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# Abstract

# Acknowledgements

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# Chapter 1: Introduction

This chapter’s aim is to set the expectations of the study that follows to the reader. First, I will communicate the essence of the topic by giving the necessary background information, as well as a timeline of the Odense Robotics ecosystem, thus setting up the backdrop of the research case. My aim is to make the reader understand what Odense Robotics is, where the problem is, and whether a solution can result in practical or theoretical applications.

For that reason I will introduce the problem statement, which includes the research question. After I have stated and explained the research question, I will describe how I intend to answer it. In order to justify the research strategy, I provide the key theoretical assumptions and research methods that the thesis is based on and I discuss why the chosen theories and methods are appropriate for solving the identified problem.

In the final part of this introductory chapter, I map the structure of the report and explain the content of the following chapters setting up the boundaries of the study.

# 1.1 Case Background

Interest in clusters has grown considerably among authors, however Michael Porter’s work is considered as the most influential (Martin & Sunley, 2003). As he explains, “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” (M E Porter, 1998, p. 78). The factors that foster a cluster’s development can often be traced to historical circumstances (M E Porter, 1998). For this reason, I shall present the evolution of the Odense Robotics in a chronological order. Figure 1 shows some of the important historical points that led to the establishment of the robotic industry in the region of Southern Denmark. The information in the figure comes from knowledge of the Odense Robotics’ history. In the next paragraph, I shall explain the figure in-depth. Steno’s 2016 book *Cluster of Success* offers assistance for the particulars of this case and is used extensively as a reference.

Figure 1 Odense Robotics Timeline; own work.

Odense is the third-largest city in Denmark, with nearly 200.000 inhabitants and is located in the broad region of southern Denmark in the island of Fynen (CamillaHansen, 2012). In the mid-1980s, the major Danish shipbuilder *Odense Steel Shipyard* (the "Lindø" Yard), owned by the MAERSK cargo conglomerate, had to reduce the wages of the workers in an attempt to raise the international competitiveness of the foundation (Steno, 2016). For that reason, the company bought a couple of welding robots from the Japanese firm Hitachi, but the problem was that there were only a few tasks that the robots could generate. The company tried to solve the issue by asking advice from researchers in the former Odense University (now known as *University of Southern Denmark* or *SDU*) (Steno, 2016). In my view, the collaboration between industry and university laid the foundations to uncover the potentials of robot technologies and thus to be the basis of the Odense Robotics cluster development.

Few years later, the Lindø shipyard, Odense University and the Danish Ministry of Science financed the *Autonomous Multiple Robot Operation in Structured Environments* (AMROSE) project. The project’s aim was to solve the operation problems in robots movements (Steno, 2016). This project seems to have been a pioneer collaboration between industry, university and state, capturing a mix of private and public resources. In 1994, the first AMROSE-guided robot entered into operation as a collaboration of the shipyard’s specialized developing team giving and a number of university’s robot engineers (Steno, 2016).

In 1997, Mr. Mærsk Mc-Kinney Møller (the chairman of Lindø shipyard) made a donation of 80 million kroner for the establishment of the Maersk Mc-Kinney Møller Institute (MMMI) as a part of the University of Southern Denmark (Steno, 2016). The institute’s target is to house robot research, as the potential for Danish industry in robotic technology seemed prominent in Odense (“The Maersk Mc-Kinney Moller Institute - Syddansk Universitet,” n.d.). Even though the environment around robotics was flourishing, the economic downturn in the beginning of 2000s caused negative effects (“The financial crisis in Denmark - causes, consequences and lessons,” 2013). As a result of the economic recession, the AMROSE project and the development department at the Odense shipyard were shut down (Steno, 2016).

The robot-environment around Fyn was still holding a great deal of knowledge and people in this area. RoboCluster was established in spring 2002 as a local growth environment based at the Maersk Mc-Kinney Møller Institute at the University of Southern Denmark to continue the work on projects in the robotics industry. The second phase of the further development of the cluster has started with public initiatives financing the organization (“History- RoboCluster,” n.d.). It was the time for local authorities to act in order to save the development of the robotic industry (Steno, 2016).

From an Internet research, it appears that RoboCluster was the first network organization of the Odense Robotics ecosystem that put also the word ‘cluster’ in its name. Therefore, in my opinion, 2002 was probably the year that the Odense Robotics ecosystem was baptized as a cluster. After that point, many companies sprung up especially from the university enviroment but also due to the fact that the public sector adopted initiatives to help the robotic industry grow. In 2005, the Danish government established the *Danish Advanced Technology Foundation* (DATF) (a part of Innovation Fund Denmark from 2014) providing resources for application-focused research projects related to innovation (“About IFD | Innovation Fund Denmark,” n.d.)Therefore, it seems that the Danish government had realized the growth potential in research and innovation and started making major technology investments. In 2006, the *Danish Technological Institute* (DTI) set up the *Center for Robotic Technologies* (DTI-RT) in Odense (“Robot Technology - About DTI,” n.d.).

The growth of the cluster is best illustrated with the great sale of the local producer of *collaborative robots* (Cobots) Universal Robots (UR) to the US Corporation Teradyne for 285 million dollars in May 2015 (“Collaborative Robots Broadening Marketplace,” n.d.). Universal Robots was founded in October 2005 as a startup company at the University of Southern Denmark with a startup capital of 1.2 million Danish kroner from the innovation incubator Syddansk Innovation (Steno, 2016). I suppose that this spectacular exit helped the cluster’s stakeholders to understand the growth potentials in the robotic industry.

In 2015, “Odense Robotics, Frontier for Robotic Technologies” was established as a network organization having specific tasks in Odense Robotics cluster branding (“Odense Robotics skal styrke Odenses robotmiljø,” n.d.) . It is worth mentioning that, in my thesis report *Odense Robotics* refers to the cluster itself, while *Odense Robotics Frontier* refers to the network organization that appeared in 2015. At the moment, Odense has 83 robotic companies, 2200 jobs in robotics, more than 30 higher education programs related to robotic technology, and many knowledge, research, and network organizations (Odense Robotics, 2015) (See Appendix D).

The case of Odense Robotics shows that a fertile ground for cooperation is developing around Odense that may provide a considerable potential for the Danish economy in advanced industrial technology. This unique robot cluster promotes ambitious technology for companies and fertile conditions for growth in several areas, with particular strength in collaborative robots, drones, and food automation (“Welcome to Odense ... City of Gamechangers ... and a place to create the future.,” 2016)

The literature shows that global industry around robots is also prominent. For example, the worldwide supply of industrial robots is expected to triple up until 2018 (“IFR Press Release - IFR International Federation of Robotics,” n.d.), providing strong indicators for growth in the global robot industry. In a national level, the robot density in Denmark is the fifth highest in the world where 166 industrial robots are employed per 10.000 people in the manufacturing industry, despite the fact that Denmark does not have car industry, which is taking the lead in robot automation (“GlobalRobot density IFR,” 2014). According to Steno (2016), Danes are welcoming towards robots taking over boring and predictable work and there is an understanding that institutes of higher learning and commercial businesses can work together for the common good. Moreover, according to a 2016 survey by the Danish Society engineers, only one present of Danes think that robots will take their jobs (Steno, 2016).

# 1.2 Problem Indication

This study’s aim is to examine the ability of the cluster to compete globally in such an innovative technology as robotics. In this notion, I will examine the environment that the cluster competes in, the structure and behaviors of the cluster, and the frictions/interactions that lead to innovation and growth as three main factors (environment, structure, frictions) that will lead to internationalization. In order to achieve this, I shall study the cluster itself and how it can continue showing cases such as the Universal Robots exit.

In my opinion, a study of this kind is important. This is because the data shows that robotics will show growth both for the Danish nation and internationally. More precisely, in Odense, the robotic companies expect growth from the current 2200 employees to more than 3000 earlier than 2020, being beneficial for the society (creating work positions) and for individuals (creating successful firms) (Odense Robotics, 2015). Furthermore, according to Steno (2016), robotics can open the way to a fifth industrial revolution, in which people will collaborate with robotics to increase productivity. In the same way, the Danish state can take advantage of robots, using them in the welfare system and in healthcare, as a way to reduce public sector costs.

# 1.3 Research Question

The above problem indication leads to the following research problem:

**Can the Odense Robotics cluster support innovation and growth in the continuous quest of internationally high competitive firms?**

The analysis of the Odense Robotics cluster in this study involves the following sub-questions:

1. Which characteristics influence Odense Robotics cluster environment?
2. How is the structure of the Odense Robotics cluster?
3. Which frictions foster innovation in Odense Robotics cluster?

# 1.4 Outline of the Theoretical Framework

The literature review of the study will follow three pillars: environment, structure, and frictions. In order to answer the first sub-question, I shall apply Porter’s diamond model and the innovation systems model. Michael Porter developed the diamond model in 1990 and explained the industrial dynamics that measure the competitiveness of a nation or a location, thus revealing the importance of clustering. The analysis of clusters is closely related to the analysis of regional innovation systems as organized initiatives to promote innovations (Doloreux & Parto, 2005). The concept of the innovation system stresses that all the important economic, social, political, organizational, and other factors influence the development, diffusion, and use of innovations (Edquist, 1997).

In order to answer the second sub-question, I shall introduce the Triple Helix model of university–industry–government relations (Leydesdorff & Etzkowitz, 1996). This model can explain the interactions of actors and its social contexts in regard to innovation systems and clusters. In this context, I will explain the role of the university and the government, separately.

Lastly, for the third sub-question, I shall use some of the relevant literature concerning the structure, the characteristics and the behaviors of the cluster. In order to connect all three sub-questions in the international context, I adopt the theories concerning global clusters of innovation.

# 1.5 Methodology

The research behind this thesis can be described as qualitative sociological research. Qualitative research methods are designed to enable greater understanding of how people experience their lives within specific cultural contexts (Buzzanell, 2015). The strategy that I used to collect the necessary data is in-depth interviews based on the snowball sampling method. Snowball or chain referral sampling is a method used in qualitative social research that yields a study sample through referrals made among people who share or know of others who possess some characteristics that are of research interest (Biernacki & Waldorf, 1981). The employment of snowball sampling in organic social networks brings to the fore the concepts of social knowledge and power relations that when employed in the study of social systems and networks deliver a unique type of knowledge (Noy, 2008).

According to Rasmussen, Østergaard, & Beckmann, (2006) there are two ways to construct and apply knowledge: inductive and deductive. The inductive creates new knowledge through the gathering of data and experience, while the deductive allows the application of such systemized knowledge in new areas. My starting point was a deductive work process due to the fact that I started studying the theory before collecting the empirical data. However, as soon as I studied and analyzed the data, new assumption came up, and my study adopted an inductive process. Overall, my study is a combination of inductive and deductive processes that helped me to examine this subject.

# 1.6 Structure of the Report

The thesis is divided into six main chapters. Besides the first introductory chapter, the second chapter provides the relevant theoretical framework. In the third chapter, I explain my methods of collecting and analyzing data, as well as how the design of the study fits for answering the research questions. In the fourth chapter, I analyze the data according to the relevant theory and method. In the fifth chapter, I discuss the topics that emerged from the analysis chapter. In the sixth and final chapter, I answer the research question, provide recommendations, and present the study’s limitations and potential for future research.

# Chapter 2: Theoretical Framework

This chapter presents an overview of previous research that I have found to be relevant for the study. The chapter starts with literature related to the competitive environment around clusters with Porter’s diamond model and the overview of Systems of Innovation. Then it goes deeper into the literature about geographical clusters, their actors and cluster characteristics. The interrelations of different entities to foster innovation are based on the Triple Helix concept as a model that describes the use, diffusion and generation of value through innovation processes. The cluster concept is then applied in a global context reviewing the Global Clusters of Innovation concept. Finally, a discussion is done about the overall theoretical framework of the study.

# 2.4 Theory on Clusters

The agglomerations of related industrial activities were first recognized by Alfred Marshall in 1890 with his book Principles of Economics. Despite the industrial simplicity of the period, Marshall identified that a localized industry gains a great advantage from the fact that it offers a constant market for skilled labor which can cause continued growth of trades over a long period through the specialization of different firms in different stages of production (Marshall, 2009). The link between location and economic efficiency shows that industrial cluster formations can benefit the participants’ activities from positive externalities (Michael E. Porter, 2007). Many treatments of agglomeration industries rely on cost minimization due to proximity to inputs or proximity to markets (Michael E. Porter, 2000). Technological development, easy access to markets and inputs make clusters a new way of thinking about national, state and local economies in enhancing competitiveness (M E Porter, 1998).

According to Porter (1998), clusters represent a new way of thinking about a location in a time that companies can source all the needed resources often with a click of the mouse. Porter (1990) claims that in order to understand competition and competitive advantage in the world of globalization, one needs a good understanding of a cluster. More importantly, enduring competitive advantages in a global economy lies increasingly in local things such as knowledge, relationships and motivation that distant rivals cannot match (M E Porter, 1998). Globalization changed the way that companies compete as resources referring to capital, technology, and other inputs can be efficiently sourced in global markets that firms can access immobile inputs via corporate networks (Michael E. Porter, 2000).

The sophistication of how companies compete in a location is strongly influenced by the quality of the microeconomic business environment (Michael E. Porter, 2000). This is a concept emphasizing on peripheral business environment that plays vital role for development and prosperity in which companies create a tangible background benefited from local cooperation and competition (Michael E. Porter, 2000). Clusters represent a new kind of spatial organizational form as a new way of organizing the value chain that offers advantages in efficiency, effectiveness and flexibility (M E Porter, 1998). Fertile ground is cultivated for new business creation using the value channels of existing structures in a productive and innovative business environment (Michael E. Porter, 1990). In such an ecosystem companies, institutions and governments should wonder how should be configured to gain competitive success, economic development and prosperity (M E Porter, 1998). Public and private investments to improve cluster circumstances benefit many firms (Michael E. Porter, 2000). Informal linkages such as networks, partnerships and alliances, complementarities and spillovers in terms of technology, skills, information, marketing, and customer needs cut across firms and industries underline the interplay and interdependence of actors gained ground (Andersson, Serger, Sörvik, & Hansson, 2004).

Porter’s definition of industrial or business clusters became the standard concept in the field of economic localization as not only promoted the idea of ‘clusters’ as an analytical concept, but also as a key policy tool (Martin & Sunley, 2003). Martin & Sunley (2003) argue that despite the fact that clusters raise the productivity, innovativeness, competitiveness, profitability and job creation performance of the localized firms, they face asymmetric disadvantages. They state that a concept as elastic as the cluster cannot provide a ‘fit all’ model on how agglomeration is related to regional economic growth as in many times geographical concentration is not the main cause of relative success.

So far, I have analyzed the basic theory concerning geographical clusters. The first identification of such an industrial agglomeration was done in 1890. Since then, the benefits of clusters have been more widely recognized. They capture increased attention due to the fact they contribute to competitiveness, innovation, and productivity. Despite the establishment of globalization, localized industrial concentrations can offer benefits such as: easy access to resources, access to markets, reduced costs, and so on. The competitive environment is also very important in the analysis of clusters, as the stakeholders realize that in order to compete, they also have to cooperate and communicate efficiently and effectively, formulating networks. Lastly, it is worth mentioning that cluster can become a key policy tool for all stakeholders, in order to gain prosperity for their interests.

In the following sub-chapters, I shall analyze cluster characteristics, actors, and the concept of global clusters of innovation. Such an analysis is important, as it shall give a more complete view of the structure of clusters, in order to apply it to the case of Odense Robotics.

# 2.6 Cluster Characteristics

According to the literature that I have studied, the following cluster characteristics are the ones that the authors mention the most. Therefore, I consider it important to cover them in my analysis. Some of the cluster characteristics are:

1. Geographical proximity
2. Competition & cooperation inside the cluster
3. Internal vs. external linkages
4. Social capital & trust
5. Increased entrepreunerial activity & leadership
6. A cluster’s life-cycle

# 2.6.1Geographical proximity

One of the most important and sometimes obvious characteristics of clusters is the geographical proximity of the cluster members, as they are always located in a close proximity to each other. It includes the presence of unique natural resources, economies of scale in production, proximity to markets, labor pooling, the presence of local input or equipment, suppliers, shared infrastructure, reduced transaction costs, and other localized externalities (Michael J. Enright, 2003).

Geographical proximity plays a vital role in the continuously upgrading of companies knowledge bases and performance (Feldman & Florida, 1994). Firms in agglomerations can reduce their costs as interfirm transactions and shipments are simplified when the distance between firms is unimportant (Malmberg & Maskell, 2002). Concerning the advantages of geographical proximity, Porter (1998) states:

The proximity of companies and institutions in one location and the repeated exchanges among them foster better coordination and trust. Thus, clusters mitigate the problems inherent in arm's-length relationships without imposing the inflexibilities of vertical integration or the management challenges of creating and maintaining formal linkages such as networks, alliances, and partnerships (page 80).

Porter (1998) highlights that the actors in the cluster facilitate communication, as the close informal relationships provide flexibility as an alternative tool for vertical integration. Personal relationships and community ties foster trust and facilitate the flow of information making them more transferable and easier to access.

Porter (1998) also underlines the effects of clusters in marketing. More precisely, the cluster can often provide the reputation needed for the buyer to turn their attention to a particular location. In this notion, cluster members benefit from a variety of cluster exposure in marketing such as marketing campaigns and magazines, trade fairs and marketing delegations (M E Porter, 1998).

# 2.6.2 Internal competition and cooperation

According to Porter (1998), clusters promote both competition and cooperation. Competition makes firms chase better performance and cooperation to take advantage of economies of scale. Regional clusters appear to entail both greater cooperation and greater competition among direct competitors than geographically dispersed industries (M. J. Enright, 2001).

Executives desire to look good in the local community feeling pride when they perform better than the local competitors. Peer pressure amplifies competitive pressure within a cluster, as the clustered community leaves space for local informalities in the interpersonal relations of the member that can cause the willingness to outdo one another. Managers have also the information needed to compare performances because local players share the same environment-labor costs, supplier’s costs- to perform (M E Porter, 1998).

Co-operation with direct competitors involves a trade-off between access to greater resources and the potential for losses in terms of information or strengthen the position of the competitor. Companies must participate actively and establish a significant local presence cultivating personal relationships with the environment, a sense of common interest, and an “insider” status (M E Porter, 1998).

According to Porter (1998, 2000), clusters affect competition in three broad ways. First, they increase the current productivity of constituent firms or industries. Second, they can augment the capacity of cluster participants for innovation, and finally they stimulate new business formation that supports innovation and expands the cluster.

The whole is greater than the sum of its parts as the result of the linkages among cluster members and the good performance by one can boost the success of the others in a mutual dependent environment (M E Porter, 1998).

Overall, it seems that competition and cooperation can benefit clusters, as factors that can increase productivity, innovation, and create new business.

# 2.6.5 Internal vs. External linkages

In order to avoid stagnation, the regional clusters not only need favorable local conditions but also free and substantial mobility between the cluster and the world around it (Sölvell et al. 2003). Complex technologies require the support of sophisticated organizational networks providing the key elements of the overall technology as these elements are situated across a wide array of locations (Wolfe & Gertler, 2004).

The relationship between firms and the competitive environments in which they operate has been a contentious issue in social science (Tracey & Clark, 2003). Networks of interaction are particularly interesting to investigate as they are closely connected to learning and innovation (Tracey & Clark, 2003). Innovative behavior requires flexibility with regard to network formation as economic agents simply respond to their environments, with little or no capacity for strategic choice (Tracey & Clark, 2003). Thus, alliances and partnerships between related firms foster interactive learning in the ecosystem through the sharing of knowledge and information facilitated from the shared values, the trust and the common ways of working.

Bathelt et al. (2004) refer to two kinds of knowledge: *local buzz* and *global pipelines*. Figure 2 depicts the strucuture and dynamics of those two kinds of knowledge.

According to the authors, buzz refers to the information and communication ecology created by face-to-face contacts, co-presence and co-location of people and firms within the same industry and place or region. In the figure, the buzz is depicted with discontinuous lines. This sort of information and communication is more or less automatically received by those who are located within the region and who participate in the cluster’s various social and economic spheres (Bathelt et al., 2004). Bathelt et al. (2004) continue that it is almost unavoidable to receive information, rumors and news about other cluster firms and their actions as the participation in the buzz do not require particular investments. Local buzz is thus a form of a network of communication between cluster members and it can take place in every segment of interactions from formal negotiations between firms but also to informal chats during a lunch break (Bathelt et al., 2004).



