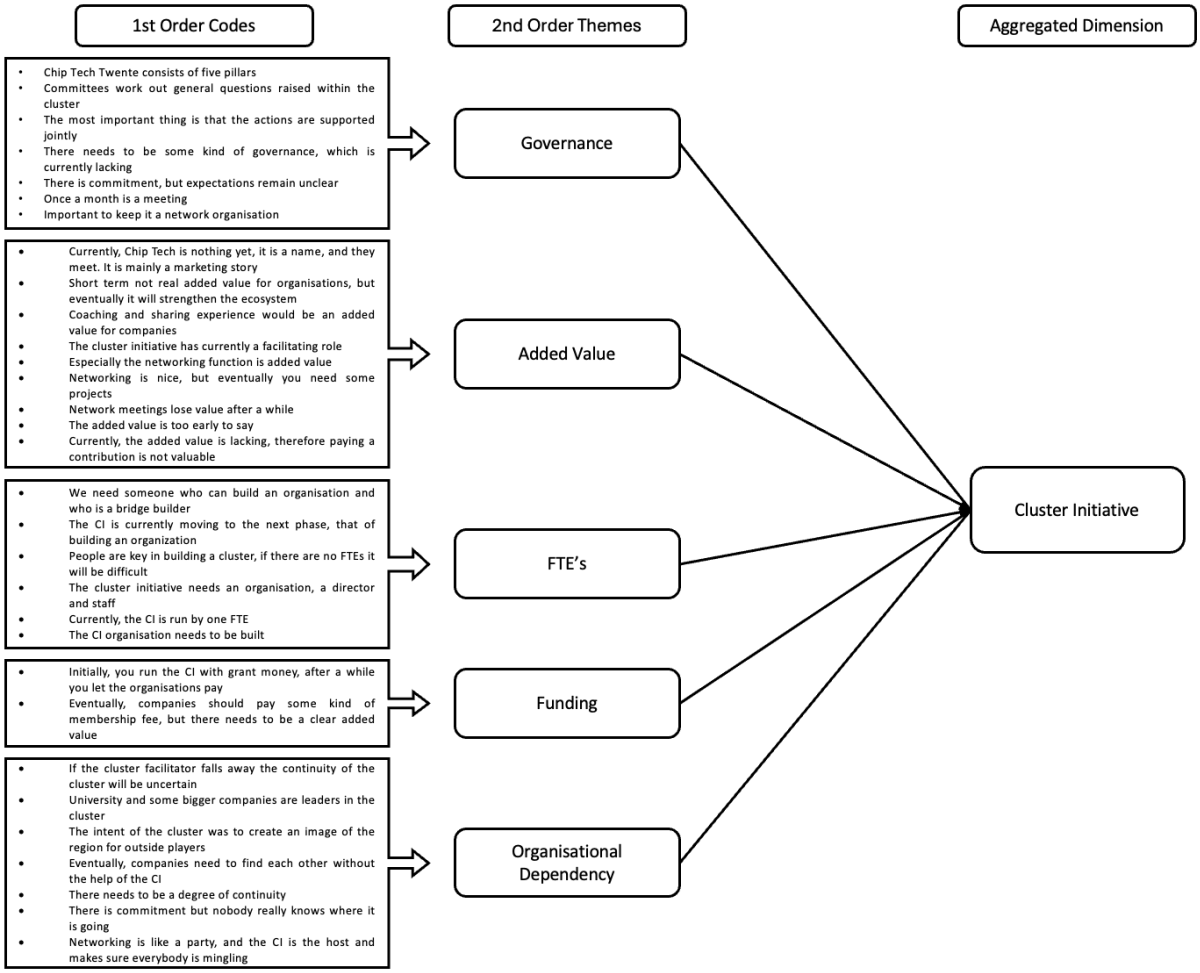


Figure 11 Aggregated Dimension Cluster Initiative Barrier

Currently, the cluster initiative is led by a single person. Although this person has created a lot of traction in the region for the cluster by initiating and organising events, connecting organisations and raising wants and needs within the respected organisations there is a need to add more personnel and build an organisation. This is acknowledged by multiple interviewees with different stakeholder backgrounds. Organisations help the cluster initiative,

nevertheless they do this in their own time. As one interviewee stated: *“What is very important is that there will soon be a leading character, so to speak, that can work on it full swing. Because we're actually kind of in a phase now where we have a core team and everyone is doing it on the side. The same goes for me. It's not my core business, but yes, I think it's very important. So you do it on the side, you don't have full swing time to be on top of it." (SO-3)* As the quote suggests, there is a need to professionalise the organisation.
The cluster initiative could be professionalised by hiring 2 to 3 FTE’s, in its current form the cluster initiative is reliable on the work of one person which brings risks. By hiring FTE’s, the continuity of the cluster initiative can be secured, and a professional organisation can be built.