Figure the structure and dynamics of local buzz and global pipelines

While interaction and information exchange within the cluster – the local buzz – is characterized as frequent, broad, relatively unstructured and largely ‘automatic’, pipelines function in a very different way (Bathelt et al., 2004). In the above figure, pipelines are shown with the arrows. Even though knowledge spillovers may be more effective within a regional network than across its borders, physical distance is not the only influence. The access to new knowledge does not just result from local and regional interaction but is often acquired through strategic partnerships of interregional and international reach (Owen-Smith & Powell, 2004). Decisive, non-incremental knowledge flows are often generated through *network pipelines*, rather than through undirected, *local broadcasting.* The establishment of global pipelines with new partners requires that new trust is being built in a conscious and systematic way. Global pipelines presuppose trust(Bathelt et al., 2004).

Both local buzz and global pipelines offer particular but different, advantages for firms in innovation and knowledge creation. Local buzz is beneficial to innovation processes because it generates opportunities for a variety of spontaneous and unanticipated situations where firms interact and form interpretative communities (Nonaka et al., 2000). The advantages of global pipelines are instead associated with the integration of multiple selection environments that open different potentialities and feed local interpretation and usage of knowledge. The continuous flow of information and knowledge into the cluster can form prosperous environment for the creation of cutting-edge ideas. Thus clusters focus should combine the use of internal and external resources (Bathelt et al., 2004).

# 2.6.3 Capital and Trust

According to Sölvell et al. (2003), there are three types of capital physical, human and social capital. Physical and financial capital consists e.g. of machinery, components, and digitized information. Human capital consists of e.g. skilled workers, scientists, and expatriates. Andersson et al. (2004) define social capital as the intangible aspects of the social organization or region or cluster that facilitates the collaboration among economic actors. Social capital is embedded in local cultures and institutions, consisting of e.g. personal networks and institutions for collaboration.

In my analysis, I shall give increased attention to the social capital, as it represents the interactants that assist in the operation of the cluster. For Porter (1998), social glue binds clusters together, as economic systems are also social systems that combine all the spectrum of interrelations. The dynamism of the region’s industrial system lies not in any single technology or product but in the competence of each of its constituent parts and their multiple interconnections (Annalee Saxenian, 1994). Firms may dislike each other and refuse to talk but can still, indirectly, contribute to each other’s competitive success in the global market (Malmberg & Maskell, 2002). Thus, most relations between companies in an industrial concentration are not ideally formed.

Social capital is closely tied to the concept of trust. Trust will provide the confidence that parties will work for mutual gain apart from opportunistic behavior. This, if secured, is an important economic asset (Cooke & Morgan, 2000). Trust is one of those rare assets, like loyalty and goodwill, which have a value but no price, as it cannot be bought, but it has to be gained by the cluster members to take advantage of opportunities in cooperation and collaboration (Cooke & Morgan, 2000). The resulting interaction is thus greatly impacted by the degree of trust that exists between the firms (Bathelt et al., 2004).

# 2.6.4 Leadership-Entrepreneurship

Individual effort and initiative is central to clustering (Andersson et al., 2004). According to Andersson et al. (2004) clusters are often initiated by a cluster entrepreneur, or *clusterpreneur* who will take the role of a broker matching the competencies of firms, universities, and government agencies on a continuous basis. A successful clusterpreneur must know how to appreciate options to expand network contacts both within the cluster initiative and externally. Leadership can also be taken over by a hired cluster facilitator (Sölvell, Lindqvist, & Ketels, 2003). Leaders can be people committed to the local area, acquiring acceptance from the cluster structure. Leadership is fostered by the knowledge of the specific cluster characteristics but clusterpreneurs have to round experiences from outside of the cluster.

The cluster leadership can differentiate one region from another as *regional entrepreneurs*, coming often from the private sector, help animate local processes of strategic visioning, stimulate socially organized activities to upgrade the innovativeness of local firms, and represent the common, collective interest of firms in the industry when required (Wolfe & Gertler, 2004).

# 2.6.5 Cluster life-cycle

Another characteristic of clusters is their life time cycle as cluster models represent organizations with a long term perpective (Andersson et al., 2004). According to Andersson et al., 2004 the evolution pace can vary between clusters but any cluster will pass through a numbers of stages and the life cycle of a cluster undergo the stages illustrated in Figure 3.

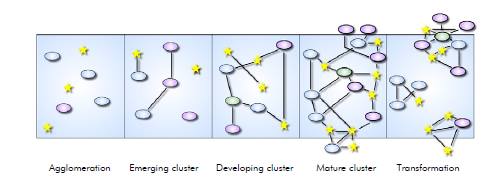


Figure 3. The cluster life-cycle

According to the figure there are five stages that a cluster adopts in its lifetime. The first is the agglomeration stage where a number of stakeholders concentrate around a region.

An emerging cluster collects a number of actors around the agglomeration. Those actors start to collaborate between each other identifiying mutual beneficiaries around a core activity.

In a developing cluster new actors and linkages are attracting into the geographical concentration. The cluster adopts formal formulation as IFCs entering the cluster. In this stage it has noticed that a common connotation or a common label is tied to the cluster’s regional activity.

A mature cluster involves a critical mass of actors that has developed relations inside and outside of the cluster. These interactions facilitate new firm creation through startups, joint ventures and spinoffs.

The final stage of the life cycle of a cluster is the transformation stage. In this stage the cluster itself can reinforce the creation of related industrial clusters. The formation of a cluster is driven by the future expectations for value creation. For this reason young clusters may be more dynamic but also more vulnerable that mature ones.

In this chapter, I have analysed the cluster characteristics that the relevant authors mention the most. Those characteristics are: geographical proximity, competition & cooperation, internal vs. external linkages, social capital & trust, entrepreneurships & leadership, and the cluster’s life-cycle.

The analysis of the cluster characteristics is important for the answering of the second research question that is concerned with the structure of the Odense Robotics cluster. Cluster characteristics can also explain the internal culture of the cluster’s environment leaving insights of how the different stakeholders are interacting with each other. Entrepreneurial initiatives foster clusters development pushing into overlapping life cycle stages. Those characteristics emphasizing to the geographical scope of the cluster setting the importance of cultivation of both internal and external linkages between parties. Competition and cooperation derives from those interactions and linkages allowing the cluster to develop its unique competitive characteristics.

In the next sub-chapter, I shall analyze the actors that make up a cluster, because they are the parties that interact with each other inside and outside the cluster.

# 2.5 The cluster actors

According to Porter (2000), clusters are geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (e.g., universities, standards agencies, trade associations) in a particular field that compete but also cooperate. He states that cluster actors are more than single industries, as they include suppliers of specialized inputs, channels or customers, and manufacturers of complementary products or companies related to skills. Many clusters include governmental and other institutions (e.g., universities, think tanks, vocational training providers, standards-setting agencies, trade associations, foreign firms) (M E Porter, 1998).

Sölvell et al. (2003) argue that clusters consist of the following main categories of actors: co-located and linked industries, government, research community, financial institutions, and institutions of collaboration (IFC) (Sölvell et al., 2003). In their analysis, Andersson et al. (2004) provide a similar to Sölvell et al. (2003) cluster formation as is depicted in Figure 3.



Figure 4. The cluster actors

Companies

In this cluster configuration, companies are critical in the system function, as they are directly involved in the cluster’s policies and actions. The firms in science-based clusters are rooted in new technology and knowledge, and to some extent they are spin-offs from universities and research institutions (Isaksen & Hauge, 2002). The firms are the ones that translate the system inputs into value by employing labor units and contributing to the economy wealth. Many successful clusters have at least one large company functioning as an anchor company with companies seen as to serve their own interests (Andersson et al., 2004).

The government

The government is more frequently in control of cluster initiatives than private sector representatives (Sölvell et al., 2003), as most cluster initiatives are dependent on public funding (Andersson et al., 2004). Governments have to see the overall image of the social benefits and thus to provide the right foundations and infrastructure for cluster’s development. Policymakers need to support the growth and competitiveness of the related industry with the proper organization, as market forces and not government decisions will determine the outcomes, states Porter (1998). Furthermore, Martin & Sunley (2003) state that it is enormously difficult to point to any examples of deliberate cluster promotion programs that have been successful without public involvement.

Research community

Research community (or Academia) is generally characterized by in-depth knowledge and analytical competencies referring to universities, public laboratories or research institutes coupled with independence and specialized communication skills (Andersson et al., 2004). Few cluster initiatives are started by universities and even fewer financed by them (Sölvell et al., 2003). However, it becomes apparent that Academia can provide a constant flow of high-skilled labor setting the foundations for clusters growth and development.

Financial institutions

The available data identifies government and industry as the main sources of financing for cluster initiatives. More precisely, new clusters primarily receive public funding, whereas mature ones tend to have more varied sources of financing (Sölvell et al., 2003). Sölvel et al. (2003) mention the following financial actors: banks, insurance companies, public pension funds, investment funds, business angels, venture capitalists- hold great competencies to the clustering process. Financial actors are unlikely to take the lead, as they are generally unwilling to be exposed to high risk. However, their long-term approach coupled with a strong presence in local markets and well-developed networks make them important players in cluster initiatives to make strategically decisive contributions (Andersson et al., 2004).

Intitutions for Collaboration (IFCs)

IFCs, known as hybrid or *glue* organizations, are formal or informal actors promoting the interest of the cluster. Hybrid organizations include incubators (university-industry hybrid), trade associations or chambers of commerce (government-industry hybrid), and government councils e.g. research/science, innovation, etc. (Andersson et al., 2004).

The representation of cluster actors is important for the study in order to categorize them into specific spheres of influences. According to the theory there are many stakeholders that formulate a cluster structure Andersson's et al. (2004) illustration (of industries, government, research community, financial institutions, and IFC) is a tool that can distinguish and help the positioning of actors into the five specific categories.

In the next chapter I shall examine the concept of the global clusters of innovation. This examination is important because it offers a collection of the characteristics and behaviors of clusters that compete internationally.

# 2.7 Global clusters of innovation

The presence of innovative clusters was identified by Michael Porter in 1998 as the high economic performance of the Silicon Valley cluster left insights of the connection to innovation with clustering. Innovation as an output is not only connected with the location factor but rather the proper cluster management should be thought as a prerequisite of the smooth function of the cluster flows (Andersson et al., 2004). Cluster management defines how well the network of knowledge sharing is facilitated, setting the importance of the good managerial confrontation (Julia Connell, Anton Kriz, & Michael Thorpe, 2014). Tracey, Heide, and Bell (2014) agree that geographical clustering does not automatically lead to improved performance.

Clusters are not isolated islands, as the most successful are often the most globally connected, utilizing linkages with other similar clusters to leverage resources, access markets and accelerate the innovation process. These linkages derive from networks far from the geographical proximity of the location benefit the participants of a cluster that they are established (Engel & del-Palacio, 2011).

Engel (2015) defines *Clusters of Innovation* (COI) as “global economic *hot spots* where new technologies germinate at an astounding rate and where pools of capital, expertise, and talent foster the development of new industries and new ways of doing businesses (Engel, 2015, p. 37)”. COIs are environments that favor the creation and development of high-potential entrepreneurial ventures (Engel & del-Palacio, 2009) and are characterized by heightened mobility of resources (principally people, capital, and information–—including intellectual property); increased velocity of business development; and a culture of mobility that leads to an affinity for collaboration, development of durable relationships (Engel & del-Palacio, 2011) .

Entrepreneurship is the core competence of COI, where innovation is augmented and accelerated through *born global* new firm creation using resources from the international pool (Engel & del-Palacio, 2011). Cluster participants formulate ties between internal and external actors and other clusters to benefit from the advantages of globalization (Engel, 2015). They combine local knowledge with external knowledge, and therefore are likely to create new value (Bathelt et al., 2004) creating the *Networks of Clusters of Innovation* (NCOI) (Engel & del-Palacio, 2011). The NCOIs connect individuals, startups, universities, research centers, associations, mature corporations, and other organizations that are globally oriented with a target to foster rapid innovation, experimentation, and commercialization (Engel & del-Palacio, 2011).

According to Engel & del-Palacio (2011), there are three types of linkages that exist in a COI. They represent formal and informal network connections that are weak ties, durable and covalent bonds. **Weak ties** are those that impose low management costs (Granovetter, 1973) consisting of interactions in international trade fairs, conferences, and other professional gatherings that create unique opportunities to share information face-to-face for a short time with people working in the same or related industries around the globe (Peter Maskell, Bathelt, & Malmberg, 2006). **Durable bonds** are dynamic and fluid interactions established between communities, entities, businesses, or people in geographically dispersed COIs consisting also a lot of weak ties (Engel & del-Palacio, 2011). **Covalent bonds** emerge if the relationships are permanent and the role of each COI is embedded in the business and processes of the other performing vital functions in multiple locations or even multiple businesses at the same time (Engel & del-Palacio, 2011). Clusters of Innovation should be understood in a global context and the above mechanisms can explain the interactions between cluster’s actors, entities, and others COIs (Engel & del-Palacio, 2011).

The influence of Silicon Valley may be even greater than its economic performance because it has been used as a role model for other regions (Adams, 2005). Silicon Valley is the leading example of a high-technology entrepreneurial environment (AnnaLee Saxenian, 2007) and three components, universities, government, and entrepreneurs played key historic roles in the transformation of this small agricultural valley into the powerhouse of the invention and business creation (Engel, 2015). For Engel (2015), other elements such as venture capital investments, mature corporations, industrial research centers, and service and management providers facilitated the success of Silicon Valley. Moreover, behaviors that characterize the development process of this cluster such as mobility of resources (principally people, capital, and information), an entrepreneurial process, increased velocity of business development, a strategic global perspective, a culture of alignment of interests and transaction structures formed a very strong environment for innovation (Engel, 2015).

Engel (2015) studied the relevance of 13 worldwide clusters with the characteristics and behaviors of Silicon Valley in order to examine the global application of the paradigm. He concluded that the components and behaviors of Silicon Valley do have global relevance, but must be adapted to local context.

Thus far, I have given an overview of the basic theory on clusters, the clusters’ basic characteristics, the clusters’ actors, and the concept of global clusters of innovation. The mention of those aspects is important in order to have a coherent image of the clustering phenomenon, before moving on to the analysis of the environment that the clusters compete in.

In the next sub-chapter, I shall analyze Porter’s diamond model in order to delve in the factors that lead clusters to evolve into a national context.

# 2.1 Porter’s Diamond model

In 1990, Michael Porter introduced the book *Competitive Advantage of Nations* describing the ways that firms gain and sustain competitive advantage emphasizing to the role of nation that they participate. The competitiveness of a nation or location is measured by the level of productivity of its industries and the rate that they are able to innovate and stay competitive (Michael E. Porter, 1990). In Porter’s concept, industries specialized in a particular sector of production can gain competitive advantage through the use of economies of scale and reduced transactional costs.

Porter highlighted that multiple factors occur beyond the ones internal to the firm and may improve its performance. The challenging question is: why do some nations succeed in a particular industry whilst others fail in international competition? He states that the nation whose home environment related to a specific industry is forward-looking, dynamic and challenging has a good foundation to succeed in a given industry (Michael E. Porter, 1990). Porter (1990) introduced the “diamond model” to explain why particular industries become competitive in particular locations. His approach looked at geographically localized or clustered firms.

The “diamond model” explains industrial dynamics and consists of four sets of interrelated forces: factor conditions (input), demand conditions, related and supporting industries, and context for firm strategy and rivalry. The role of chance and the role of government shape the determinants of a nation’s business environment as it is illustrated in Figure 2. This system is specialized to a particular industry structure but discontinuities created by chance events allowing new specialized national “diamonds” to compliment others (Michael E. Porter, 1990). Chance can exercise influence of the system but the system cannot affect it. Government can both influence and be influenced by the diamond’s determinants.



Figure 5 Porter's Diamond

First of all, **factor conditions**, most notably education, labor force, infrastructure and research institutions are about creating a match between the factor endowments of the country, or region and the needs of the industry. These factors should be specialized to the relevant industry, be of high quality but the critical point is to deploy them productively (Michael E. Porter, 1990). According to Porter (1990), the efficiency and effectiveness in the use of factor conditions is not correlated with just the mere access to them.

Secondly, **demand conditions** in the home market are important in the quest of gaining and sustaining the competitive advantage. A large domestic market is naturally positive for business, as the company has a great potential to compete nationally (Michael E. Porter, 1990). However, what is more significant than market size is the nature of domestic demand. In Porter’s opinion, sophisticated clients will force companies to become more equipped to satisfy their needs. Also, each producer wants to serve a geographically extensive market from a single location as low transactional cost occur regarding to transportation and communication (Michael E. Porter, 1990).

Third, the existence of nearby **related and supporting industries** eases the coordination of technology and labor (Michael E. Porter, 1990). In Silicon Valley, for example, the workforce is extremely mobile and knowledge flows relatively freely between competing firms, facilitating the use of high-quality cost-effective inputs at the lowest possible transaction costs (M E Porter, 1998). Geographical proximity to one’s suppliers also makes close relationships and joint product development easier, especially in technologically advanced processes (Michael E. Porter, 1990).

Furthermore, the flexible environment of the firm influences the **firm’s strategy, structure and rivalry**. It is a direct competition that forces firms to produce innovations and increase their productivity developing superior technologies, products and management practices to survive. A company which is forced to innovate and stay competitive is more likely to succeed also internationally (Michael E. Porter, 1990).

As far as the **government** is concerned, it can influence the supply conditions of key production factors, demand conditions in the home market, and competition between firms by establishing product standards or regulations that can influence buyer’s needs (Michael E. Porter, 1990). On the other hand, **chance** events are occurrences that are outside of the control of a firm being important because they create discontinuities in which some gain competitive positions and some lose (Michael E. Porter, 1990).

Although the model was developed to analyze the competitive advantage over nations, it focuses on the local clustering of industries within which those nations compete. The model also concludes that competitors in many internationally successful industries, and often entire clusters of industries, are often located in a single town or region within a nation (Michael E. Porter, 1990). Advantages throughout the diamond are necessary for achieving and sustaining competitive success in the knowledge intensive industries that form the back bone of advanced economies (Michael E. Porter, 1990, p. 73).

Overall, Porter’s diamond model seems to be sufficient to analyze the factors that influence the competitive environment around an industry in a nation, as it gathers collectively what appear to be the main industrial characteristics: factor conditions, demand conditions, firm strategy, structure, and rivalry, related and supporting industries. Moreover, except for industrial characteristics, the diamond model highlights the role of the government as an influencer that can regulate the system. Due to its inclusiveness of many factors, I believe that the diamond model can assist in the examination of the Odense Robotics cluster.

However, Porter’s diamond model does not examine in depth the factors that influence innovation. Engel (2015), for example, states that Porter’s model cannot explain how highly innovative clusters support the continuous emergence of high-growth firms, that some of them diverge from the original related industry. The concept of the innovation systems, on the other side, takes into the account the environment that leads to innovation. In the following sub-chapter I will give an overview of the concept of innovation before examining innovation systems.

# 2.2 Innovation Systems

**2.2.1 Innovation**

Innovation is attracting the attention of economists as a mean of gaining and sustaining the competitive advantage for companies and organizations (Michael E. Porter, 1990). Innovation and entrepreneurship have become the buzzword of the decade with both individuals and societies realizing that innovation can create value and prosperity (P. Drucker, 2014; Engel, 2014). Already in 1934, Schumpeter explained innovation as a principal driver for long-term economic growth and defined that innovation includes new products, new methods of production, new sources of supply, exploitation of new markets and new ways to organize businesses, as a process that in general needs change (Schumpeter, 1934).

Some authors draw attention to the distinction between invention and innovation. Despite the fact, that innovation is connected to invention and that an invention needs innovation to occur, the invention is the process of creating something new that never existed before (O’Sullivan & Dooley, 2008). Invention by itself is not an innovation (Freeman & Engel, 2007) and innovations need not necessarily be any inventions at all (Schumpeter, 1934). There are many other factors that derived from innovation and others that foster it. Innovation is not only connected with economic development and growth (P. F. Drucker & others, 1988) but also with concepts such as creativity (Heunks, 1998), design, and decision-making process by which information (an idea) is transformed into an outcome (Stark, 2011).

**2.2.2 Innovation Systems**

Systems of innovation (SI) are all the important economic, social, political, organizational, and other factors that influence the development, diffusion, and use of innovations (Edquist, 1997, p. 14) . The geographical boundaries of an innovation system can vary from national, sectoral and regional approaches but national, regional and sectoral systems of innovation can be regarded as three variants of a generic SI approach (Edquist, 2001). One of the most important characteristics of SI is that innovations are based on learning processes and interactions between organizations as companies generally do not innovate in isolation (Edquist, 1997). The main components in SIs are organizations, companies, universities, venture capital organizations and public innovation policy agencies influencing the relations between universities and firms (M. J. Enright, 2001).

The **National Innovation System** (NIS) approach generally focuses on institutional characteristics of innovation systems on a national scale and favors those at the expense of other scales (Oinas & Malecki, 2002). Public sector is intensively involved in the innovation systems both directly and indirectly by creating incentive structures, education and training systems, and promoting exports through monetary, and trade policy packages (Oinas & Malecki, 2002).

Cooke et al., (1997) applied the former work of Lundvall, (1992) on NIS to the regional scale and developed the concept of **Regional Innovation System** (RIS), shifting the analytical focus on the subnational or regional level (Cooke, Gomez Uranga, & Etxebarria, 1997). In this context, Doloreux and Parto (2005) defined regional innovation systems as “cooperative innovation activities between firms and knowledge-creating and diffusing organizations, such as universities, training organizations, R&D institutes, technology transfer agencies etc., and the innovation-supportive culture that enables both firms and systems to evolve over times” (Doloreux & Parto, 2005, p. 135). RIS balance the focus between economic and social interactions between both public and private agents (Asheim et al., 2011). The role of geographic proximity in diffusing knowledge and creating informal personal networks highlights the role of innovation systems due to regional differences in industrial specializations and institutions (Tödtling & Trippl, 2005). Edquist (2001) points out that within a country there are huge differences regarding its economic structure, institutional set-ups, R&D bases and innovation performance. There are usually several clusters and many industries in an RIS that play a larger role in the context of innovation formulating relevant organizations, rules and behavioral characteristics as an interactive process that involves many actors (Tödtling & Trippl, 2005). The RIS concept has evolved into a widely used analytical framework the development of innovation policies around a strong foundation (Doloreux & Parto, 2005).

**Sectoral innovation systems** can explain a variety of such as an analysis of how sectors operate, their dynamics and patterns of change, but also for the identification of the factors affecting the performance and competitiveness of firms and countries and finally for the development of new public policy indications. The studies on regional/local innovation systems are traditionally closer to sectoral systems as very often evolve when local systems overlap with a sector (Malerba, 2002). Carlsson and Stankiweicz (1991) define the Technological System as networks of agents, who act in a specific technology area within which a particular institutional set‐up exists. They conceptualize their approach with four main elements:

At this point, it is worth mentioning that clusters and regional innovation systems are closely related but with fundamentally different ideas (Doloreux & Parto, 2005). The cluster is regarded as an industry specific phenomenon narrower than the concept of innovation systems as an innovation system is a broader framework affecting the innovative capacity of firms in a variety of sectors and thus a cluster is not a necessary ingredient in an innovation system (Andersson et al., 2004).

So far, I have analyzed Porter’s diamond model in an attempt to provide the theoretical framework on the environment that an industry competes in. Porter (1990) mentions four main factors that structure the competitive environment of an industry within a nation: factor conditions, demand conditions, related and supporting industries, and firm strategy, structure, and rivalry. Lastly, the model highlights the importance chance events and the influence of the government.

However, on its own, Porter’s diamond model cannot explain organized public policies that are relevant to innovation system approach. The concept of innovation systems helps fill this gap and provides a structured view on how a society can foster innovation through policies and initiatives. The literature makes the distinction between national, regional, and sectoral innovation systems.

In the following sub-chapter, I will provide the relevant theoretical framework that can help answer how the stakeholders interact with each other in order to produce innovative results. More precisely, I will present the Triple Helix Model as a tool that explains the interactions of university, academia, and state in the setting of innovation. More precisely, Triple Helix is a model of the structure and dynamics underlying the ways that innovation systems functioning at various levels while NIS and RIS are institutional programs focused on wealth creation at the national or regional level (Leydesdorff & Zawdie, 2010).

# 2.3 The Triple Helix Model

The triple Helix model highlights the interconnectedness and collaboration between public agencies, universities and the industry when it comes to innovation (Etzkowitz & Leydesdorff, 2000). The configuration of the model is a way to create competitiveness of regions by the formulation of synergies and cooperation between the different entities of the Helix (Etzkowitz & Leydesdorff, 2000). Etzkowitz and Leydesdorff (2000) mentions that universities and research centers are involved in projects with the private sector with a target to deliver technology, knowledge and to innovate. The authors continue that new businesses can be created using the spin-off resources from academia seeking financial support from private companies. The business environment that involves higher education in research projects can support private entrepreneurship. Public financed research can facilitate outsourcing outputs into the business world with the development of initiatives and projects such as technological parks.

There are three distinct different figures of Triple Helix, which each gives a complete different resolution between the relationships between academia, state and industry. Figure 3 shows the different variations of the triple helix model. The goal for all is to generate alternative strategies for economic growth and social transformation (Etzkowitz & Leydesdorff, 2000).



Figure 6 The Triple Helix Models

The first dimension, the *statist* model, focuses on the authority of the state as being the dominant force which dictates and encompasses both the industry and the academia (Etzkowitz, 2002). In the specific triple helix configuration there is limited space for bottom-up initiatives and innovation is discouraged as the state keep its own national industry separate from the outside world and the university conducts research that is not intended to create growth (Etzkowitz, 2002). This version could be found in nations such as the former Soviet Union and many Eastern European nations that embraced socialism (Etzkowitz & Leydesdorff, 2000). In the second dimension, the *laissez-faire* model, the players are separated and do not have any significant relationships with each other. This particular model entails a policy of minimum governmental interference that can be used as shock therapy to reduce the role of the state in the first model (Etzkowitz & Leydesdorff, 2000).

Most countries and regions are trying to form the configuration of the *Triple Helix* that fosters tri-lateral networks and hybrid organizations. In this model, academia, state, and industry are mutually contributing to competitiveness from separate spheres into a more flexible overlapping system where the institutional spheres collaborate and cooperate with each other (Etzkowitz, 2002). The objective is to capture an environment with innovativeness, consisting of university spin-offs, trilateral initiatives for knowledge-based economic development, and strategic alliances between the Triple Helix actors (Etzkowitz & Leydesdorff 2000). This can bring new organizations into the scene as knowledge from all three spheres are connected at the interfaces and sometimes can function to aid and assist each other.

In this notion, the Triple Helix is a spiral model of innovation that captures multiple reciprocal relationships at different points in the process of knowledge capitalization in the triad of government-university-industry relationships (Etzkowitz, 2002). The Triple Helix model is used for both macroeconomic (nation) and also-economic (region) research with the future national developments to be the outcomes of changes in the regional contingencies and their relevant environments (Leydesdorff & Etzkowitz, 1998).

The Triple Helix thesis states that the university can play an enhanced role in innovation in increasingly knowledge-based societies, transforming from a teaching institution into one which combines teaching with research (Etzkowitz & Leydesdorff, 2000). The focus is still on the network of communications and expectations that reshape the institutional arrangements among universities, industries, and governmental agencies. The Triple Helix denotes not only the relationship of university, industry, and government but also internal transformation within each of these spheres (Etzkowitz & Leydesdorff, 2000).

# 2.3.1 The role of the University

The first mission of universities was teaching, followed by research, and then economic and social development as a third mission (Etzkowitz, 1998, 2003). With growing social pressure to go beyond traditional missions and contribute to regional development, universities took on an integral role working closely with government and industry in economic and social development (Etzkowitz, 1998). Even less research-intensive regions are aware that science, applied to local resources, is the basis of much of their future potential for economic and social development (Etzkowitz & Leydesdorff, 2000). The ‘capitalization of knowledge’ is central to the new academic mission, linking universities to users of knowledge more tightly and establishing the university as an economic actor in its own capabilities (Etzkowitz, 2014). Academic involvement in technology transfer, new business formation, and regional development signifies the transition from a research to an entrepreneurial university (Etzkowitz, 2014). The university’s unique comparative advantage is that it combines continuity with change, organizational and research memory with new persons and new ideas, through the passage of student generations as students represent a dynamic flow-through of ‘‘human capital’’ in academic research groups that ensures the primacy of the university as a source of innovation (Etzkowitz & Leydesdorff, 2000). As knowledge becomes an important component of innovation universities are expected to take on an entrepreneurial role focusing on economic development having an equal role with the other part of the Helix, the industry, and the state (Etzkowitz, 2007). University outcomes include the creation of technology parks, spinoffs firms, patents and licenses, consulting, contract research, joint research, publications, and producing skilled graduates (Philpott, Dooley, O’Reilly, & Lupton, 2011) and an array of research contribution.

# 2.3.2 The role of the government

The role of the government in cluster formation and development is crucial (Michael E. Porter, 2000). The state has a constant presence in the cluster, being the main actor providing financial incentives to attract new investors or to define structures or agencies to manage cluster initiatives or regional development (Sölvell et al., 2003). Moreover, the government has to reorganize its structure to deal with new forms of collaboration, networking and resource allocation that emerged from the Triple Helix interaction (Ranga & Etzkowitz, 2013). The role of the government becomes much more fluid and dynamic according to the needs of knowledge institutions and firms that can lead to new hybrid organizations or organizational structures that encompass all three Helix spheres (Etzkowitz, 2003a). Once a cluster begins to form, government at all levels plays a role in reinforcing it through investments to create specialized factors such as university specialized institutes, training centers, data banks and specialized infrastructure (Michael E. Porter, 1990).

As an additional role of the government, Porter (2000) mentions that it should facilitate and upgrade cluster development as many of the productivity and innovation advantages of clusters rest on spillovers and externalities that involve public entities (Michael E. Porter, 2000). Thus, public sector after the recognition of a cluster existence should remove obstacles, relax constraints, and eliminate inefficiencies (Michael E. Porter, 2000). All clusters have the potential to contribute to the economic growth of a location and governments should reinforce and build on existing and emerging clusters than trying to create entirely new ones (M E Porter, 1998; Michael E. Porter, 2000).

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# Chapter 3: Methodology

The purpose of this chapter is to describe how I will analyze the problem defined in the introduction and has two major goals. The first one is to analyze the ways that empirical data was collected and the second one, to explain the methods used to analyze these data in an attempt to demonstrate the relation of the problem to the relevant method as the capable one to produce an answer for the problem. This study uses only qualitative methods, therefore the focus of the study relies on the significance that derives from the data and mainly focuses on behaviors, attitudes, feelings and motives (Rasmussen et al., 2006).

# 3.1 Research design and strategy

A research design provides a framework for collection and analysis of data. A choice of research design reflects the priorities of the research (Collis et al., 2003).The research behind this thesis can be described as qualitative sociological research and the strategy that I used to collect the necessary data as in-depth interviews based on the snowball sampling method. Snowball or chain referral sampling is a method used in qualitative social research that yield a study sample through referrals made among people who share or know of others who possess some characteristics that are of research interest (Biernacki & Waldorf, 1981).

The purpose of a qualitative study is not to generalize based on a large population but to go into depth with an issue, luxuriate into individual perceptions providing non-numerical data and focusing on the significance that derives from the data, thus the aim is to understand the subject and not to measure it as a method that works with flexibility (Rasmussen et al., 2006).

A project based on qualitative method begins with an issue that reformulated into a research problem with the choice of related theory (Rasmussen et al., 2006). At the beginning of my study the issue was how Odense robotic ecosystem can support positive expectations for development but after going through the literature research, I possessed the basic reasons of why these development expectations were correct. Research problems are more loosely formulated in qualitative studies (Rasmussen et al., 2006) and for this reason, I was looking for answering a research question as precise as possible.

As the literature review will define the level of knowledge that the researcher obtains about the issue stating as a precise research problem (Rasmussen et al,. 2006), I created a descriptive interview guide with some specific questions but mainly topics of discussion (Appendix 3). I shall explain, in the next chapter, how I constructed the interview guide.

# 3.2 Data Collection Method

In order for an interview to be characterized as an in-depth interview, there are some requirements to be fulfilled. Most researchers agree that an effective duration time of an interview can be from 30 minutes to 2 hours as enough time to treat a subject in depth (Rasmussen et al., 2006). There must be time for both the researcher and the responder to go beyond introductory questioning but not to exaggerate in time as both become tired. The content of the interview is determined by the degree of how structured and standardized an in depth interview is varying from very structured and formal to completely unstructured and informal. Even as a completely unstructured is very rare and it can only happen in the first interview (Rasmussen et al., 2006) I used an interview guide with the main questions to be the pilots of the future interviews. The interview guide is located in Appendix 3 and it is a one-page overview of the central themes of the discussion. The interview guide is the core of in-depth interviews (Rasmussen et al., 2006) and helped me to keep up a semi-structured interviews. During the interviews I was adding or eliminating questions, wherever necessary. Furthermore, such a guide could give me a level of comparison among the results as it was acting as a memo in my mind and also as a tool for keeping in pace with the main discussion subjects.

# 3.3 Sampling method

# 3.3.1 Snowball sampling

Snowball or chain referral sampling is a method used in qualitative social research that yield a study sample through referrals made among people who share or know of others who possess some characteristics that are of research interest (Biernacki & Waldorf, 1981).

Table . Overview of interviews and interviewees

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Name** | **Age** | **Organization** | **Type of Actor** | **Date** | **Duration** |
| **1** | Bjarke Felk Nielsen | 42 | Robocluster | IFC | 25/04/2016 | 41 minutes |
| **2** | Mikkel Christoffersen | 46 | Odense Robotics | IFC | 18/05/2016 | 40 minutes |
| **3** | Casper Harlev | 24 | Sensohive | Industry | 10/6/16 | 50 minutes |
| **4** | Jimmy Alison Jorgensen | 36 | CorePath | Industry | 14/06/2016 | 42 minutes |
| **5** | Lars-Peter Ellekilde | 34 | Associate Professor | Academia | 29/06/2016 | 39 minutes |
| **6** | Tommy Otzen | 34 | Kubo Robot | Industry | 29/06/2016 | 40 minutes |
| **7** | Mathias Flind | 26 | Researcher | Academia | 7/7/16 | 41minutes |
| **8** | Anders Beck | 35 | DTI-RT | IFC | 27/07/2016 | 41minutes |
| **9** | Bilge Jacob Christiansen | 35 | On Robots | Industry | 17/08/2016 | 59 minutes |

Table 1 presents an overview of the interviews and interviewees, sorted by date of interview. All in all, I interviewed 9 people from various organizations of the cluster. The duration of the interviews ranged from 41 to 59 minutes and the ages of the interviewees ranged from 24 to 46 years old. The organizations of the interviewees included IFCs, startups, and academia.

Biernacki and Waldorf (1981) suggested that chain referral method of sampling is a self-contained and self-propelled phenomenon that once it is started it somehow magically proceeds on its own. This popular sampling method can generate a unique type of social knowledge, showing the power relations which arise between researcher and researched, and between the informants themselves (Noy, 2008). The author continues that the employment of snowball sampling in organic social networks brings to the fore the concepts of social knowledge and power relations that when employed in the study of social systems and networks, this sampling method delivers a unique type of knowledge. Despite the fact that snowball sampling is applicable to methods that aim to research hidden population characteristics (drug users for example) (Biernacki & Waldorf, 1981), snowball sampling is essentially social because it both uses and activates existing social networks (Noy, 2008).

# 3.3.2 Snowball Stemma

Figure 7 Snowball Stemma

Figure 8 represents the snowball stemma of the research method employed in the study. Despite the fact that Odense Robotics cluster participants does not comprise a hidden population, initially, snowball sampling method helped me gain access to interview participants as I had no contacts or connections. By explaining the snowball stemma above I demonstrate also my entrance into the cluster as an external party.

In our third meeting my supervisor professor proposed me to speak with Pernille Kjaer from Business Development Centre - Southern Denmark (Væksthus Syddanmark), a regional Institute for Collaboration that is partly financed by national and regional authorities. I contacted her via email, explaining my study objectives and requesting a meeting with her. In respond, she forwarded my email to Bjarke Falk Nielsen from RoboCluster, stating that she thought that he had much more experience in my study subject than her. The snowball method started by interviewing the cluster manager of the national robotic network in 25/04/2016. With Bjarke we met on his office in the new engineering building on SDU campus were the RoboCluster offices are located. After our discussion I asked him to recommend another person with knowledge in my research area. He put me in touch with Mikkel Christoffersen, the business manager of Odense Robotics Frontier for Robotic Technologies, as he stated that these people have some specific tasks for the development of the cluster. Odense Robotics frontier is another IFC organizationally anchored in Developing Fyn that conducts business and tourism efforts for the five largest municipalities on Fyn (Odense, Svendborg, Nyborg, Faaborg and Assens) and is financed by both Developing Fyn and the municipality of Odense (“OR About us,” n.d.).

I met Mikkel on 18/05/2016, in Forskerparken, where the Frontier has its offices. Parallel to our discussion, Mikkel illustrated a power point presentation of the frontier facts and tasks which I received after our interview via email. He also provided me with a hardcopy of the cluster’s value chain that can be found in Appendix X, thus giving me important data for the Odense robotic environment. At the end of our talk Mikkel proposed to me to continue by interviewing two startupers. Those were Jimmy Alison Jorgensen, the CEO of CorePath robotics and Casper Harlev, the CEO and co-founder of SensoHive. The first generation of data collection has been collected with Bjarke and Mikkel Interviews.

The second generation of interviews started on 10/06/2016 when I discussed my research subject with Casper in Videnbyen. SensoHive is a startup company which provides sensor-based solutions that, at the moment, have two core products: a climate sensor solution for greenhouses and a wireless temperature sensor for concrete monitoring. I was also given a tour of the company offices and had tha chance to observe some of the company’s routine. Casper introduced me to the other members of the team-company but he also presented me the products and their components. According to Casper, the company is fully integrated in the product, having the assembling part in-house but they also develop software for the solution. The interview took place in a quiet lobby on the fourth floor in Videnbyen and Casper connected me with Tommy Otzen from Kubo Robot, a newbie startup part of the Odense Robotics StartUp Hub.

Jimmy Alison Jorgensen was the second of Mikkel’s recommendations and the fourth interview in the stemma. The meeting was arranged in Foskerparken, where the company, CorePath, holds its offices and laboratory. The company is a member of Odense Robotics StartUp Hub, the new robot startup accelerator program. The recorded interview lasted 42 minutes but my whole stay in the company lasted one and a half hour. I spent around 20 minutes with Jeshith, the robotic software engineer of the company until Jimmy appeared. Jeshith conducted a tour in the Hub showing and explaining to me the surroundings. He also demonstrated the company’s product in the UR5 robotic arm that they employ, trying to explain some technical parameters. He also elaborated on how the startup companies inside the hub can collaborate with each other. He gave the example of their neighbors RoboAtWork. CorePath’s software can be applicable to RoboAtWork’s solution. At the end of the visit and after the interview, Jimmy made two referrals: the Associate Professor, Lars-Peter Ellekilde from Maersk Mc-Kinney Moller Institute- SDU Robotics and Bilge Jacob Christiansen the CEO and founder of OnRobot Company.

The second generation of informants had finished by then. For the next phase, I had three more contacts to continue my data collection. At 29/06/2016 I interviewed both Lars-Peter and Tommy. The talk with the associate professor took place at his office in the new SDU engineering building, just a few meters away from RoboCluster offices. The discussion with the founder of Kubo Robots was conducted in a quiet spot in the cantine of Foskerparken, where the company’s offices are. Due to the heavy program of Bilge, we arranged our interview on the 17th of August in his company’s offices just 4 kilometers from the center of Odense.

The third and last generation of informants consist of Mathias, the former research assistant of SDU Drone Center-MMMI and now a Ph.D. candidate, and Anders, a team leader in DTI-RT. The meeting with Mathias took place in SDU ‘Winter Garden’ and in Foskerparken DTI offices, respectively.

# 3.4 Data analysis

In relation to studies based on qualitative methods, data analysis might appear as a mechanical process. Direct presentation, condensation, and interpretation of data are techniques that one can adopt to examine the way in which aspects of the theory find expression in a particular context. Despite the fact that these techniques can stand alone as data analysis tools in most times they are used together (Rasmussen et al., 2006).

Data analysis begins during the data collection stage and aspects of the subject will arise without any prior knowledge before the start of the study. The researcher becomes familiar with the subject of the research and the in-depth interviews are becoming a source of archival information providing an online feedback for new insights. If the new aspects also present themselves in the next interview, then a new insight might have been discovered. Studies based on qualitative methods are distinguished from those based on quantitative methods in that the data analysis already starts while collecting the data (Rasmussen et al., 2006). The fact that intrigued me more in the process of completing my master thesis research was that as a researcher I had the virtue of being the interviewer and thus, I was directly involved in the collection of data.

For that reason, after, during, and before every interview I modified the interview guide in the needs of each respondent. Before each interview, I performed a quick online research in order to gather as much as information for each person’s connections, background, qualifications, and tasks.

I took comprehensive notes before, during, and after each interview, as I knew that new aspects would appear once I took a look at my notes again. For example, the terms: soft money and integrators almost showed up from the first interview and they were terms that I did not know before.

In the stage of data collection I tried to gather the data with integrity, having the position of the interviewer. I tried keeping my own opinions and prejudices out of the study, despite the fact that in the first audio transcriptions I fell in this mistake.

Every interview transcription has been done after each interview, as I wanted to have the context of the discussion fresh in my mind. After each transcription, I read the transcribed interview again. In a third part, I was listening the conversation taking the most incremental notes as a first piece of coding the data.