The current set-up of the cluster initiative consists of five working groups, these working groups work out the wants and needs of the regional organisations, this is led by individuals within the member organisations. Yet, there remains no governance structure for this set-up as one participant stated: *"Yes, there is commitment, but what can we expect? I'm in the talent group, I'm very happy with that, and I see people with a lot of passion and energy putting time into it. But you can't say, why haven't we seen you do this and that. Because they don't have money, they don't have a mandate, there's no level of organization, there's no governance, there's nothing." (CA-5).* Therefore, stakeholders of the cluster initiative can’t govern progress and accountability is lacking. Thus, it is necessary to create a governance structure so that the cluster initiative can be professionalised, and accountability can be taken care of. Furthermore, it would create more clarity among the stakeholders on different responsibilities.

Another issue is funding. Whilst the cluster facilitator is currently subsidised with public funds, it remains uncertain if the project can continue on the mid-to-long-term. Having issues with governance, process reporting, and accountability chances are that the project could be stopped. Nonetheless, in cluster development it is known that tangible results take time, therefore it is needed to provide funding over a longer period. However, accountability is key when working with public funds. Hence, that chances are that funding for the cluster initiative will be stopped in the short to mid-term. For the cluster initiative to be privately funded the added value needs to be clear.

Although all interviewees acknowledge the role of the cluster initiative in developing the cluster is crucial, the added value is lacking. This is due to the fact that the cluster initiative is mainly organising network events, as one participant stated: *"Network meetings are very important to keep the conversation going. But if you only have network meetings, at a certain point, then the question of 'what's in it for me?' to go to such a network meeting, is answered negatively, then you no longer go." (RO-2)* The added value is paradoxical, whereas actors all acknowledge the crucial role of the cluster initiative acting as a linking pin in the region, they perceive the added value as insufficient to already pay a financial contribution. This can also be explained by the fact that most organisations outgrew the start-up phase, therefore they are less dependent on help from others.

Despite the current lacking added value, it became clear that there is a certain organisational dependency towards the cluster initiative. The cluster initiative takes the lead and connects actors, if this role fades away it is unclear who will take that leading role upon. Therefore, again creating a paradox. Organisations say they don't need the cluster initiative, lacking its added value, yet they all acknowledge the importance of the continuity of the cluster initiative. One view that actors do perceive as added value is the proposition of the cluster initiative to the 'outside' world. Were the region is propositioned as one big chip-tech hub.

5 Discussion

The following section answers the research question of: *"How is the high-tech, chip-related cluster in Twente structured and what are the potential barriers in the development of this cluster?"* First, the structure of the cluster is discussed in which the results and theory are discussed. Secondly, the identified barriers in the results section are discussed and linked to the theory, as outlined in the theoretical background. Moreover, the practical implications of this research are discussed. Ending this section with limitations of this study, future research and a conclusion.

5.1 Theoretical Implications

The results show how the different roles within the cluster are linked to each other, and how they deliver their service or product, as the figure the value map (Figure 6) clarifies. Taking a theoretical step back, taking in account the work of both Marshall and Porter (Marshall, 1920; Porter, 1998) many elements and benefits of clustering can be linked to the high-tech cluster in Twente. As Marshall defined three main benefits, i.e. access to high skilled workers, access to specialised suppliers and knowledge spillovers through collaborations, results of this study show to a certain degree all three of these benefits, some more than others.

Although one of the findings of this study is a human capital issue, that of lack of skilled talent. It remains one of the benefits identified in this cluster. In the case of the Twente cluster, access to high skilled workers is not an issue perse, it is that the demand for high skilled workers is higher than the available talent pool. Presence and access to high skilled workers, can be linked to the presence of the university. As the results showcase, the university has a rather unique position in the cluster acting as a pull factor for both talent and organisations.