# 3.4.1 Coding the data

When working with the data, I found my study to be based on a theoretical frame of reference, adopting the deductive work process. With the basis of the theoretical knowledge I was trying to identify and examine the relevance of these theories in the context of the cultural phenomenon being studying, as Rasmussen et al. (2006) recommend. I was able to connect the interviews with the already known theory but the data analysis helped me achieve even greater knowledge in the data that probably do not form part of the theoretical assumptions mentioned in the interview guide. In the analysis part, I felt that my study took on a more inductive way of processing knowledge. As experience from the empirical data was being connected with theories, I identified that knowledge also came from the empirical data. Moreover, new perspectives appeared on the subject that made me able to continue developing the *business model* of my research.

Coding takes place by noting down spots in the interview where something relevant is said about the issue (Rasmussen et al., 2006) and for this study, the first elements of coding held in the interview guide as discussion categories. The discussion categories were therefore connected to theoretical topics from the literature review to the specific cultural context.

In the presentation of data analysis part the researcher should result with how the categorization of the data helps to answer the research question. The set of categories have established in the literature review, after as question categories in the interview guide and lastly as interpretations in the data analysis. A new category can appear as a result of new knowledge discovery but categories are created primarily on the basis of theory (Rasmussen et al., 2006). An interpretation can translate a statement into an applied theory and thus the words in their literal meaning are expressed as a theoretical category with its frame of references.

# 3.4.2 Secondary Data

In addition to the primary data, the data collection method also consisted of secondary data of both qualitative and quantitative nature. That data derived from sources such as: statistics from Statistics Denmark, the European Commission, the Global Competitiveness Index and Odense Robotics Frontier; articles; industry and government reports. Despite the fact that the information from the secondary data was originally collected for a different purpose than this thesis, Saunders et al (2007) argue that this data often has a high degree of quality and is valuable when carrying out research in a specific field.

# 3.6 Trustworthiness of results

Rasmussen et al. (2006) mention that in using qualitative methods, there are not the same strict rules for data analysis as there are when using quantitative methods as the researcher must, of necessity being involved in the process. The assessment of credibility is thus, of major importance and a range of technical features has to be taken into account to identify the needed results. Openness and transparency are central elements in science (Rasmussen et al., 2006). Transparency must be applied to all features of the research process. Lastly, the authors mention that the researcher must assess if the issue has a precise formulation in a relevant frame of reference. The precision of the research problem and the precision of the theoretical background are the basic elements for the trustworthiness of the study.

# 3.7 Verification and Reflection

There are some ways that I used to ensure the quality of the study and to assess its credibility. One target was to depict the knowledge from the theoretical review and the data examination into a specific context as an answer to my research question. One of the first tools for transparency was the categorization of the core topics of research. The reader can have a clear understanding of the main issues of the study having a theoretical review, a contemporary question (interview guide topics) and the analysis of their connection into results.

When the results of the study are presented it is taken for granted that things are as they are shown in the study and the principle of verification becomes a parameter for the credibility of the research. Anyone that conducts a qualitative study can be characterized as not being reflective, as representativity can always be questioned (Rasmussen et al., 2006). Personally, I was conscious that many theories and methods exist in order to examine the subject. Therefore, I had to choose the most capable for describing the issue. The links between the issue, the theory and the method can reflect the quality of the data analysis for answering the research question.

Reflectivity demands awareness in the whole process of the study as the researcher has to take decisions about the formulation of the study. Not only the research question has to be chosen precisely, the researcher has also to decide the best plan to examine the issue using existing theories and models. It is necessary to assess some knowledge of scientific theory or something more than just common sense and to match the knowledge with the issue to fight against the lack of theoretical basis (Rasmussen et al., 2006).

The first point is the assessment of the theoretical foundation to make clear what is known for the subject. The next point in the evaluation is the connection between the theoretical foundation and the interview guide. Documents should be able to explain how the data analysis has been carried out, to give examples of coding and condensation of meaning, to clarify the process from data collection via analysis to conclusions (Rasmussen et al., 2006). The final report should be able to illustrate the processes, the methods and the frameworks applied.

In the next chapter I shall apply the theoretical framework to the case of Odense Robotics. More precisely, first of all, I shall apply Porter’s diamond model in order to see the environment of the Odense Robotics cluster. Afterwards, I shall introduce the Danish innovation system in order to complete the image of the environment and innovation. Moreover, I will examine the structural characteristics of the cluster, its actors and the relations and interactions between them, before moving on to the ability of the cluster to be global. Lastly, the chapter of the discussion will [….]

# Chapter 4: Analysis

Introductory paragraph saying blah blah

# 4.1 Diamond analysis of the Odense Robotics Cluster

The empirical portion of the master thesis includes an analysis of the Odense Robotics cluster environment that I will conduct by utilizing the Porter’s (1990) national diamond model of competitive advantage. I will analyze the quality of the business environment in which Odense robotic companies compete based on the four attributes that promote the creation of competitive advantage as stated in chapter 2 (Theoritical Framework). Porter’s diamond model has the whole nation as the center of its study. However, in my analysis, I shall cover both the nation conditions as well as the regional ones that affect the Odense robotics environment.

After conducting the interviews, I have identified different specialized conditions that are of major importance for the robotic industry.

# 4.1.1 Factor Conditions

In each of the interviews that I conducted, I asked the respondents what business environment factors they considered as the most important success factors for the growing robotic industry (Appendix something). Most interviewees addressed as the most important factors conditions the human, knowledge and capital resources that I will analyze accordingly. The examination of infrastructure for the robotic industry will complete the factor conditions analysis.

In general, one can find **knowledge resources** in universities, public and private research facilities, government agencies and other sources of knowledge (Michael E. Porter, 1990). In Denmark, knowledge resources exist both at a national and a cluster or regional level.

In 2011, at a national level, public spending on education relative to GDP was observed in Denmark as 8.8 % of GDP the highest among European countries (Eurostat, 2012). SDU has approximately 15 relevant academic and engineering programs in robot and software technology. To this, I can add the Lillabaelt Academy (EAL) which has 10 relevant bachelor programs in automation manufacturing and IT (both entities are located in Odense). These programs supply the robotics cluster with a flow of skilled pool of human capital. The establishment of the MMMI in 1997 is another example of knowledge resource that can be found locally in the region of Odense and can strengthen the robotic ecosystem.

The A.P. Møller foundation donated 80 million DKK to SDU, the biggest donation that a Danish university had ever received at that time (1997) (Steno, 2016). The Institute's research is application-oriented and involves a wide range of Danish and international large, small and medium-sized enterprises with collaboration from research employees that both produce knowledge and excel the human capital attributes. Except from research projects, MMMI offers 4 bachelor, 3 master’s and 5 PhD programs for educations (“The Maersk Mc-Kinney Moller Institute - Syddansk Universitet,” n.d.).

Knowledge resources are concentrated around Odense in the robotic industry. DTI is an independent and non-profit institution that develops, applies and disseminates research-based and technology-based knowledge to the Danish business sector (DTI Annual Report, 2015). According to the DTI Annual Report (2015), the institution participates in development projects of public utility, performs consultancy and standardization activities and works together with new and existing enterprises. Their most important task is to ensure that new knowledge and technology can be quickly converted into value for end costumes. The development of the Funen robot cluster forced DTI, in 2006, to set up the DTI-RT in Odense. By now it has a staff of more than 85 robotic experts and more than 125 robotic projects in its portfolio (“Robot Technology - About DTI,” n.d.). Indeed, many of the respondents mentioned both DTI and DTI-RT as knowledge providers for the robotic environment in Odense.

**Human resources** refer to the quantity, skills and cost of personnel (Michael E. Porter, 1990). Robotics and automation industry is a highly intensive, knowledge-based, industry and growth depends on successful research and innovation. Therefore, one can assume that the robotics industry is an industry that requires specialized knowledge and skills, something that exists in the Danish society.

Denmark has a highly performing labor market with a high employment rate and low unemployment (European Commission, 2016). As the informants mentioned, specialized human resources are ‘produced’ by the educational system in Denmark and can support the robotic industry. Furthermore, a high proportion of specialists (that hold knowledge, experience, and skills) are moving inside the cluster, as Lars-Peter explained in the quote below:

*A lot of, also students, first of all, they end up in the companies around. But there are also former colleagues which end up at around and then there are the university's spin-offs.*

It seems that the specialists’ knowledge helps the cluster environment grow. Indeed, many interviewees mentioned specialists as an advantage for the cluster environment as they spread their knowledge and at many times they create new companies. In Odense, those resources come from the academic personnel or from people from the industry that have gained experience from their long-term cooperation with the robotic technology. Knowledge and research staff that work for the university or for IFCs can feed the cluster with active human resources.

The quantity of personnel appears to be one into question for factor conditions, in the Odense Robotics cluster. All the interviewees mentioned that in the near future they will need human capital in different positions. Odense Robotics Frontier expects significant growth in employment until 2020. They estimate that companies will employ more than 3.000 of the total 2.200 that are today (Odense Robotics, 2015). Mikkel Christoffersen from the same organization stated that the companies will reach that number possibly until 2017 as the industry is growing very fast:

*We just did a survey asking them what candidates they need in the next year. On a really specific competence level. And we have identified 500 roles that the companies know already now they have to put--. To attract people within a year.*

**Capital resources** represent the amount and cost of capital available to finance the industry (Michael E. Porter, 1990). Denmark remains one of the most stable economies in the EU, as proven by its “AAA” ratings from the global credit-analysis agencies Moody’s and Standard & Poor’s (“Denmark | Credit Rating,” n.d.). According to the Danish Bankers Association, until 2012 the financial sector accounted for 11 percent of the business community’s total investment showing that the banks increasingly engage in research collaboration with universities and other knowledge institutions (The financial Denmark, 2015).

All the interviewees mentioned the importance of capital resources and agreed that they are accessible in the robotics environment. Financial resources are essential for the development and growth of the robotic cluster as there are high costs in the product development and research. Public-oriented national foundations were the most mentioned sources of financing such as Innovation Fund Denmark (Innovationsfonden) (IFD), and The Danish Growth Fund (Vækstfonden) (DGF) but also regional funds such as the Southdanish Technological Innovation (SDTI) (Syddansk Innovation). Casper illustrated his point of view about capital resources.

*In my opinion--. At least from our journey, the money hasn’t been a problem that much. There are quite many opportunities here in Denmark to get also free money. Grants, foundations, etc.*

IFD was established in April 2014 following a broad party-political agreement to consolidate three existing national funding bodies within a single new entity. This agreement was made to create one large innovation foundation of 1.5 billion kroner annually to ensure that significant investments in research and development result in concrete solutions to societal challenges, growth and jobs (“Innovation Fund Denmark’s strategy,” 2015). IFD forms part of the Danish Innovation system, which consists of a number of public and private-sector stakeholders. Most of the interviewees talked about public funding and many of them used the term *soft money* as illustrated below.

Mikkel: *In a Danish context sometimes with the startups we talk about soft money. Soft money Yeah {laughs}. Is a term if--.So is really helpful for the startups that they can apply for publicly funding in an early stage. So what we deliver to them is also publicly funded. All the resources and being a part of our startup hub. This is also publicly funded.*

The DGF is also a Danish state’s investment fund that together with private investors co-finances companies to promote growth and renewal for small and medium-sized enterprises in order to achieve a greater socio-economic return (“Objectives and strategy,” n.d.). In their website, DGF claims that every time DGF invests 1 DKK via a fund, the companies that receive funding will ultimately receive more than 10 DKK, because they also attract private interest. This fact shows the involvement of the private sector in funding. In 2014, the Venture capital market analysis of DGF showed that the Danish investors are investing at the early stages of the firms’ development as more than 90 percent of the 37 initial investments in 2013 were in firms at the seed or start-up stage (“The Danish VC tmarket 2014,” n.d.). However, the study showed a decrease in the VC investors in the Danish VC market from a peak of more than 50 in 2001 to a low of about 20 in 2014.

There is quite a unique proposition of **infrastructure** around the robotics industry in Odense. It is the municipality’s decision to transform Odense from a major Danish city into a Danish metropolis, by investing 34 billion DKK in a strategic urban development plan over the period of 2012-2022 as Anker Boye (the Mayor of Odense) stated (Steno, 2016). Infrastructure is the type, quality and user cost constructions available in the business environment, which affects the quality of life and the attractiveness of a nation as a place to work and live (Michael E. Porter, 1990).

The interviewees directly mentioned the importance of infrastructure for the development of the robotic environment in Fynen. The Science Park (Forskerparken) and Odense Knowledge city (Videnbyen) are power centers for welfare, robot technology and business. Videnbyen is a new building near SDU, established in September 2015 as a new house for talents and entrepreneurship. The Science Park opened in 1992 and now houses 60 companies, institutions and centers with over 500 employees but also hosts the Odense robotics startup hub. The park consists of offices, laboratories, innovation center, showroom, multimedia rooms and auditorium that support also the business environment around robotics (“Welcome: Syddansk Research,” n.d.).

Odense Robotics StartUp Hub is a new robot startup accelerator program to support companies at an early stage so that they are prepared to cooperate with one or more private or institutional investors funded by Odense Robotics frontier, the Danish Technological Institute and the Municipality of Odense, in December 2015 (“Odense Robotics StartUp Hub” n.d.). Mikkel explained the function of the startup hub as an entity that helps new entry businesses in the industry but also the statupers of the interviews enjoyed free office space and collaboration into those infrastructures.

Mikkel: *We have a set up for startups .We help startups to build their prototype, Robotic prototype. We help them to set up product, costumers. We help them set up partnerships with established robotic companies and finally we help them to find investors when they are ready.*

*Casper: It was actually --. When we came into this program we got free Office Space at the Science Park. There was kind of the included in the program.so through this entrepreneurial program, we were located at the Science Park and in the Science Park we met all these people at Odense Robotics and Udvikling Fyn.*

As one can see, in the case of Odense Robotics, factors conditions are strong. More precisely, they were either noticed by the interviewees themselves or became apparent from the secondary data. Those factor conditions are: knowledge-, human-, capital resources, and infrastructure. Those conditions were the more obvious factor conditions in my study and support the environment around robotics, building the backbone of the Odense Robotics cluster. In the next sub-chapter, I shall analyze Odense Robotics’ demand conditions, the second element of Porter’s diamond model.

# 4.1.2 Demand conditions

The mix and character of home buyer needs is the most important influence on competitive advantage as the home demand gives to local firms a clearer or earlier picture of buyer needs that foreign rivals cannot have (Michael E. Porter, 1990).

According to International Federation of Robotics (IFR), the robot density in Denmark is among the highest in the world capturing the fifth position where 166 robots are employed per 10.000 people in the manufacturing industry despite the fact that Denmark is not competing in the automotive industry, an industry that takes the lead in robot applications (“GlobalRobot density IFR,” 2014). Moreover, according to an analysis by the DTI, only 4 percent of the Danish enterprises have made a serious investment in robotics but expects that in the next five years 115.000 workers in Danish companies will be familiar with working with robots (Steno, 2016).

According to the interviewees there are two main factors that foster the demand conditions in the environment of the Odense Robotics ecosystem. The first factor is the large number of established companies that implement robotic solutions in the manufacturing industry: the *integrators*. The second factor is the remarkable success of companies such as UR. Based on the latter, the significant growth of the company leaves space for other actors to make business in the related market. Those actors take advantage of the large sales network of UR as they can sell components directly to an end costumer that has employed a UR robotic arm. This is a factor that can raise the home demand conditions as Mikkel, the 46 years old business manager of Odense Robotics frontier described:

*For instance, On Robot, a small company who has a lot of success now. They have been here for one and a half year. They are doing small engineer grippers which function on Universal arm for instance. And they are sort of piggy begging on the UR global market access.*

On the other hand, is what all of the responders mentioned as integrators. Integrators are the companies involved in integrating the robots at the end customer (Steno, 2016). The integrators are well-established companies with experience in designing, installing and servicing robotic and automation solutions and have been established since the creation of business agglomeration in Odense.

*Jimmy: Right now we are building products as cases for companies. We want to sell our software as a platform to system integrators that they can then build on top of that and sell it to others. […] System integrators. So they create robot solutions for customers. That is the system integrators so--. It could be Gibotech they have Fanuc Robots and then they could solve some problems for the customers using their Fanuc Robots. And then they sell. That is the system integrators.*

Home buyers can pressure local firms to innovate faster and achieve more sophisticated competitive advantages (Michael E. Porter, 1990). The public sector is a stable source of home demand for the Odense Robotics ecosystem. The project *Patient at Home,* for example, aims to develop 40 new welfare-technology products and services that can reduce the number and duration of hospital stays in Denmark (“Patientathome Project,” n.d.; Steno, 2016). This public initiative can contribute in raising the home demand point to future needs and press companies to continuously develop new products.

According to the interviewees, the factors that raised the home demand for robotics are: the public sector’s needs, the function of the integrators inside the ecosystem, and also the demand that successful companies are creating. In this sub-chapter I have analyzed Odense Robotics’ demand conditions, as the second element in Porter’s diamond model. In the next sub-chapter, I shall analyze the third element, mainly: related and supporting industries of the robotic industry environment.

# 4.1.3 Related and Supporting Industries

The presence in a nation of supplier or related industries that are internationally competitive is the third determinant of the Porter’s 1990 diamond. In the case of the robotics industry around Odense, there are also related and supporting industries.

*Scape Technologies A/S* was founded in 2004 after many years of research and development at the University of Southern Denmark and shortly after the company’s establishment, a partnership between the leading pump manufacturers *Grundfos A/S* came into the surface (“Scape tech History,” n.d.). Grundfos is one of the world’s leading pump manufacturers (“Facts about Grundfos | Grundfos,” n.d.) and the partnership with the young Scape Technologies established for the development of the bin-picker robot project. In this case, the local presence of related industry affects the competitiveness of the cluster. This is because, now, Scape robots are in active use at the Volkswagen factories in Germany, and Chinese investors have put also money in the company (Steno, 2016). Indeed, one of the interviewees, Anders, also expressed an example for the presence of related and supporting industries into the cluster, this time related to Danfoss, a company that is working with DTI-RT but does not have its main business in robotics.

*Well, in current research projects, we have..- we 're working together with Danfoss in... that is big thermostat factories that make these thermostats and there is some more number of research projects in the University, but this research projects are based on how do you do camera configuration, how do you plan perfect robot motions to do a task.* [...]

According to RoboGlobal the related technologies around robotics are sensing, processing, actuation, computing and integration (“ROBO Global,” 2016). This concept is illustrated in Figure 8. The responders mentioned the existence of robot actuation with the manufacturers and robotic integration to exist as related industries. There are companies that cooperate with the rest of the technologies such as Sensohive with sensing and CorePath Robotics with computing and programing but according to the data there are not yet significant industries around them. The global penetration of Universal Robots makes a stream for the creation of related industries.



Figure 8. Components that enable robots to sense, plan, and act

The linkages in the value chains of firms and their suppliers are important to competitive advantage and they are facilitated if the essential activities and senior management of suppliers are located nearby (Michael E. Porter, 1990). According to the interviewees, local suppliers exist to some extent around Fyn but the globalized market lets the space search for the most efficient way of building their products.

*Casper: For example our plastic supplier is 5 km from here and we were actually working together with companies in China.*

*Tommy:* *We asked some local companies here in Odense and it was very expensive. If they should do it maybe cost, I don’t know, 30000 and this guy did it for 1500.*

According to the theory, robotics is a technology that, by default, needs related and supporting industries to function. Also in the case of Odense, we have examples companies that operate as related and supporting industries to the Odense Robotics ecosystem. It is worth mentioning that those companies’ core business is different from robotics. Nevertheless, they utilize robotics in order to maximize their capabilities and production efficiency. This sub-chapter covered the third element of Porter’s diamond model. In the next sub-chapter, I shall analyze the fourth component of the model: firm strategy, structure and rivalry.

# 4.1.4 Firm Strategy, structure and Rivalry

The fourth determinant of national competitive advantage in an industry is the context in which firms are created, organized and managed and the nature of the local rivalry (Michael E. Porter, 1990).

Domestic rivalry in the case of Odense Robotics is not significant, according to the data. The interviewees mentioned that the collaboration between different stakeholders outstand in the robotic environment. Due to the fact that companies are very specialized, more room for local collaboration exists and companies rely on regional research collaborations. Rivalry can be found around the competition that local companies have for external resources, such as access to capital and acquisition of human talent, and not so much for products.

Anders*: There is a lot of competition between candidates, I mean Universal Robots is recruiting a lot, real recruiting a lot, so actually finding good, clever people is quite difficult. […] so it's a quite..- so it's not a war, it's a positive situation because it really creates the market and creates a lot of young people to seek into this business.*

Porter (1990) states that the motivations of the individuals who manage and work in firms can enhance from success in particular industries. Indeed, in Odense, the resent success of UR and the well being of other companies have created strong role models in the cluster showing the feasibility of international competitiveness to other actors. Those role models affect new business creation in the robotic cluster but also work as determinants for structure and organization of new entry firms. IFCs mentor young startups on how to organize and scale up their companies based on these industrial role models. After all, the companies can set their goals according to their capabilities in the framework of patterns that others have passed in the ecosystem.

Mikkel: *But what we have in Odense is some really strong role models. So we have companies who have really done that with success. And we can show those companies to the startups and say ok here is a role model how they have done it in UR. How they do it in MiR. How has OnRobots done it? How is Effimat done it?*

Entrepreneurship is an important determinant for increasing rivalry and the Danish government has set the right initiatives to foster it. Government provides funding to foster startup activity and several stakeholders from private and public sectors are involved. According to Jimmy, the CEO of CorePath Robotics, SDU and SDTI are the prime owners of the company that has also received 1 million Danish DKK funding from the European Union’s Automation boost program. SDTI is an innovation incubator in the region of Southern Denmark that also was involved in the establishment of UR in 2005 (Steno, 2016). Those diversified ownership structures, with public and private capital, show the potentials both for companies and the state to contribute in high potential ideas for commercialization.

In this sub-chapter I have identified which elements influence the firms’ strategy, structure, and rivalry, in the case of the robotics industry around Odense. This was the fourth component of Porter’s diamond model. According to the data from the interviews and the secondary data, I have identified that firms’ strategy and structure is very much affected by the environment. Furthermore, the rivalry’s effect on it is limited but not insignificant. In the next two sections, I shall examine the effects that chance and the government have into the whole diamond model, in the case of Odense Robotics.

**Chance**

In general, chance events can have a significant effect. However, in this case chance is not the core basis of discussion. Jimmy illustrated the point of chance when I asked him about the reasons of the success of UR.

*Interviewer: What is your thought about UR success?*

*Jimmy: So I know Esben Ostergaard the CTO. They spanned out of the university. I've seen them in the labs over all the years. So I kind of know their development there. If you ask Esben I think he will say that they got lucky [laughs]. I've heard him say that.*

This quote shows that some stakeholders connect chance with success. On the other hand, chance can also be connected with failure. For Odense Robotics, chance can also be connected with timing. Many interviewers had the concept of what is the right time and speed for their organizations. However, I did not find further data that can shed more light on the effect of chance on Odense Robotics.

**Government**

Government can both influence and be influenced by the other determinants of the diamond. Public involvement is one of the characteristics in the Odense robotics cluster. The state affects factor conditions with the strong presence of capital resources driven into the economy, acting as venture capital fund. Many knowledge resources are also publicly owned, as the example of SDU shows: SDU is a public entity. The government participates also in the demand conditions creating home demand for robotic products for application in the welfare system. Government policy can also influence firm strategy, structure and rivalry by participating in the ownership shapes of firms*.*

So far, I have applied the four main components of Porter’s diamond model to the case of Odense Robotics. Additionally I have identified the role of the role of the government and of chance. Overall, I have found that all four elements exist in the case of Odense Robotics: factor conditions, demand conditions, firm strategy, structure, and rivalry, related and supporting industries. Support of this fact came primarily from the interviews, but also from analysis of secondary data.

In general, Porter’s diamond model can assist in the examination of the Odense Robotics environment. However, it is worth shedding more light in the participation of the government in the environment formation of Odense Robotics. This is due to the fact that the government is fostering innovation through innovation policies. Seeing as Porter’s diamond model does not include this kind of analysis, it is important to turn to other frameworks, such as the Innovation Systems framework, that follows in the next chapter.

# 4.2 Danish Innovation systems

Danish government has set initiatives for being competitive through productivity raise. According to the World’s economic forum Global Competitiveness Report 2015–2016, Danish most problematic factors for doing business are the taxes rates and the complexity of tax regulations. The Report on Growth and Competitiveness by the Danish ministry of business and growth 2016, identifies that despite Denmark has a high level of prosperity, growth in productivity has been relatively weak. High productivity growth is a precondition for Denmark to keep up a steady rise in standards of living and maintain a high level of prosperity by international standards. The report shows that Danish government has adopted a policy towards productivity with three main pillars as focus the Industrialization 4.0, the generation growth and the new global economy programs.

The model of establishing time limited process and institutions to deal with specific issues relating to Danish competitiveness has worked well, in combination with ongoing analysis of the Danish economy from economic agencies(Ketels, 2016). Government sponsorship and involvement means that they are well integrated into the policy process, and the three examples discussed above have had meaningful impact on policy choices.(Ketels, 2016) However, this model does mean that there is not an independent body with strong economic capacity to engage on competitiveness issues on an ongoing basis and to shape the policy debate and agenda.(Ketels, 2016)

The above diamond analysis could be applied in three different levels based on the concept of notional (NIS), regional (RSI) and sectoral innovation systems (SIS) as discussed in the literature review. Three diamonds could appear in the previous section. The first could be attached to the analysis of the whole Danish competitive environment the second could contain the regional characteristics that contribute in competitiveness including the region of Southern Denmark and possibly the broad Jutland-Funen territory (Rushforth, Jørgensen, Arbo, & Puukka, 2006) and the latter as a focus on the cluster policy in the sector of Odense and its Robotics ecosystem, locally. The identification of the innovation system boundaries is crucial for the study of the total system that Odense Robotics cluster is a part of it.

According to Edquist 2005, a system of innovation refers to the determinants of innovation process, and is formed by all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovation. The approaches of National innovation system (NIS), regional innovation system (RIS) and sectoral innovation system (SIS) can be viewed as complementing each other rather than excluding each other (Edquist, 1997). Figure X, provides a simple representation Danish innovation system boundaries that includes the national innovation policy for competitiveness that is distributed to regional innovation initiatives before it concludes to cluster’s formation.

Figure 9 The Danish Innovation Systems

National innovation systems are crucial for understanding national competitiveness and competitive advantage (Edquist, 2001). According to the Research and Innovation Observatory Denmark country report of 2015, the Danish research & innovation (R&I) system has expanded over the last 20 years and its R&D intensity is now one of the highest in the EU but there are concerns about the Danish economy surrounding weak productivity growth. Denmark's Innovation Strategy 2012-2020 aims to shift to a demand-driven innovation policy, enhancing knowledge flows and improving education (“European Commission-RIO,” 2016). European Commission's Innovation Scoreboard, 2015 identifies the main challenges for Denmark’s innovation system. Those are measures to increase university-industry collaboration and improve commercialization of public research, increase the quality and availability of human resources in research and innovation and to support innovation in order to boost productivity (“European Commission-RIO,” 2016)

Danish government has set up initiatives to strength the nation’s competitive advantages in three pillars. Initiatives that target private R&D investments and public research commercialization are supported by the Innovation Fund Denmark with its InnoBooster program for SMEs to interact with public science, and innovation networks to support demonstration facilities(“European Commission-RIO,” 2016). CorePath robotics the university spin off company participated in the InnoBooster program receiving funds of 1 million Danish kroner. SensoHive got also into national financial support from the program Entrepreneurial Pilots for young graduates who wish to explore the possibility of creating a start-up under the Innovation Fund Denmark.

Denmark’s national innovation strategy includes also a range of initiatives to increase innovation capacity through education. The Innovation Centre Denmark-Silicon Valley established in 2006 in order to bridge companies, research institutions and capital in Denmark and Silicon Valley. This initiative can accelerate the entry of Danish companies into Silicon Valley and promote US investments in Denmark but also can facilitate research cooperation and provide inspiration to drive innovation in Denmark. Innovation Centre Denmark (ICDK) is a partnership between the Ministry of Higher Education and Science and the Ministry of Foreign Affairs of Denmark having another five innovation centers around the word (“ICDK,” n.d.).

Stronger productivity growth is a challenge for Denmark. The government set up an independent Productivity Commission giving high priorities in R&D programs. Innovation Fund provides efficient and effective funding for research and innovation and the Growth Fund is supporting on-going business development in sectors of high societal importance. Moreover, the government published specific growth plans to address barriers on investments and focus on areas in which new markets can be developed. Those strategic plans include the following areas: Blue Denmark, Creative Industries and Design, Water, Bio and Environmental Solutions, Health and Care solutions, Energy and Climate, Food Sector, Tourism and Experience Economy and a growth plan for ICT and Digital Growth.(“European Commission-RIO,” 2016)

The RIS boundaries should be defined on the basis of coherence in the region and not administrative boundaries representing a level of learning spill-overs, skilled workers and a minimum level of collaborations between organizations (C. Edquist, 2001). The region of Southern Denmark is capturing Odense robotics cluster as the main businesses are located around the island of Fynen. The region of Southern Denmark has a population of 1.2 million people, which corresponds to 21% of the Danish population (CamillaHansen, 2012). The most important organization for developing and implementing the regional strategies is the Southern Denmark Growth Forum targeting to influence the commercial development of the region. According to Region Syddanmark, the regional business development strategy is financed with 75% from the central government and 25% from the municipalities. This fact shows the link between national and regional innovation system.

The growth forum has prepared a development strategy and an action plan that focuses on initiatives within areas such as sustainable energy, experience economy and welfare and health innovation. Developing Fyn (Udvikling Fyn) and SDTI (Syddansk Innovation) are two entities focused in the regional competitive advantages trying to facilitate the procedures for growth and innovation in specific areas of interest where local industries meet high potentials.

A sectoral innovation system is a system constituted by parts of a RIS or NIS and it is delimited to a specific technology field or product area as well as a geographical delimitation (C. Edquist, 2001). Odense robotics cluster lends institutional resources from the two broader innovation systems to construct its own policy indicators for growth and innovation. As the figure X shows the innovation systems are organized from the top to the bottom and each one includes characteristics of the upper. Capital resources are following the top-bottom path as the primary capital resources are coming from the central government’s national innovation system.

The distinction between the three innovation systems and the interdependencies among them helps the study to understand the value creation that is driven by the top policies. A sectoral innovation system is formulated by using resources and policy initiatives that are pre-constructed. The national innovation system can explain the rapid funding that Sensohive awarded only one month after its foundation. The regional innovation system identified early the potentials of Universal Robots facilitating its growth progress also by providing funds through SDTI in 2005. Sectoral innovation systems have a more specialized role as they capture the unique attributes of a specific technology building on that a framework for growth and development.

# 4.3 The Triple Helix Model

The Triple Helix model is functioning in Odense Robotics cluster. It adopts the configuration that is depicted in Figure 9 in which the innovative environment consists of university spin-offs, tri-lateral initiatives, and strategic alliances between the actors (Etzkowitz & Leydesdorff, 2000).

All the participants in the study, where moving inside the three Helices that the cycles of Academia, State and Industry create. Both the researchers (Lalrs-Peter and Mathias) in the helix of academia have strong collaboration with the industry helix as private companies are those which finance their research work. The Danish Technological institution, RoboCluster and Odense Robotics have their boarders inside the trilateral space in the core of the systems as they represent agreements between duo lateral or tri lateral initiatives. The 1990’s AMROSE project can be characterize as the first result of the collaboration between Industry, State and University showing that seeds for the tri-lateral networks and hybrid organizations adopted early in the cluster.

Figure 10 Odense Robotics Triple Helix

Despite the diversity of the participants in the study all of them have cooperation with other Helices where ever they were belonging. They either got soft funding from state financing organization, private funding, mentoring from ICTs or they used knowledge resources from the university to develop their ideas into innovative products. CorePath robotics is a university’s spin off company that born in the core of Odense Robotic cluster. The company used resources from the trilateral space being based in University of Southern Denmark and financed by public and private organizations. Mikel in our interview stated that Odense Robotics cluster is a true example of Triple Helix collaboration.

*Mikkel: So we actually have a lot of innovative companies. We have strong educational research and we have public sector the municipality primary which supports this triple helix.* So *this is actually a functional Triple Helix network. And a lot of people are saying that 'oh I want to build that' but it is actually working here. I think this is very significant. So I think the triple Helix together with the openness to collaborate with other companies are really key to the success here in Odense*.

Each of these entities may have strong preposition in their field and the key to innovation comes through the communication between them. When I asked Bjarke what innovation is in his opinion he answered that innovation is to bring together University and Private company persons as they very seldom interact with each other. As a consequence of this collaboration new technologies will raise as the knowledge transfer will be facilitated. Bjarke despite the fact that does not include the state sphere in his words connects innovation with the collaboration of University with industry persons. RoboCluster as a ‘glue’ organization have the target to bring those entities together with their frictions to produce innovations. The government is the one that produces this ‘glue’ bringing its innovation policy with the other Helices of Triple Helix model.

*Bjarke: The easy answer is the society helps the environment in Odense, the cluster because of the large donation of innovation projects. The whole innovative environment that Robocluster is a part of-- We are seeking money in a region and in a national foundation and they are providing money for lifting the innovation But also--This is more like--This is the core of innovation projects is that the government and the region provide money to it.*

Anders from DTI-RT has also the same view about the connection of the cluster’s stakeholders. He characterized DTI as a bridging organization between university and industry but he also leaves the state out of the context of the discussion.

Anders: *So in that sense we are a lot of connection between the start-up companies, between the industry, between the Universities and it's pretty much our key role to facilitate this bridging and to develop the technologies. Close the missing gaps between what's coming from research and what are the needs and requirements from the Industry. Make sure that the whole thing works. So in that sense we are bringing commercialization.*

With the focus on Triple Helix model in Odense Robotics cluster the interaction between University and Industry can produce innovative results and government organizations fosters the trilateral collaboration.

# 4.4 Odense Robotics Cluster

# 4.4.1 Actors and their role in Odense Robotics cluster

The analysis of the Odense robotics cluster will be based on the design that Odense Robotics frontier provided in February 2016(Appendix 4). The cluster actors will be divided into five categories according to (Andersson et al., 2004) representation analyzed in the theoretical framework of the thesis. The interviewees were asked to comment on the key actors in the cluster, as a detailed picture of the whole system actors was already known. I collected different answers to this specific question that will be analyzed together with the snowball stemma of the next chapter.

According to Odense robotics frontier 2016 mapping, the cluster consists of 83 companies related to the robotic industry that employ around 2200 employees. 800 of these employees work on developing robots and related components and another 950 in companies that integrate robot solutions to the end customers (Steno, 2016). According to Steno, 2016 five companies have more than 100 employees (for example Universal robots and ABB) and another 10 have between 50 and 100 employees. The rests, are firms with little or very little personnel. According to that, the main technologies that the cluster develops are on integration and actuation of robots. The remaining companies have their business in the domains of automation, sensors, and software or they are specialized partners and others employing the rest 350 personnel.

**IFC**

**Financing**

**Academia**

**Companies**

Figure 11 Odense Robotics Cluster actors

The Research community or Academia has as the main knowledge resource the University of Southern Denmark. The university provides education in robot technologies with a number of offered degrees but also provides research programs for specialization in the field. The Maersk Mc-Kinney Moller Institute (MMMI) constitutes an entity that thrives on historical significance for the cluster itself due to the early establishment in 1997 that came into practice from private initiatives. The institute became the house of robotic research in Odense from where also Universal Robots has started(Steno, 2016). Moreover the Lillebaelt Academy, the largest business academy in the Region of Southern Denmark(“EAL. About us,” n.d.) is an important actor for the cluster having 10 relevant bachelor programs in automation manufacturing and IT.

My presentation of the cluster actors in Figure 8 deviates from the one that (Andersson et al., 2004; Sölvell et al., 2003) provided and is illustrated in Figure X in the theoretical part. The reason for this alternation is that I find financing and IFCs to be influenced from the Danish Systems of Innovation. State initiatives are translated into financing or establishments of Institutes for collaboration. Public sector is presented with the cycle ‘state’ in the Figure 8 and can be either the municipality Odense in the sectoral level, the county of Southern Denmark regionally or the Danish government nationally as presented in Figure 7 on Danish innovation systems analysis. The state creates organizations positing in IFCs and financing to explain its involvement in the cluster as a bridge to reach industry and Academia.

A great example is RoboCluster the first network organization that put officially the word ‘cluster’ in the Odense robotics ecosystem. Probably the Robocluster establishment in 2002 was the moment that the cluster recognized as ‘cluster’ in the robotic environment. The initiative was supported by the University of Southern Denmark, Odense Technical College, the former County of Funen, Odense Municipality and the Ministry of Science as a so-called growth environment based at the Maersk Mc-Kinney Moller Institute (“History- RoboCluster,” n.d.). The theory is confirmed here that public initiatives more frequently promote cluster development (Andersson et al., 2004; Sölvell et al., 2003) but also the three innovation systems(sectoral, regional and national) cooperate to form the first IFC. Following the example, in 2006 RoboCluster added regional partners to the group processing from sectoral to regional level and in 2008 until today is recognized as a national innovation network for robots, automation and intelligent systems (“History- RoboCluster,” n.d.) that connects the Danes.

The state put also the foundations for constant capital flow in the cluster. In 2005 the Advanced Technology foundation started to promote application focused research allocating 1 billion kroner per year (500million public and 500 million private) in research projects (Steno, 2016). Advanced Technology foundation was one of the three national funding bodies that formed Innovation Fund Denmark (IFD) in 2014 (“Innovation Fund Denmark’s strategy,” 2015) which now investing 1.5 billion kroner annually in research and development projects. Additionally, Odense Robotics frontier categorizes the financing actors in national and regional funds supporting my claim that regional and national systems of innovation (the state) financing the cluster. IFD and Vaekstfonden are the most recognized foundations nationally that support a broader range of related industries within Denmark.

As a result the main actors in Odense Robotics cluster are University, Industry, IFCs and financing organizations. The state translates its influence in the system with the establishment of organizations IFCs and Finance organizations and in rare occasion’s direct investments. None of the interviewees included the state in the key players of the cluster. Bjarke claimed that University and integrators are the key players in the cluster despite that he finds core of innovation projects is that the government and the region provide money and to it. His opinion about the government is interesting:

*Bjarke: The government is not a receiver. The government is more like a supporter. For me, the government is you know, few persons sitting in Copenhagen. It is in the second role*.

Tommy finds that Odense Robotics frontier is the heart of the cluster as an organ that makes work.

*Ioannis: Which are the main components of the cluster?*

*Tommy: Well there is--. Odense Robotics is actually kind of a--. Do you know Mikkel Christoffersen?*

*Ioannis: Yes. I had an interview with him before.*

*Tommy: He and his team is the people behind--. The people driving the cluster and they are responsible for all the activities. Making sure that people know about the cluster. He was the one that told us about the cluster and help us get into the cluster. So the cluster has a kind of organ that makes sure that the cluster stays alive. And then there are all the companies that get into the cluster. Mikkel and his team are also the ones who makes sure that there is financing --. So we have an office space we can apply for an amount of money for example for producing our electronic parts. They helped us. And he has the same agreement with the local municipalities so they have invested some money in the cluster for these startup hubs.*

University and Industry appeared as the main key players of the cluster. Mathias for instance, finds MMMI the most important actor as it set the research bases for the cluster as a Lindo Shipyard’s descendant along with the successful industry leaders like universal robots. Casper finds the industry as the most critical player in the ecosystem but he admits that his company received more help from governmental organization like IFD and Odense Robotics frontier. Anders explains his views about the key actors in the cluster:

*Anders: So we have of course the University and we have DTI as probably the two larger in the cluster. Of course then we have Universal Robots, as an individual company that now has a lot of employees and they play a powerful role in, especially, the market. They created the belief of there is actually jobs, there is actually..- and that is probably a key driver to filling up the University with new promising students that I can see that now there is really a market and a workplace within Robotics. And the of course we have quite recently, Udvikling Fyn, and always we have Odense Robotics has been established to help facilitating the efforts as well. So to me, these are some other really key players.*

Anders description of the cluster actors includes University, Industry (the UR example) and after that the facilitators DTI, Odense Robotics frontier and Udvikling Fyn. Institutes for collaboration can give directions and mentoring for financial support either private or public. Government again appears in the system as an undercover agent behind collaboration facilitator organizations.

# 4.4.2 Odense robotics Cluster and Innovation

Innovation in Odense Robotic cluster is a fuzzy world as everywhere else that the term innovation is used. Innovation for many of the interviewees is connected with commercialization of an idea to convert knowledge into money. All industry participants in the study answered positively and in a sort time when I asked them if their products are innovative. In their explanations they explained that their products are not radical innovations rather combinations of existing technologies. Their products are not one of the kind and they are already facing the competition from abroad. In a sense they are not building something new rather they are combining technologies that can work better than their competitors. The dialogue with Jimmy illustrates this point.