Moreover, access to specialised suppliers is also an advantage this study found evidence for. As both the value chain analysis and the value network analysis show, many actors in the region deliver their service to regional actors. These services can only be delivered by specialists and as a participant mentioned, one of the reasons his organisation choose to locate themselves in the Twente region, was so because then the company would be in close proximity of its potential customers.

One key advantage, as Marshal defined, that of knowledge spillovers is lacking to a certain extent. When analysing the data, it became apparent that many regional actors are hesitant to collaborate with other regional actors. This can be explained by a couple of reasons.

1) Most organisations in the cluster are small medium enterprises. Compared to large organisations, SME is more reluctant to collaborate with others. This is due to the nature of SME since they are often scared to lose their competitive advantage when collaborating with others, one of the identified barriers is linked to this phenomenon (barrier 2: role of IP)
2) The cluster contains a concentration of companies active in a similar vertical of the value chain. Although most companies have their own niche, collaborating with (in essence) a competitor is not always advantageous.
3) Most organisations in the cluster are service providers, thereby selling their know-how. This know-how is often not protected through patents; therefore these organisations are hesitant to collaborate.
4) The regional culture. As participants described, in comparison to the region of Eindhoven, some perceive the region as being more on 'your own island'. Where in the region of Eindhoven, regional actors are more open to collaborate. However, this statement has not been further researched. Yet, cultural differences could have a potential impact on collaborations.

In conclusion to how the cluster is structed, this study was able to portray as Porter defined a geographical concentration of interconnected companies and institutions in a particular field (Porter, 1998). By first identifying the regional value chain and having an understanding of how value is converted in the industry via a step-by-step overview, thereby clarifying the interpretation of the value network. As within any cluster, some elements are lacking, and some elements are unique. This study provides insights in both missing elements, as well as strong elements, as well as creating a complete overview of the structure of the cluster.

This study also identified potential barriers potentially impacting the development of the cluster. In relation to other research regarding barriers in cluster development no overlaps were found in terms of the identified barriers in this study. Therefore, these findings are unique. However these barriers could be only applicable to the cluster under research and therefore caution is needed for the generalization of these identified barriers.

In order to link the barriers to theory, each barrier is discussed in comparison to the work of Gagné et al. (2010); Klofsten et al. (2015); Tavassoli & Tsagdis (2014). A total of 32 success factors were derived from the literature, all discussed in the theoretical background of this study. These factors were categorised into 5 categories (Human Capital, Social Capital, Physical Capital, Financial Capital and the Cluster Initiative). The identified barriers can be linked to the 4 out of 5 categories.

The barrier of talent can be linked to the human capital category. As Gagné et al. (2010) and Tavassoli & Tsagdis (2014) outline, having access to high skilled talent and having the environment in which they can strive is the core building block of any cluster to grow. By having pre-existing knowledge, innovative technology, technological transfers and networks the fundament is created to attract talent. Also, for the cluster under research is this the case. However, evidence was found that as a region it is a challenge to keep talent and attract sufficient talent to supply the demand. Regional attractiveness, perceived by foreign workers or graduates plays a role in this issue. If the cluster actors are not able to change this perceived attitude towards to region, the growth of the cluster could be jeopardized. However, the right talent is present in the region. The challenge is to keep that talent and to attract more specialised workers.

The barrier of the role of IP can be linked to the social capital category. As social capital consists of networking, external linkages and geographical proximity of firms according to Gagné et al. (2010) and Tavassoli & Tsagdis (2014). The role of IP is a factor of external linkages. Relationships and possible collaborations with other firms are part of external linkages. A cluster aims to create knowledge spillovers, this study found evidence that when organisations are active in a high-tech industry hesitancy and reluctancy play a key role in enabling collaborations, especially in regard to Intellectual Property concerns. This barrier on itself is interesting to research further, as it could have impact in high-tech clusters, active in other industries.

The barrier of the realisation of the new foundry can be linked to the physical capital category. The physical capital category is comprised of specialised training and educational infrastructure and other factors such as geographical proximity, innovation, physical

infrastructure, growing company base, pre-existing knowledge and entrepreneurship (Gagné et al., 2010; Tavassoli & Tsagdis, 2014). Although most of these factors are present in the cluster, having the needed critical physical infrastructure to provide specialised training and educational infrastructure, having a growing company base, with innovative start-ups. Is the realisation of a new foundry a potential barrier for the development of the cluster. As the barrier outlines, many factors impacting its feasibility are uncertain or unclear. However, this barrier is lacking its theoretical implications in general for the literature space, as it is only impacting the development of the cluster under research. Perhaps the role of high capital intensive projects in the development of cluster could be a topic for researchers to study its impact on cluster development. Currently, in the literature space nothing relevant was found.