*Ioannis: Do you find your product innovative?*

*Jimmy: Definitely.*

*Ioannis: For which reasons let's say?*

*Jimmy: Because--Well--Ok--There is not really any products there now which is--. Well, one of them--.Of course, there is a number of products that are trying to get to the same kind of choice. We are talking -- Low series of one of a kind production in process manufacturing. There are different companies that are trying to reach this kind of flexibility from different ways. But in a traditional way. So we are trying to combine online programming with very strong offline software which is really the innovative part here. We are not really--. It's in the software and -- Sort of a concept, a new concept of combining these things with this kind of online planning, because--. Well offline planning-- Offline software has been for many many years. The sensors have been used for many years tools that we use are the same. So it's not-- We didn't create a new piece of hardware but it's a new way to use robots and to think of robots. And also the idea of creating intuitive robotics is not new. Like Universal Robots and MiR that are also here in Odense have that kind of approach. I think On Robots also has this approach that it should be programmed play and everybody should be able to use that robots. This is the same of what we are seeing.*

For Jimmy in the above quotation was difficult to describe why the CorePath product is innovative that depends on the match between new and existing technologies used in an innovative way. Mathias on the other hand stretches the need to distinguish the line between technology development and innovation. He explains:

*Mathias: For my perspective, it (the line between innovation and technical development) is when the new technologies and the ideas take into the commercial world, where it is commercialized and because it is a lot of big ideas and a lot of interesting stuff going on in engineering areas here to University, but innovation is..- in my opinion, is when it's used in real world for something in a new way on new technologies used to.*

Lars-Peter that innovation is a fancy word for coming up with something new and for Anders innovation is created by having new ideas on what to do with technology. The success of Universal Robots influence the cluster participant’s perception in innovation as it is used as an anchor role model for their product types as also is obvious in Jimmy’s above statement. The robot in a box that Universal Robot created with the series of robotic arms made visible for the cluster members to realize that the combination of technologies can produce innovation. Universal Robot arm is a good example of an innovation that the majority of the participants used as example. The product itself created a lot of opportunities for other companies to create innovation on top of that. It also gave the opportunity to take advantage of the large sales network that the company created through its international penetration.

Details about Universal robots effect on innovation. and MiR

* mention how innovation is in general in odense robotics

Innovation in Odense Robotics cluster is seen to be a combination of existing technologies to new applications that can be commercialized into a final product.

* For example: universal robots🡪leader in cobots
* Maybe study some products from the company
* Mention their opinions concerning their products and innovation

# 4.5 Odense Robotics cluster Characteristics

# 4.5.1 Geographical proximity

Geographical proximity is a characteristic of the Odense robotic cluster. Most of the companies have their home bases around the Region of Southern Denmark. The University of Southern Denmark is also located in Odense and many of the institutions for collaboration and research institutes are situated in the region. Proximity mentioned from all the interviewees as one of the main advantage of the cluster that promotes the collaboration and close communication between the cluster’s members.

Figure 10 shows the proximity of the Odense Robotics companies in Denmark. Most of them are located around the city of Odense and the other in the broad region of Southern Denmark inside the borders of Fynen Island.

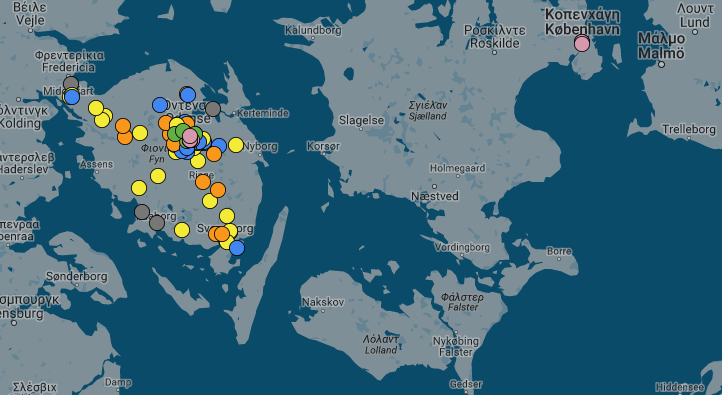


Figure 12. Odense Robotics industry proximity

The proximity of the cluster member was a sensation that I received through the research but was also a profound characteristic. In the procedure of data collection eight out of nine of my interviewees where locating in facilities around the university of Southern Denmark. Those eight interviews were conducted in either the campus of SDU or in the two facilities Forskerparker and Videnbyen the power centers for welfare, robot technology and business. Those three places are located less than 1km far from each other giving me the opportunity to feel that this geographical triangle is the heart of the cluster.

My meeting with Bilge was the only interview that was out from the above borders. Despite the fact that OnRobots is located 3km far for the Odense city center, the talk with Bilge let me understand that clustering was not in a big focus for his company. As he admitted it was hard for him to elaborate with terms around clustering as they were not in a close collaboration with it. It was tough for high to give a definition for the cluster as also to describe the main cluster actors. When I asked him the question about the actors Bilge replied:

*Bilge: I'm sorry I don't know. We don't use the Cluster a lot. We are our own company.*

Geographical proximity matters in Odense Robotics cluster as communication and collaboration is facilitated when moving in the core of it. The Odense Robotics Frontier Startup Hub fosters startup companies to house their business and laboratories but also exploits the advantages of proximity to the technology side. CorePath Robotics found a new application in their neighbor company RoboAtWork. But also the Science Parks infrastructures (forskerparker and Videnbyen) take advantage of the geographical proximity as in one building they are hosting a large number of different entities. Forskerparker for example houses 60 companies, institutions and centers with over 500 employees but also hosts the Odense robotics startup hub. Jimmy gives his sense for being located in the Science Park:

*Jimmy: Yeah. So I think it's-- Right now we are sitting in this takeoff and there is everything from companies that does homepage for pregnant women to companies that do robotics or does sensors or whatever. And that's actually very nice [laughs]. So actually I'm thinking if--. When we grow bigger it could be nice still to have this variation in the skillsets of the people that you share office with. It makes for much more interesting conversations and working environment in my opinion at least becomes much better.*

The positive effects of proximity let Universal Robot to hold its headquarters in Odense after the acquisition of the U.S Teradyne. The company that was founded in the University of Southern Denmark remained in Odense having its own strategic plans in place acting as an independent unit with its own CEO but a pure American board of directors. As a result UR was able to keep in track the established ties with the local market but also to expand its boundaries internationally.

# 4.5.2 Internal versus external linkages

In Odense Robotics cluster the linkages that the players are formulating with the internal and external cluster environment target to easier knowledge sharing. Geographical proximity enables cluster participants to understand the local networking in a meaningful way but globalization and the complexity of robot technology make external linkages as important as local. Internal and external linkages are useful for the actors as a mean to gain and create knowledge (Bathelt et al., 2004).

Odense Robotics holds a combination of local learning processes and distant interactions. I find that the participants exploit their network interactions to the direction that serves their organization’s vision. With being located in the same place many actors’ especially young organizations take advantage of the effortless communication and information sharing. Especially being located in the triangle of University, Foskerparker and Videnbyen in the heart of the cluster, interactions are becoming routine. My interview with Tommy for example was arranged in the canteen of Foskerparker at 12 o’clock on June 29th. The tables in front of the cafeteria were half full with people from the offices around. I could recognize Mikkel the business manager of Odense Robotics frontier having lunch break with three other persons. It was the moment that information flows, gossip and news could move frictionless in the network environment.

Actors especially those working in institutes for collaboration hold an amount of connection that can facilitate the network flow. They are becoming connectors for problem-solving and mentors providing information to their surroundings. Casper in our talk was impressed of the second level network size of the cluster that is the connections that your connections have.

*Casper: And I guess that is the most interesting this and surprises most is how broad a set of different competences and companies that you can find here at Fyn. For example we have produced our first electronic prototypes in China because we didn’t know that was any could actually produce prototypes in electronics in Odense and Fyn. It was actually through the consultants from Odense Robotics (frontier) that they mentioned: Hey why not to talk with, here? There is an electronic company 15 km far from here in the office! And we have found a supplier 20.000 km from here.[…]That was what it surprises me most about the Odense Robotics network is how large the network is behind the network. And not just the 80 companies within robotics but that is the entire second level suppliers. For example our plastic supplier is 5 km from here and we are actually working together with also companies in China. When some people from OR said why you haven't spoken with them and we say why should we know them from?*

The above quotation of Casper shows also the importance of both internal and external linkages. His company was free to address its attention in the global market in order to find the propriety resources to build its product. Sensohive first use the global pipelines to find suppliers abroad and after local buzz let them return locally as was the most profitable choice. I noticed the opposite example in the interview with Tommy.

*Tommy: For mass production we had to customize our electronic board and then we spoke with another company within the cluster called Sensohive. Because they had already passed that step and so they helped us to find some guy who could design the board for us and a manufacturer in Thailand that could give us 10 examples of the board before we ordered 5000.And finding a guy that could make the drawings for us for the electronic boards was time saving. We asked some local companies here in Odense and it was very expensive if they should do it maybe I don’t know 30000 and this guy did it for 1500. The second part is to actually get it manufactured in Thailand would probably never have found the guy in Thailand if we didn't use the network. So that's one way that we learn from the other startups. The other one is that the cluster has a kind of a group of people that are here to support us. And especially on the business development they gave us a lot of support.*

KuboRobot first use the local linkages to find a supplier that fits to the company needs. Those local buzzes showed the direction for a match in the cheaper global market. Another point that both Tommy and Casper stressed is the involvement of people in IFCs in giving directions to cluster actors. They are mentoring companies and organizations on where they should steer their attention.

Odense robotics as an emerging cluster fosters new business creation consisting of many small and startup companies. Those companies employ few people that are mainly engineers that build new robotic technologies. From this point of view, engineers in a new company have also the role to manage their company but naturally they miss knowledge and experience on how to handle administrative and managerial skills for commercialization. IFCs try to fulfil this gap by providing business mentoring in those companies. The interviewees claimed that it is unique in the cluster to have the right business model for a new company’s strategy and ‘glue’ organizations provide knowledge and connections to steer them in the right path.

Mentoring combines a diversified mix of tools that can help companies, especially startups, to achieve sustainable growth. Those tools are mainly internal and external linkages that participants can use for their business development. Connectors from IFCs match competences between cluster actors providing maintenance is sectors that companies need. They provide resources to young firms to apply for public funding or to find private investors but also to set partnerships with existing companies or research institutes for acquiring fit to the ecosystem. In this way cluster participants spread knowledge and information constructed from the local buzz and from the strong role models that Odense Robotics has created from the success of existing companies such as UR and MiR. Mikkel explains how Odense Robotics frontier facilitates the use of internal cluster linkages from new established companies in the ecosystem.

*Mikkel: And then we set them up with partnerships and we help them to build the business plan. So when they have the prototype working and they have the right business plan we send them to investors.*

Internal linkages aid cluster firms in knowledge transition in a wide range of fields. Odense Robotics frontier holds strategic and organizational knowledge but also the connections for funding guidance. Moreover DTI-RT can act as a consultancy company and as a private research organization filling the gap of getting new technologies into the market. RoboCluster as well has a task to distribute the right projects to the right teams but also to seek the right mix of money for that innovation projects. As a result the internal cluster linkages are strong to some extend in the Odense Robotics environment. The existence of high quality and relevance local buzz leads to a more dynamic cluster(Bathelt et al., 2004). The network behind the network that Casper mentioned is probably the external linkages that internal cluster participants hold that can solve many limitations that companies face. The actors in Odense Robotics cluster are surrounded by other actors with relevant or irrelevant skills and competences.

Knowledge is also created in other parts of the world and firms in Odense Robotics cluster build pipelines to such sites to gain competitive advantage. KuboRobot will use Indegogo crowdfunding solution to finance their production parts. OnRobot create its sales network based on linkages that Universal Robots have developed with their distributors. CorePath Robotics is attending conferences and meetings with local and international players in order to increase its network capabilities. Companies generally do not innovate in isolation (Edquist, 1997) and information that one cluster firm can acquire through its pipelines will spill over to other firms in the cluster through local buzz (Bathelt et al., 2004).

Most of the interactions observed in Odense Robotics cluster had a target to commercialize knowledge. The cluster cannot be characterized as too much inward looking or a too much outward-looking structure. Odense Robotics seems to have a well-structured technological knowledge on robotics. Technological based knowledge resources are those used in framing a technology and in that part the cluster superiors with its academic wisdom around robotics. One the commercialization part external linkages, the pipelines, dominate as the knowledge on how to get a product in the market need missing competences.

* Local buzz local face to face interactions
* global pipelines🡪startups have cooperation with China

# 4.5.3 Capital and trust

The interviewees mentioned all the according to Sölvell et al. (2003), three types of capital physical, human and social capital as to be presented in Odense Robotics cluster. Human capital resources around robotics Physical resources such as machinery, components, and digitized information are available in the university’s facilities or in the O.R startup hub in Forskerparken. Many spin offs start developing robots in university facilities before have a reasonable size to go out. Casper I our talk express some limitations that they face in getting restrictions from the university. Those limitations are mentioned from Jimmy as restrictions that the university poses to the people in the use of equipment but also from the point of bureaucracy. As Casper mentioned:

*Casper: We have found a professor within electronics called him and say: Hey i guess you are the right person that maybe can help us. We are a young startup here from university and we used that a couple of times. We succeed every time that we used that approach at least. All the professors opened the door and we came in and helped us find the right resources and maybe some test equipment at the university that we could use maybe not 100% legal but after the rules [laughs]. They gave us access.*

Casper illustrates the open community environment that the participants in the cluster share resources. The scientific personnel from the university is becoming knowledge resource to benefit the participants. The role of academia in social capital is increased and connected with the local linkages. As it seems the university can facilitate knowledge transition. The other point Casper was the limitations that the university organizational structure poses to cluster actors. Jimmy elaborates more on this point and concludes that in the industrial world there is more freedom because the flow of capital resources in higher.

*Jimmy: The problems--I can't speak for everybody of course. At the university, you have a lot of freedom to think and write and talk to others. But there is not a lot of money going in there. If you want to do something it can take a lot of time. To get money, funding you have to apply for funding. It takes a half year, a year. Also the borders of sort of the rules and the whole--. So it is not very hierarchical it's very fluffy what you actually allowed doing and that’s difficult to maneuver in. At least how it is now for me I have a set of quite clearly defined rules with a lot of freedom inside those and funding to actually apply that freedom. If you don't have the funding to do that freedom it not really worth much.*

Key aspect of cluster success is the existence of facilitative social networks, social capital and institutional structures. (Porter, 1998). Social capital is the information, trust and norms of reciprocity inherent in one’s social networks (Woolcock, 1998). Clusters are ‘social technologies’ that enable and support knowledge generation and diffusion between economic actors (Steiner & Hartmann, 2006). Mikkel describes Odense Robotics cluster social capital interactions:

*Mikkel : If we ask the companies in the cluster about collaboration with other companies,85% will say we are really open to collaborate with other companies. And 94 % of the companies will say it is very easy to find partners in Odense. So there is a culture of openness. All the companies have core development object core products. Which is secret and they are not sharing that with anybody. But they have shared vision about creating an ecosystem of companies whose products are valuating to other companies product.*

Trust is high among Odense Robotics cluster participants being eager to share knowledge. The willingness to talk to each other in conferences or in informal interactions improves communication channels. Most of the participants highlighted that they are open to share a large amount of information having a small amount of details that they keep in house. Startups are the most open to share with the cluster environment trying to expand the periphery of the company having a strict core of confidential. Trust and openness create an environment where the participants can feel the superiority of the cluster having shared values and visions.

The participants in the study expressed that there is a shared belief in the cluster potentials to be the frontier for Robotics in Europe. There are shared informal values of the superiority of the cluster but also the intention to promote the nation’s productivity and prosperity. Anders stated that the cluster had also the time for a cultural change on thinking the robots as a prominent business. The fact that were a lot of educated people in Robotics but also Universal Robots that made the success visible cultivated this culture. Actors are active in sharing marketing material and learning experiences with their periphery. Below is Bjarke’s opinion about trust in the cluster.

*Bjarke : The trust is very high among the cluster participants .Very high. Of course, some things must be kept to their own of course but general they are very eager to share knowledge. They are very eager to talk to each other to come if we have a conference and talk here in Robocluster we can just call them and they will gladly come and tell how they have done things*

* when they talk to each other, they are open to discussing but up until one point
* startups are more open to discussion

# 4.5.4 Internal competition and cooperation

As far as the subject goes internal cooperation dominates competition in Odense Robotics cluster. This presents a disadvantage in the cluster, as the theory mentions that competition and rivalry is vital for cluster development (M E Porter, 1998). From the interviewees point of view competition can be found between companies among candidates selection. The shortage of human resources in robot technologies scientists was mentioned as the main problem that the cluster could face in the future. This danger makes companies compete for qualified personnel as Anders states:

*Ioannis: Do you see competition inside the Industry?*

*Anders: We feel quite a lot now. There is a lot of competition between candidates; I mean Universal Robots is recruiting a lot. Really recruiting a lot, so actually finding good, clever people is quite difficult. So we don't see, for now we don't see the competition being--. So the people are really picking out of each other’s companies. So it's a quite...- So it's not a war, it's a positive situation because it really creates the market and creates a lot of young people to seek into this business.*

The robotic industry in Odense does not have also the volume to support high competition as a developing cluster. According to Andersson et al.,(2004) in developing cluster new actors in the same or related activities emerge or are attracted to the region, new linkages develop between all these actors and formal or informal IFCs may enter the field. Universal Robots success did not create competition in the industry but contrary the environment build on the UR success to further exploit the capabilities of collaborative robots. Many companies develop peripherals for UR robotic arms to benefit from the international firm’s sales network. In the robot technology there are several segments of development and at many times the combination of those segments produce new products. Integrators have the role to make complete robot solutions and so an entrepreneur can form an idea on capturing a completely new market share than to compete in an established one.

The few examples of high growth firms in the study support the view of diminishing competition. However, there must have been competition among the companies, as they operate in the same industry and are based in the same geographical area. The research must have not gone that far because of the limited number of participants in the medium sized firms that are also those established many years in the robot environment around Odense. Bilge in his try to formulate a definition for the cluster states:

*Bilge: I would define it (the cluster) as many groups that come together and work on a common case but don't compete but help each other to grow. (thinking) That's an effect, that's not the cluster itself. The cluster is a group of people. (laughing). A group of groups, if we can say so.*

As I mentioned before for Bilge was difficult to elaborate in cluster terms as there are in common use in OnRobots. He puts the observation that the clusters are not competing in the definition that he is trying to create about the cluster phenomenon. This sensation has to be established from the fact that his company does not face internal industry competition but only internationally. The threat that Bilge identifies is if his company’s product is not anymore compatible with the UR robotic arm that is designed to fit in that is irrelevant with direct competition.

Cooperation on the other hand was mentioned from all of the participants in the study. As it was explained in the triple Helix section of the chapter there is collaboration between state, university and academia actors in producing innovations and new technologies. The cooperation is driver through commercialization as the interaction between the participants target into translating knowledge to money. Collaboration could also be strengthening among participants and the university has specific role to that as the one that holds the majority of knowledge around the robot technology. As Lars-Peter states:

*Lars-Peter: I think the role of the university could potentially increase. I think that we know each other as I mentioned before but we do not have any strong collaboration in anyways. For instance with defining projects for students. For instance OR if they talk to companies they could facilitate the contact to the university to help the students get into industrial related projects instead of the university to make arrangements for this thing and the student go out for themselves to look for things. I think that could be one notion.*

Afterwards, many companies are acting as business angels to startups providing their collaboration for mutual development. KuboRobot has for example strong collaboration with Blue Ocean Robotics as they both find a match with each other. Companies such as Blue Ocean try to find companies in an early stage to provide them available resources that have in a big quantity. They have different competences teams that can help startups as Tommy mentions:

*Tommy: Blue ocean robotics also tries to find companies that are in the early stage of startup. And they have a huge team of all kind of competencies. From marketing to product development and from project management to financing. Then we have a relationship where we work with them and they get some equity based on--. Then they give us access to their people. Because we are just two people and we cannot deal with everything on our own*

Partnerships and strong collaboration between companies can in many times be difficult. The industrial interviewees highlighted that large organizations are too busy to devote time in mentoring an incubator. Casper stated that his company used a lot of energy on keeping up the collaboration with companies from the peripheral environment. The peripheral environment have high expectations for collaboration with a young company and for that reason the interviewees mentioned that they miss the industrial knowledge that established organizations acquire. Institutes for collaboration are driving the cluster into the ‘connect and develop’ principle. Acording to Mikkel the role of Odense Robotics frontier is:

*Mikkel: So our role is real to be the starting point or the catalyst for a lot of cooperation between different partners in the cluster.*

* As far as this subject goes, internal competition was not mentioned by the interviewees This presents a disadvantage in the research, as the theory mentions that competition and rivalry is vital for cluster development.
* However , there must have been competition among the companies, as they operate in the same industry and are based in the same geographical area🡪research must have not gone that far because of startups and not big companies.
* Cooperation: the interviewees talked about cooperation. Example: ifcs cooperate because they have meetings and conferences together.

# 4.5.5 Leadership-Entrepreneurship

One of the factors that forces entrepreneurship in Odense Robotics cluster is the establishment of the O.R startup hub in Foskerparken Odense. The new robot startup accelerator hub support companies at an early stage to create the shortest route from prototyping to financing and commercialization. According to Odense Robotics Fortier the Hub is the world’s only robot startup accelerator that doesn’t take shares or ownership interests in a try to further push entrepreneurship. Both CorePath Robotics and KuboRobot were a member of the startup Hub receiving benefits from the program regarding free office space, soft funding, organization mentoring, the entrance in the cluster networks and their marketing exposal.

Entrepreneurship comes also from the university. Universal Robots was a university’s spin off and many other companies were established from teams based on the university research. In this study SensoHive is actually a company founded by students that haven’t still complete their studies. Tommy from KuboRobot had recently finished his master’s degree when we had our interview. His idea for the KuboRobot educational robot came after a project in social technology that he had through his studies. On the other hand CorePath Robotics is another form of an entrepreneurial idea as a university’s spin out. The research behind CorePath Robotics is created by SDU and funded by SDTI. The company gives the opportunity to individuals coming from the University to cultivate their leadership skills by managing these companies. Jimmy was hired as a CEO in the company coming from academia. In our interview he mentioned many attributes of leadership and entrepreneurial skills and aspects that haven’t considered as a researcher.

Jimmy but also Lars Peter that have studied and worked in SDU robotics department both thinks that the university can potentially have stronger position in entrepreneurial process. Jimmy elaborates more on this point and concludes that in the industrial world there is more freedom because the flow of capital resources is higher. Moreover stresses his feelings in the comparison of his work in the University as a researcher and in the Industry as a manager.

*Jimmy: The problems--I can't speak for everybody of course. At the university, you have a lot of freedom to think and write and talk to others. But there is not a lot of money going in there. If you want to do something it can take a lot of time. To get money, funding you have to apply for funding. It takes a half year, a year. Also the borders of sort of the rules and the whole--. So it is not very hierarchical it's very fluffy what you actually allowed doing and that’s difficult to maneuver in. At least how it is now for me I have a set of quite clearly defined rules with a lot of freedom inside those and funding to actually apply that freedom. If you don't have the funding to do that freedom it not really worth much. […]If I had the freedom to hire some people to help me implement something. I didn't have the freedom at the university and I can take decision quite fast now that I couldn't take before. Because it needed to go passed several instances of something and then half year after you might ...*

The interviewees gave examples of people that are moving inside the cluster in different positions and often found new companies. Bilge from OnRobots is an example of entrepreneurship that according to Andersson et al. (2004), took the role of a broker matching competencies to establish his own company.

*Mikkel :What we see now is the former sales and marketing director of UR is today the CEO in one of the new robotics companies who have grown from 3 to 25 people in number in a year. So you know, the knowledge is building up in one company are spreading out to some of the other companies. So--.*

Entrepreneurship is also generated in Odense Robotics cluster by experts. Experts are people moving inside the cluster with knowledge and experience in Robotic industry and technology. Those people have worked in different organizations inside the Robotic cluster in Odense capturing positions in University, Industry and IFCs. They act as clusterpreneurs and mentors interesting to invest resources into an idea. For example Claus Risager the now Co-founder and CEO of the Blue Ocean Robotics have had worked as a robotics engineer at Lindo shipyard but also was the head of DTI-RT until 2012 (“Claus Risager | LinkedIn,” n.d.). Blue Ocean Robotics board of director’s team combines a cross-disciplinary research team that invests resources and capital into the exponentially growing robotics ideas.

# 4.6 Odense Robotics Global Cluster of innovation

Here I will analyze the linkages that Odense Robotics cluster has out of the national level. The interviewees have identified the cluster’s ability to compete internationally and for that reason as it discussed in external linkages section, they form global pipelines to explore their potentials. The participants in the study recognized the global perspective of the cluster that is combined with the global perspective of the robot industry.

Innovation Centre Denmark has established six innovations centers around the word in order to bridge companies, research institutions and capital in Denmark and abroad. This public initiative can accelerate the entry of Danish companies in foreign markets but also can facilitate research cooperation and provide inspiration to drive innovation in Denmark (“ICDK,” n.d.). DTI-RT and SDU-RT cooperates with research centers from abroad as Anders mentions:

*Ioannis: Which frictions will drive the cluster into that direction being globally competitive?*

*[00:24:57] Anders : All of us are working because Robotics is..- I mean, nowadays the boarders between countries are quite invisible, perhaps. So all the partners in the cluster are working very heavily internationally. We work, I think 60-70% of our projects that we do within Robotics are international projects. Universal Robots have been working heavily on an international market and have a very international focus. University the same that they are working on the international market. So the internationalization is definitely something that we are quite heavily involved in.*

Anders mentioned the main points of the international scope of the cluster. Globalization has diminished boarders between countries and a robotic product or solution can have global applications. Universal Robots is becoming a gate to international market for the company itself but also for peripheral ones that develop technologies using UR as a platform. Universal Robot sales network is an explored country for the cluster participants knowing that they can build on coring their market segmentation. OnRobot is an example of a company that born global through the use of that sales network. OnRobot produces an electrical industrial robot gripper that can handle a variation of different object sizes being compatible with UR robotic arms. OnRobot develop its sales network by setting partnerships with UR distributors as is illustrated in the photo in figure 11.



Figure 13 OnRobot Distributors

The map is the first image that I observed when I met Bilge in OnRobot officies in the harbor of Odense. The pins in the map are agreements that OnRobot have fixed with distributors worldwide. All of these distributors are selling the UR arm and OnRobot is trying to gain market share providing a peripheral UR component as Mikkel comments for OnRobots:

*Mikkel: They are sort of piggy begging on the UR global market access.*

As Anders stated above the university is also working on the international market. Lars-Peter mentions the collaboration that SDU-RT is having with Universities around the word but also with projects that have international perspective. MADE is an initiative that targets to lift Danish production combining research, innovation and education having positive effects on the externality of the University as Lars-Peter states:

*Lars-Peter: The University is a big entity in itself and it already has a network with the other universities and there are certain large research projects, for instance, the MADE project. And there is the MADE organization which is sort of manufacturing academy of Denmark which the university is part of. So, from there we get a lot of collaboration with companies and there are also the EU grants. Basically, European projects which the universities are involved with. Odense Robotics they are locally focused where the university is more globally focused in some ways.*

**Chapter 5: Discussion**

# 5.1 Odense Robotics Diamond

The nation of Denmark and the region around Odense have strong positions in the diamond analysis according to the data. Factor conditions and government have significant importance in the study according to the data. Government has an empowered influence in the system. The Danish national innovation policy is the reason why government has this role. Thus in the Diamond analysis Government position is strong because represents structured National, Regional or Sectoral Systems of Innovation. For this reason Government is separately analyzed in the chapter of Danish System of Innovation that this analysis represents the role of the Government in the Porter’s Diamond analysis.

From the four conditions that create the Diamond, factor conditions dominated the system according to the analysis. I find demand conditions to be positive in the system. Related and Supporting industries and firm’s strategy, structure and rivalry seems to be neutral having both advantages and disadvantages. Chance as always plays its own role in the system as it describes unpredictable conditions but in Odense Robotics chance is connected with timing. Further analysis of the chance condition is out of the study’s interest.

# 5.1.1 Factor Conditions

Factor conditions are overall strong and positive for the Odense Robotics Cluster. According to the data knowledge resources were strong both for Denmark and the cluster. Denmark spends among the highest percentage of GDP in education and research (Eurostat, 2012) having a level of education above OECD average (Statistics Denmark, 2016). Around Odense there is a concentration of knowledge resources around robotics. SDU and MMMI cultivate robot technology with programs in the related technology. EAL and the technical College of Southern Denmark (SDE) support also the technical foundation for Robotics. Technological institutes such as the DTI-RT and the MADE organization provide knowledge resources nationally and regionally in the cluster.

Denmark ranks seventh in the Human Capital Index 2015 by World Economic Forum among 124 economies (Word Economic Forum, 2015). Denmark has a high performing and well-educated population with a very good level in English skills. According to the 2015 report of the World Economic forum Talent and not capital, will be the key factor linking innovation, competitiveness and growth. The skills of human resources are strong both in the whole nation but also in the cluster level. The region around Odense due to the long history holds a strong preposition of experts around robotic technology but also continuously educates human capital in the technology. Specialists and candidates create a pool of high quality personnel if quality is connected with skills.

One of the most significant ‘disadvantages’ referred to the cluster were found in the quantity of human resources. All the interviewees mentioned this potential threat for the cluster development. I state potential here because everybody is talking about that in the cluster but the interviewees were in an ‘early stage’ to affect. Universal Robots and MiR was mentioned to continuously ‘search and hire’ personnel following their strategy to growth. As it derives from the analysis the shortage refers in personnel with a Ph.D. in robotics technologies. More over Technology transfer organizations absorb a big quantity of the human capital resources. As Anders mentioned only DTI-RT employees 83 people that the majority holds a Ph.D. in robotics. The Absorbers of human capital with the growth potential of the cluster strengthens the position for limited quantity. Overall, I find human resources for Odense Robotics cluster as positive in the diamond model. Strong quality and moderated quantity of personnel are the characteristics in human resources for the Odense Robotics cluster.

Denmark is a stable economy with a competitive currency. According to the analysis, capital resources are strong in the Odense Robotics environment. All of the interviewees mentioned that money is not the problem that they face for growth and innovation. Restrictions to capital resources were mentioned only in the Academia part as tool to hire more research personnel. In the industry all the players find capital resources available in the environment. Danish innovation policy attracts a lot of interest of the private sector and innovation projects are financed by a Public-Private mix of capital. Public initiatives attract investments in innovation that are pushing the cluster to develop. After public schemes of financing that are directed from IFCs the next step for a company in the cluster is to match with an external venture capital investor. Money will give cash injection to companies but also close collaboration with market experts.

Infrastructure holds a unique position in the Odense Robotics cluster. Odense municipality’s initiative to transform Odense from a major Danish city into a Danish metropolis over the period of 2012-2022 is an example on investments in infrastructure. SDU is also a contemporary infrastructure that houses resources for the robotic cluster. The new MMMI building that came as a donation of the private company is another example. The Science Parks (forskerparker and Videnbyen) are two other important for the cluster entities that host diversified sources of organizations. In the Science Park is also hosted the O.R startup Hub. Overall infrastructure is strong mentioned from the interviewees. The analysis shows that infrastructure help the cluster to house its activities being open to collaboration.

# 5.1.2 Demand Conditions

Demand conditions can be characterizes as strong for the Robotic Diamond analysis. In Denmark there is high Robot density and small percentage on investments in Robotics by companies as observed in the analysis. Public sector pushes home demand conditions in developing technologies that will be applicable in the welfare system. For Odense Robotics cluster the data highlighted two factors that foster the demand for robots. The first is the integrators that implement robot solutions. Those companies are becoming the step in stone for other players to develop technologies that have the readiness to be introduced in the market. Those companies both buy and integrate technologies creating the need for more solutions. The second factor is the success of Universal Robots. The company due to the high sales and innovative based product became a platform that other companies can rely for development. They produce peripherals or developed technologies that are supported from the usability of the UR robotic arms and the UR’s establishment of strong sales network. I characterize demand conditions as strong in Odense Robotics cluster.

# 5**.1.3 Firms’ strategy, structure and rivalry**

According to the analysis rivalry in Odense Robotics is insignificant among firms. The developing stage of the cluster and the wide range that robotic technology captures, diminishing the role of competition in the ecosystem. The cluster consists of few larger companies and a majority of young startups with few personnel. According to the data there is no example of direct competition among actors. The only source of rivalry mentioned was the competition for skilled candidates as an extension of the threat of labor stagnation. The companies were facing the global competition without the concern of local rivalry. Despite that at the moment may be positive for the cluster to luck competition an amount of rivalry should be established as an effect of development.

On the other side, strategy and structure of firms appear strong in the analysis. Both are influenced by strong role models and the public policy towards innovation. Universal Robots business model became a role model for success in the cluster. Entrepreneurs and mentors have constructed a business framework of how to compete internationally anchored by the success of Universal Robots. Business ideas are framed inside the Universal Robots model trying to reach the same characteristics. Those are a rather simple innovative product with high functionality and easy to use towards an international perceptive. KuboRobot, SensoHive, Corepath Robotics and OnRobots adopt this philosophy for their products.

Mentors and connectors inside the IFCs that provide business advices to companies are also anchored by the success of UR. Young companies follows to some extent the UR path foreseeing short and long term obstacles in business development. Mentors plan specific steps for growth that companies will need to make before competing internationally and the UR lesson helps to reduce the time to success. For this reason I characterize the firms’ strategy in Odense Robotics cluster as strong to the environment and influenced by role models. The structure of the firms depends on public policy that fosters the formation of startup firms that work around innovation. Public entrepreneurial programs provide financial support and sparring for commercializing innovative propositions (“About IFD | Innovation Fund Denmark,” n.d.) helping the establishment of young companies. Overall firms’ strategy, structure and rivalry is moderated in the Odense Robotics cluster. Structure and strategy are important characteristics for the environment that the cluster competes but rivalry is weak in the system.

# 5.1.4 Related and Supporting Industries

The business environment around Odense has lost some power in the recent years. The closure of Lindo Shipyard and the global economic downturn in the begging of 2000s took from Odense a big part of domestic productivity. Despite this fact there are still strong related and supporting industries that can be linked to robotics. ABB and Grundfos are two strong examples of companies that outperforming globally and are based in Odense balancing the condition.

In Odense Robotics cluster the significance of the factor is aligned with the related and supporting technologies around robotics. Figure 12 presents the components that enable robots to sense, act and plan according to RoboGlobal report (2016) as a combination of sensing, processing, actuation, computing and integration processes.



Figure 14 Related and Supporting Robo-Technologies

The informants described robotics as a combination of related technologies and in Odense Robotics those industries dominate the Porter‘s (1990) traditional related and supporting industry like ABB and Grundfos. It is easier for a company that develops software for robotics to interact with a sensor company as they matching competences. The traditional related industries can interact mainly with integrators which have the role to provide complete robot solutions. Firms in Odense Robotics cluster depend on related and supported industries but around the robotic technologies the breadth of related industries is still low.

# 5.2 Danish Systems of Innovation

According to Edquist (2001), an innovation system is an alternative way to understand the Porter’s Diamond. In this study the Danish Innovation systems explain the role of the government in the diamond model. The Danish government has adopted policies to boost national productivity with investments in research and innovation making available pools of capital for projects. The total Danish R&D expenditure in the public and private sector has doubled in the period 2000- 2014 estimated at DKK 59 billion in 2014 (Statistics Denmark, 2016) and . Money and initiatives have to be distributed into the national system to bring utility back to the system. The Government distributes those resources by formulating financing and IFCs organizations in the three layers of the figure 7. Institutes for collaborations undertake the role of distributor but also absorber of capital resources. IFCs distribute the amount of money to projects by setting specific rules that the participants have to achieve guideline for the national competitive policy.

The government in the Porter’s (1990) diamond model represents a whole innovation policy for the Odense Robotics cluster. The participants had different opinions regarding the role of the government in the cluster but there are two outcomes from the analysis. The first is that the government is not a main actor in the cluster stakeholders and the second that the government has strong position in the system. None of the participants referred government as a key player in Odense Robotics cluster when asked. In the more specific question about the government’s role in the cluster they all agreed that government has a strong position for the ecosystem. In the study the government represents the Danish innovation system as depicted in Figure 7. Government appears in the cluster either as a financing organization either as an Institute for Collaboration as there a lot of these two actors in the cluster that involves state’s initiatives (for example IFD, SDTI, Odense &Co., Vaekstfonden, Udvikling Fyn, Odense Robotics, Robocluster and others).

Focusing in the Danish Innovation system, Danes due to low productivity growth adopted initiatives to support innovation. Policies to increase University –industry collaboration, improve commercialization of public research, and increase the quality and availability of human resources target to boost Danish economy. Government investments in innovation represent a pool of money distributed to the correct projects. The Danish innovation system as depicted in figure 7 leaves space for ‘bottom up initiatives’ and thus innovation is supported by a central national policy as the state encourages industry and Academia to grow internationally. The pool of capital resources is supported by private funding and local and regional innovation systems. Regions and cities form their own innovation systems creating more specific space for investments. Innovation Fund Denmark is according to the data an organization that supports financially startup companies via entrepreneurial programs. SDTI and Developing Fyn that represent organizations acting in the region of Southern Denmark are connected with the cluster stakeholders.

The Region of Southern Denmark and the city of Odense historically promoted the evolution of the Odense Robotics cluster but also at the moment the municipality of Odense supports the cluster. The regional and the sectoral innovation system can identify quicker opportunities for growth due to geographical proximity but once an emerging industry is recognized such as the robotic industry in Odense, attract the interest in a national level. Robocluster is an organization that illustrates this point best. RoboCluster IFC born as a sectoral entity in Odense after adopted a regional perceptive and at the moment is a Danish national network for Robotics. The focused innovation policy put Odense Robotics frontier in the position of Robocluster .Odense Robotics IFC created as to be the central IFC for managing and branding the cluster and includes private and public initiatives. Following the national prototype, Odense city has adopted its own sectoral innovation system by investing resources to transform the city’s value prepositions having an investment plan until 2022. The timing match with the development of the cluster as all actors can mutually benefit from interactions.

Odense Robotics cluster seems to have one leg into the national and the other leg into the sectoral system of innovation for the perceptive of capital resources flow. The main finding here is that innovation system influence Odense Robotics cluster as it represents the role of the state in the ecosystem. Positive national, regional and sectoral innovation policies have identified giving a strong positive image in the public sector for the cluster. The governmental organizations that spread the policies are the means of collaboration between government, industry and University. For that reason government in the study represents IFCs and financing organizations.

# 5.3 Odense Robotics Triple Helix configuration

The discussion about Triple Helix collaboration between University, State and Industry will be in accordance with the Danish innovation systems that represents the state in the model. The Triple Helix describes the connection and collaboration between University, State and Industry when it comes to innovation. All the interviewees had at least duo lateral strong relationships with the other spheres of the helix but also tri lateral networks and hybrid organizations spin out from the system.



Figure 15 Odense RoboticsTriple Helix collaboration

None of the stakeholders were acting in isolation. University, State and Industry connection and collaboration around robotics situated in the shaded part in Figure 13. In the interactions that produce innovation, the interviewees noticed the importance of the University. According to the data, the university has the capabilities to contribute in knowledge capitalization. Research in university is combined with industry funding as a step to commercialization but the university is still a public entity that has follow specific restrictions. Being in the industry gives more freedom to the stakeholders as Jimmy admitted being a person that entered industry from academia being the CEO of CorePath robotics which is a university’s spin out. Trilateral organizations exist in Odense Robotics cluster as the authorities understand that one entity cannot make it all.

In industry the existence of dynamic companies open to collaborate push Triple Helix to spin. Experts, mentors and connectors are trying to match stakeholder competences in order to commercialize and exploit innovations. In such way they bring together missing resources from Academia, State or Industry. There is no dominant force between the three helices according to the data with University, Government and Industry to share initiatives for the cluster development. Historically, the collaboration for innovation has started by the industry approaching university with the Lindo Shipyard example in 1985. The AMROSE project was a trilateral-hybrid organization pioneer for its time. In 2002 after the economic crisis public initiatives revive the cluster with the establishment of RoboCluster IFC. The state as it discussed in the section of innovation systems is very much involved to foster collaboration for innovation in the Triple Helix model.

The Triple Helix in Odense Robotics cluster captures the area that is formulated by the spin of the helices. No matter who is giving the spin the data revealed that the other two helices are following when it comes to innovation in the Odense Robotics cluster. IFCs can further spin the helices as bridging or glue organizations that promote collaboration. The trilateral space is not the ideal positing in the Figure but it is the one that can boost young companies into large corporations.

# 5.4 Odense Robotics Cluster of Innovation

# 5.4.1 Odense Robotics actors

Odense Robotics cluster actors categorized in five groups according to the analysis. Because of the fact that none of the interviewees characterized government as a key actor the state adopts the configuration of the Danish innovation system that includes the main four stakeholders Industry, Academia, IFC and financing organizations. Government represents the whole national system of innovation and makes its appearance in the system as IFCs and financing organizations. IFCs and financing represent public-private organizations that foster the collaboration inside the ecosystem.



Figure 16 Odense Robotics actors

The three cycles represent the sectoral, regional and national layers of the Danish innovation systems. The core of Odense Robotics cluster is lying around the city of Odense that concentrates many of the cluster ingredients such the University and can be positioned in the city of Odense. The Regional innovation system includes the broad region of Southern Denmark and especially the island of Fynen. As it depicted in Firure 10 the majority of the companies are located in the territory of the Fynen Island. The national system of innovation with its bottom up initiatives completes the construction of the environment around Odense Robotics.