The final barrier, that of the cluster initiative can be linked to the category of the same name. Variables linked to this category are the right vision, brand name, trust, strong actor, support organisation and leadership. More specifically regarding the organisation itself factors like idea, activities, critical mass, driving forces and commitment and organisation play an important role (Gagné et al., 2010a; Klofsten et al., 2015a; Tavassoli & Tsagdis, 2014). This study found evidence that in the cluster under research similar factors play a role. As the cluster initiative in the studied cluster has gathered the critical mass and commitment among its regional actors, is acting as driving force for the cluster, is organising activities and is creating an awareness by creating a brand name.

However, despite implementing many of the associated success factors, the cluster initiative is bound to some variables impacting the organisations in a negative way. Despite having an organisation, there is a need to professionalise since the cluster initiative is currently managed by a single person. As the cluster and its development is dependent on the cluster initiative it is important to add more fulltime employees to the organisation to secure continuity. Moreover, given the current structure of the organisation, governance is lacking and need to be improved. Also, funding could potentially impact the continuity of the cluster initiative as it is publicly funded in its current form. The variables who were identified as potentially harming for the cluster initiative, aren't identified by other scholars. Thereby, adding to the literature space of cluster initiatives/cluster facilitators. As it is likely that other cluster initiatives are prone to similar forces identified in this study.

All in all, although this study is a case study, many factors and variables were identified potentially influencing the development of the cluster. As the topic of clusters remains ambiguous, this study provides new insights in cluster development, and adds the literature space of regional cluster case studies.

5.2 Practical Implications

This study provides multiple implications for practitioners. Firstly, the provided overview can be used for regional policymakers to distinguish how certain goods and services flow within the regional network. Therefore, it could be used in practise to decided which areas of the value network need to be improved, and which areas are sufficiently developed. Regional policy can be developed based on the provided overview of the cluster's structure.

Moreover, regional policymakers, entrepreneurs and leaders could act upon the identified barriers and start to tackle these barriers. Each barrier asks for a different approach and strategy. The first barrier for example, could be approached from a triple helix perspective (Etzkowitz & Leydesdorff, 2000), whereas the human capital issue is not only an issue for companies, but also for other organisations such as knowledge institutions and local governments. Moreover, the human capital issue is broader then only the high-tech, chip-related companies. Nevertheless, within this industry the human capital problem remains an urgent, relevant problem as the participants of this study underscored.

Regarding the barrier of the role of IP, a general framework could be developed in collaboration with the different organisations active in the cluster. This general framework, consisting of a legal document, outlining how IP is developed when collaborating, and which elements within the collaboration are perceived as Intellectual Property, and which are perceived as Know How. Especially in the context of the cluster, it will be important to create a clear distinction between these two phenomena, as it is plausible that companies won't share their unprotected know-how.

Thirdly, the identified barrier of the realisation of the new foundry. For regional actors, this barrier could be perceived as a warning sign by regional actors and could be taking in account when debating this highly capital-intensive project. As participants showed their hesitance in

regard to the project, its feasibility should be further researched by regional policymakers, entrepreneurs and leaders. However, given the fact that most funding is provided through university linked organisations, eventually will result in the expansion of the current facilities, either via a completely new foundry or as an addition to the current nanolab. In general, this barrier is less useful for practitioners outside the cluster, as it mainly impacts the cluster under research.

Finally, the role of the cluster initiative. This barrier is perhaps the most relevant barrier for practitioners. The role of the cluster initiative within the cluster is indispensable and essential for the development of the cluster, as this study shows. However, this study provided multiple factors in regard to the cluster initiative that need to be tackled in the short term. For regional actors, such as policymakers, entrepreneurs and other relevant actors this barrier could be interpreted as a warning. This study showed the importance of the cluster initiative within the cluster and serves therefore as another example of its importance in general cluster development. Moreover, this study identified factors impacting the possible continuity of such firms, practitioners working in cluster could take these factors in account.

In conclusion, this study provides multiple insights for practitioners. As some barriers are prone to more local implications, the barriers of the cluster initiative and the role of IP could be generalized. Moreover, the value network provides insights in how the cluster is structured and how different actors interact with each other.

5.3 Limitations & Future Research

As with any study, this study also contains limitations. First, this study was conducted by a single individual. Although, supervised by experts, this remains a limitation as biases and errors could occur when analysing the data, and during data collection. Having a single person performing data analysis, errors could be made in for example transcribing the audio files or during analysis of the data. By taking time to transcribe the interviews and by discussing the progress of the analysis with supervisors the researcher tried to limit potential errors, however doing the analysis by a single person remains a possible limitation.

Another limitation is the possibility for conformation bias, although the researcher tried to remain open minded during data collection having semi-structured interviews, there will remain a possibility that certain conformation bias occurred when the different topics were discussed by the participants. Conformation bias remains a phenomenon in research which always needs to be taken in account, therefore this is noted as a potential limitation for this study.

Moreover, another limitation is the focus of this study as it potentially lacks generalizability. This study focused on one cluster, and one region particularly therefore this study is a case study. However, as with most case studies, they are difficult to generalize. In order to tackle this limitation, general variables were used (e.g. the critical success factors, the value chain model and the value network (Gagné et al., 2010; Klofsten et al., 2015; Peppard & Rylander, 2006; Tavassoli & Tsagdis, 2014)). By applying general variables in a regional context, the researcher tried to tackle this limitation.

Future research could include other clusters, by expanding the geographical boundaries. For example, by including the Eindhoven region, where ASML is located (a company with many ties to the Twente cluster) differences and overlaps could be studied.

As one of the main purposes of clustering is collaborations, one future avenue in research could be the role of regional culture in cluster collaborations. During data collection the researcher received signs from participants that the cultural differences in the region, compared to the Randstad or Eindhoven, could play a role in collaborations within the cluster.

Therefore, future research could include culture when researching dynamics of a regional cluster.

Finaly, researchers could study this cluster again in the future and research if any differences occurred compared to this study. As this study is in essence a snapshot of the cluster, it is plausible that the cluster, its structure, perceived barriers, actors, roles and activities change over time. A longitudinal study of the high-tech chip-related cluster could therefore be an interesting topic for other researchers to conduct.

5.4 Conclusion

In conclusion, this study provides a comprehensive description of a regional high-tech focussed cluster in a rural area in the Netherlands. The concept of regional clusters remains ambiguous, as this research shows. The aim of this study was to create insight into how this complex industry is structured in the region, by first researching the regional value chain and secondly mapping out the regional value network. This combination of itself and the researched cluster had not been studied yet, thereby adding to the literature space. Moreover, the identified barriers could be used by regional policymakers and decisionmakers in their strategic planning. Next to this, researchers could research the identified barriers within other high-tech clusters and measure if these barriers have similar impact on their development. All in all, this study answers the research question of how the cluster is structured and what barriers could impact its development.

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7 Appendix (Interview Guide)

Introduction

Section 1: Company related questions

- Ask the participant to introduce him/herself? (work-experience, role within the company, etc)
- Ask the participant to introduce the organisation? (founding, products, employees, revenue?)

Section 2: Access to capital

- From the participants perspective, how accessible is financial capital and what could be improved? (e.g., venture capital, angel investors, grants, public funds)
- How did the organisation raised capital. If any?

Section 3: Access to human capital

- How big is the firm currently in terms of FTE's and how many new hires does the participant expect in the next 5 years?
- What is the participant's perspective on finding talent in the region, or do they need to outsource in different regions (nationwide or abroad)?
- How does the participant perceive the availability of skilled and talented individuals within the cluster?
- Does the participant think there is enough skilled talent in the region, in other words do the local educational institutions contribute significantly to the development of human capital in the cluster?

Section 4: Access to Physical capital

- How does the participant look at the critical physical infrastructure from your organisation's perspective in the cluster?
- With the current MESA+ institute and the nano lab, there is already some infrastructure in the region, does the organization use the current facilities? And if so, how often?
- In terms of innovation and R&D, how would the participant describe the level of networking and collaboration among actors (entrepreneurs, investors, mentors) within our cluster?

Section 5: Access to Social capital

- How does the participant network with other actors in the region?
- How would the participant describe the internal and external linkages of the organization in the region?
- What is the participants perspective regarding collaborations with regional actors?

Section 6: Cluster initiative

- What is the participant perspective on the cluster initiative in its current form?
- What value does the cluster initiative bring to the participants organisation?

Conclusion