The cluster actors configuration in Figure 14 coming close with the ‘statist model’ of Triple Helix presented by Etzkowitz & Leydesdorff, (2000) . Despite the fact that the triple Helix model describes the collaboration between stakeholders for generating innovation in the actor’s configuration the state dominates the system adopting the socialism- statist configuration. The state by investing in the cluster expects growth in employment, prosperity and productivity of the nation, region or sector accordingly. Financing is the key resources that the government provides to the system.

IFCs role in Odense Robotics is important according to the analysis. Institutes for Collaboration match stakeholder competences targeting to commercialization. They provide a wide range of mentoring to especially to young organizations. IFCs such as Odense Robotics frontier, RoboCluster, DTI and DTI-RT are becoming glue organization for the ecosystem and are established by public and private initiates. This is a reason that I claim government to influence the system through financing and IFCs not having a direct connection with the bureaucracy. IFCs are flexible organizations that are bridging competences around robotics becoming the connectors for the Triple Helix actors. All of the IFCs around robotics have as a target to strength the robotic industry around Odense for the benefit of the authorities that are established by (sectoral, regional, national).

Financing organizations are strong stakeholders in the cluster actor’s formation. The interviewees had access to capital resources due to public and private financing organizations. Especially in the early stage of enterprises public funding is appearing intensively in the cluster. After the companies begin their function having a concrete product to be commercialized private investors that represent venture capitals and funding through collaboration with a bigger company startups are directed into schemes with less public involvement.

# 5.4.2 Odense Robotics and Innovation

According to the data, innovation in Odense Robotics cluster is connected with the commercialization of an idea. Innovation is seen as a combination of technologies that form a concrete product. The commercialization and capitalization of innovations is a key public policy and the cluster’s stakeholders align the perceptions of innovation to that notion. The success of few companies such as Universal Robots and MiR inspired cluster participant to align innovation plan with models that have achieved in the robotic environment around Odense. Those innovation platforms are becoming role models for the actors putting innovative ideas into a tested framework of success.

Innovation as a fuzzy concept can be seen as a label that gives new characteristics into a product. Many of the interviewees separate innovation from technology development but all of them agreed that in robotics innovation can occur through combination of the peripheral robotic technologies. This is the reason that many products can be characterized as innovations without the notion of invention inside. Innovation is important for the Robotic cluster in Odense as the nature of robotics commands.

# 5.4.3 Odense Robotics characteristics

The characteristics of the Odense Robotics cluster analyzed based on five categories that include geographical proximity of the members the linkages that develop with their environment, the culture in the cluster, competition and cooperation between cluster’s stakeholders and the characteristic of entrepreneurship in the ecosystem.

Geographical proximity facilitates the collaboration and communication in the cluster. The area around Odense houses the majority of entities for the robotic industry. Also the method that I conducted showed the close proximity of the stakeholders. University Foskerparker and Videnbyen are the three entities that give an extravagant meaning in proximity for the cluster. Between these entities there are gathered plenty of resources ranging from human, capital and infrastructure. Companies and organization benefit from being in the center of the cluster as knowledge spills out easily. The role of the university is crucial for the cluster member’s proximity as it is becoming an advantage especially for young organization to be located near to knowledge resources.

There is a balance between internal and external linkages between cluster participants in the Odense Robotics. Due to intensive geographical proximity internal linkages facilitates the flow of information and the connection between actors. The Internal network is well structured in the cluster and young companies can rely on it to find proper guidance and resources for their purposes. Institutes for collaboration adopt the role of the connector for bridging competences for other organizations being a facilitator in the cluster. IFCs are becoming knowledge spillovers for the cluster. The establishment of the strong network for communication enables actors to search in the peripheral environment of the ecosystem for matching missing parts of their organizations.

External linkages with actors outside of the cluster are also a characteristic of Odense Robotics. Organizations use external linkages to form an international perspective or to collaborate with distant stakeholders to develop their position in the market. The dynamism of globalization pushes actors in the cluster to search for available resources internationally recognizing the global scope of robotic technology. The nature of organizations around robotics that they are born global forces the intention of establishing global pipelines. Conferences and exhibitions that the cluster actors participate in empower the dynamic of both local buzz and global pipelines in the system.

Social, human and physical capitals hold strong position in Odense Robotics cluster. Physical and human capital is available in the University and according to the data many companies have used academia to form companies and organizations. Machinery and knowledge facilitate the intentions of entrepreneurs for accessing resources for their entities. Social capital represents the culture, the trust and the easiness of knowledge and information flow. The openness of the environment was mentioned from all the interviewees as a key cluster characteristic. Actors in the cluster are open to communicate and share information regarding technologies. Trust is cultivated into the system especially from young organizations that desire to expand their capabilities. Companies and organizations are extrovert to share information and only few and big entities in the cluster seem to hold secrets in house. There is an established culture to make Odense Robotics as a leader in robot technologies worldwide and the participants share this vision.

Internal cooperation dominates competition in Odense Robotics cluster. The only sources of rivalry among firms in the cluster found in the labor market as companies compete to employ the best talents for the benefit of their organizations. Low competition is found due to the low volume of high growth firm but also due to the nature of the robotic industry that is a combination of different components in order a robot to act and sense. The few examples of high growth firms did not create the willingness for other actors to compete in same market segments but push the stakeholders to adopt successful firms as role models that technologies can be built on top of that examples. Strong cooperation has derived from the data through collaboration between actors for rapid and innovative commercialization. University, Industry and Academia in Odense Robotics cluster has recognized that through collaborations the participant can be mutual benefitted and the connect and develop principle seems to work in the cluster.

Finally according to the analysis of the data, entrepreneurship is a characteristic of the robotic ecosystem around Odense. Entrepreneurship is fostered by the national innovation policy with the entrepreneurial programs that are providing by public organizations like IFD. Moreover, the establishment of the Odense Robotics Startup Hub is an initiative that can support entrepreneurship as ideas are formulating from concepts to commercialized products.

The University is an entity is an entity that historically promoted the establishment of new businesses. Many companies started their activities based on academia resources and the university seems to facilitate individuals to cultivate their entrepreneurial skills. According to the data the University is an entity that gathers potentials of producing more leaders and startups. SensoHive and KuboRobot have established as companies by students that have not finished their education yet. Universal Robots also started from the University being at the moment one of the biggest companies for collaborative robots internationally.

Entrepreneurship is also fostered in the ecosystem by the quantity of experts that are moving inside the cluster. According to the data those people are active in the entrepreneurial process and they are acting as clusterpreneurs for the Robotic environment. With their knowledge and experience in the robotic technology and market help the cluster to develop in a sustainable way by establishing companies or by providing business advice, financing or mentoring to young prominent startups.

# 5.4.4 Odense Robotics Global Perspective

The Global perspective of the Odense Robotics cluster is a combination of different factors. All the interviewees mentioned the international scope of the clustered robot industry in Odense. Industry, Academia and State have developed linkages with international stakeholders according to the data. University interacts with other universities from abroad, the companies use global pipelines to strengthen the position of their organizations and public sector have set collaborations with worldwide hot spots of contemporary technologies such as the Silicon Valley cluster. For example Innovation Center Denmark has set collaborations with global international centers in Munich, New Delhi, São Paulo, Seoul, Shanghai and Silicon Valley. The center helps companies to find partners, key players, investors, and knowledge environments in order to operate and grow globally using global networks. Moreover DTI-RT has also established global linkages to explore the potential of robot technologies.

Odense Robotics cluster is a Global Cluster of Innovation according to Engel (2015) definition. Global clusters of innovation hold specific characteristics that are derived for the global applicability of Silicon Valley cluster. Odense Robotics cluster is rapidly promotes the creation of new forms that commercialize new technologies, addressing in global markets and at times create new ones. Odense Robotics cluster gather the behaviors and components that a cluster has to collect in order to be characterized as a Global cluster of Innovation. These characteristics are based in the Silicon Valley model that is the archetype of cluster formation.

In the behaviors side Odense Robotics is facing high mobility of resources. Capital, people, and knowledge are continually on the move inside the cluster with public, industry and university to provide the ingredients for a multidimensional environment around the cluster. The entrepreneurial process targets to rapid commercialization and according to the data are strong in the robotic environment around Odense as it is discussed. Firms and stakeholders adopt the global strategic perspective with organization to born global but also with the intension to penetrate in global market according to the glob-ability of robotic technologies. Moreover Odense Robotics also benefits from perspective of shared values and cluster culture. It is a common belief that the cluster has to grow and be globally competitive so the cluster actors act under the same values umbrella. Afterwards the cluster has developed international linkages with external actors to work on shared projects and to mutually develop technologies.

The components of a Cluster of Innovation are gathered around Odense Robotics. Universities, Government, Entrepreneurs, Venture Capital, Mature corporations, Industrial research centers, Service providers and management are included in the Odense Robotics cluster as illustrated in Engel’s (2015) representation of the components of a Cluster of Innovation. Odense Robotics holds strong components of these entities not only on the side of the historical importance as University, Government and Industry but also in the peripheral ones. Mature corporations have established around Odense through its progress with mostly integrators to be established for many years in the industry. Research institutes (the Global technology Services-GTSs) along with service and management providers that represent the IFCs in the study have also strong appearance in the ecosystem. For that reason Odense Robotics can be characterized as a cluster of innovation with satisfactory global linkages. Global linkages can be developed parallel with the maturation of the cluster as they can support the transformation from a developing to a mature cluster.

# 5.5 Answering the research sub-questions

The formulation of the research sub- questions that I pose in the introduction has as a purpose to describe the operation of the Odense Robotics cluster of innovation from three different scopes. The first in the analysis of the environment that the cluster competes, the second aspect is the structure and characteristics of the cluster itself and the last is the analysis of the interactions that produce innovation in the ecosystem. The three sub-questions target to address the problem statement of the study and uncover to what extend can Odense Robotics cluster be internationally competitive combining growth and innovation in the continuous quest of high growth firms. Each of the research sub-questions will be answered separately supporting the main argument of the thesis that will be discussed in the conclusion section.

# 5.5.1 Which characteristics influence Odense Robotics cluster environment?

The environment that Odense Robotics competes is strong according to the data. The Danish national Diamond as analyzed is dynamic, forward-looking and challenging providing good foundations for the robotic industry to succeed. The role of the Government in the Porter’s (1990) diamond model is a strong determinative factor for the competitiveness of the companies in the Robotic industry as it is connected with a structured innovation policy. For this reason the Danish innovation systems influence the environment in which robotic companies function around Odense. Innovation System is a collective system with different actors and entities involved (Edquist, 1997) having as a target to use and spread knowledge, which in turn would lead to innovation and growth(Doloreux & Parto, 2005). The Danish innovation system faces ‘bottom-up’ initiatives that can support the cluster’s ability to innovate and grow. Moreover the distinction between sectoral, regional and national systems of innovation empower the environment around Robotics as each layer of the system identifies and invests in specific capabilities that the cluster can support.

Another factor that influences the environment around Odense Robotics is the nature and potentials of the Robotics Industry. Robot technology is globally applicable and dynamic and for some robotics open the way for the fifth industrial revolution (Steno, 2016). According to RoboGlobal (2016) report today’s global turnover for the Robotic industry is calculated to $64 billion and until 2025 it is estimated that this number will increase to $1.2 trillion making robotics an industry to invest. Moreover as Robotics combine a set of peripheral technologies that needed in order a robot to act, sense and plan companies can match competences from their peripheral environment to innovate. According to the analysis of the data, the technological environment of the peripheral robotic industries is currently developing in the cluster. There is strong preposition around robot integration and actuation but sensing, computing and processing are in an early stage.

The success that Universal Robots achieved constitutes another factor that influences the Odense Robotics cluster environment. The company revealed the potentials of the industry to the cluster stakeholders creating an environment with high standards. UR became a role model for the cluster as it combined an innovative product with international penetration. Different actors realized that the participation in the cluster provides euphoric environment for robotic business creation and expansion.

For these reasons, the characteristics that influence Odense Robotics cluster environment are: a competitive national diamond, a structured innovation system, the prominent global robotic industry and the great example of success of Universal Robots. Overall I characterize the environment that Odense Robotics cluster of innovation is competing as dynamic and supportive for growth and innovation in the Robotic industry.

# 5.5.2 How is the structure of the Odense Robotics cluster?

The next sub-question of the problem statement in the thesis is regarding to the structural characteristics of the cluster. According to the data Odense Robotics is a developing cluster with new actors entering the cluster, developing new linkages between the established ones. The role of the IFCs is vital in that notion as they facilitate new business creation, mentoring to the existing companies acting as glue organizations for the ecosystem. Odense Robotics frontier is becoming the common point in the cluster representing the values and strategies for the whole cluster management. Moreover is becoming the organization that brands the whole cluster labeled as Odense Robotics.

The Odense Robotics cluster formation follows the representation depicted in Figure 14. In the Figure I present the main cluster actors and the interactions among them giving an image of how the ecosystem is functioning in the robotic industry around Odense. Academia, Industry, IFCs and Financing organizations create a diamond of stakeholders that are interacting inside the sphere of state. The state represents public innovation policies adopted by national, regional and sectoral authorities to foster the business environment around robotics in Denmark. The main actors change spheres of influence between sector, region and nation adopting the linkages that are more profitable for their interests. Actor’s activities can be found as well outside of the system in the international market as explained with the local buzz and global pipelines framework. Internally the government seems to have a dominant role as Figure 14 can be compared with the ‘statist’, socialistic model of triple Helix (Etzkowitz & Leydesdorff, 2000) with the government to have a dominant force in the system. Government in Odense Robotics has a dominant role for the current cluster development that is characterized by intense new businesses and organizations creation. This dominant role provides a ‘bottom-up and up-bottom’ opportunity for innovation but the state is indirectly involved in the implementation of the policy. For the implementation the state creates IFCs or financing organizations that distributes policies, money and projects into the system. For example the Odense municipality has established the Odense&Co and InvestinOdense organizations to support innovation and growth in the region and these two organizations belong to the IFC category of actors. Furthermore, the Danish government distributes its innovation policy through the financing organization IFD. Again the government influences the system by the establishment of a financing organization.

Odense Robotics cluster is in a developing state where new businesses and organizations are establishing around Robot technologies in Odense. Startup companies communication the growth potentials trying to commercialize innovations around Robotics. At an early stage, those organizations need support for growth and the state has strong position in supporting young organizations. This is the reason that I give a dominant role to the state in the Odense Robotis cluster actors formation.

The cluster is situated in the sectoral sphere of the state that represents the city of Odense showing where the cluster core is laying. This fact was representative in the snowball sampling method that I conduct to collect my data. The cluster is structured organizationally around the city of Odense and the geographical tringle of the SDU, Forskerparker and Videnbyen seems to be the heart of the ecosystem.

I find that the actors have the tendency to jump out of the cluster’s core as a sign of development. Companies hosted in O.R startup hub have the target to internally grow around the cluster core benefitted and depended on the availability of resources in this position but a sign of development will be to reach a volume to explore higher position in the layer. The main purpose is to growth internationally as global success will exploit value for the organization and the society. According to Steno (2016), the from 285 million dollars UR exit money 210 million were spitted between the Danish Growth Fund and Enrico Krog Iversen the company’s CEO. Both individuals and state benefitted from the transaction as also the two co-founders of the company shared about $28 millions. The company started in the triangle inside SDU moved to the regional layer financed by the Syddansk innovation foundation jumping into the national Danish growth fund. This route established as a consequence of the global success of the company as now public entities hold no shares in the company.

Overall, Odense Robotics cluster is a developing cluster that includes different stakeholders. The dynamic environment around knowledge-based technologies and innovation in the Danish nation makes the government’s position superior in the formation of the cluster The state is becoming the Firestarter for many of the interactions between University, Industry, IFCs and Financing organizations and for the study those are the main players that can develop the cluster. They have equal and strong importance in the cluster and the diversity of competences that they collect can exploit further the cluster’s ability to innovate and grow.

# 5.5.3 Which frictions foster innovation in Odense Robotics cluster?

The frictions that foster innovation in Odense Robotics cluster are divined in two categories. The frictions that produce innovation in technology and the frictions that make the commercialized innovation to grow.

The interactions that foster innovation are explained with the Triple Helix model and are covering the area that the helices create when spinning. None of the interviewees had monomeric relationships when comes to innovation in the cluster and many organizations were positioned into the Trilateral space in the Figure 13. No matter who is giving the push to the University, Industry and State interaction Helices produce innovation in the Odense Robotics cluster. University holds the knowledge, the state holds the money and the industry holds the keys to commercialization. Private, public and Private-Public actors are positioned inside the innovation Cycle in Figure 13 such as Institutes for Collaboration (that include networks and other clusters, Research and technology organizations and management and services organizations and other actors) and Financing organizations. Those hybrid organizations bridge the gaps between innovation and successful commercialization of ideas.

The cluster search for innovation in the local buzz being benefitted from knowledge and human resources internally but access to commercialization in the global market requires global pipelines that are cultivated by the actors. The Danish Ministry of Foreign Affairs establishes innovation hot spots around the world to support global pipelines between research and business internationally. Anders admitted that 60 to 70 percent of DTI-RT projects have global perspective but also Lars-Peter expressed the international linkages of the SDU-RT with universities from abroad.

The shaded area in Figure 15 represents the behaviors and the culture of Odense Robotics cluster that let the interactions to occur and develop. Many individuals and organizations operate as knowledge spill overs keen to collaborate with each other to diffuse innovation. The openness of the environment let actors to share information and to communicate with an established level of trust. The interviewees confirmed the trustworthiness of the environment noting that the actors trust to each other keeping little confidential information. Only ‘big players’ can afford having secrets that can interrupt frictions to occur.

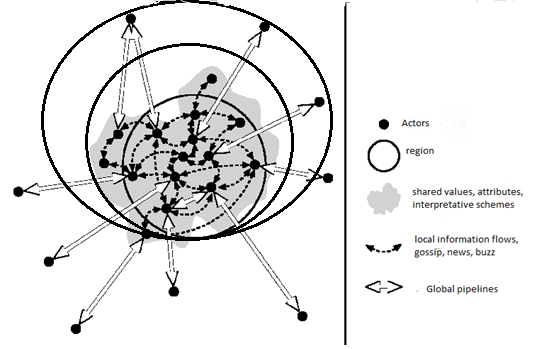


Figure 17 Odense Robotics fictions

According to the analysis Odense Robotics cluster gathers characteristics for productive interactions for innovation. Specialists, money and information are mobile inside the cluster promoting entrepreneurship through business creation. The actors and especially the industry cultivate global ties and bond with external stakeholders having global orientation. Young companies are born global in the cluster and the openness of the environment allows them to goal in the international success. Moreover, the incentives and shared values between actors exploit the limits of robotics using as a platform the cluster make them seek for the prestige.

**Chapter 6: Conclusion**

**Findings**

By connecting all the parts of the study the answer in the research problem is positive about the ability of Odense Robotics cluster to compete internationally. Odense Robotics can support growth and innovation to its participants generating globally competitive firms proving that the example of Universal Robot success will not be on of a kind.

* Euphoric environment nationally🡪According to the diamond the environment supports business development. Internationally 🡪 The demand for robotics increasing globally
* The frictions between University-Industry-State formed the internal euphoric environment and these three created the cluster. As Triple helix those interactions aim to innovation and Odense Robotics competitive advantage lies in innovation.
* As the interactions were increasing the need for a more concrete structure created financing and IFCs that facilitate collaboration. Adding those two entities to the University-Industry-State format the main actors in the cluster.
* The cluster is in the developing stage with the time to count in the study. Collaboration between actors means interactions. More actors represent more interactions. Interactions can be explained by Bathlet.
* The culture internally characterized by openness and ‘suspicious’ trust. Suspicious is because they are open to discuss their ideas but the more sophisticated actors share with limits. Mostly Danish personnel 🡪the cluster has to work on that.
* The international extroversion is cultivated all the participants referred to pipelines
* Entrepreneurship is moving the people around in the cluster.
* Money very much accessible public and private money 🡪 the cluster has to establish venture capital network for bringing private money in the industry. The government is dominant at the moment as provides the venture capital money(financing organizations) or the resources to reach money(IFCs)
* Government takes dominant role in the frictions adopting a socialistic formulation that foster innovation with strong bottom up and up bottom initiatives. But also the state when expresses initiatives for investments in innovation public sector is following as a supporter (co financing). The role of the government will probably be balanced when the cluster reach an established formulation where private venture capital have more power. The shaded area in the Bathelt’s Figure can illustrate the boundaries of the state influence in the system that in the core of the cluster has intense power.
* IFCs provide collaboration. Bridge missing gaps between Industry and Academia and they can take a lot of forms (DTI-RT, O.R, MADE, Robocluster) and different structures (Public-Private). Odense Robotics frontier has to manage the brand of the whole cluster as the core strategic cluster organization.
* Financing balance between public and private. No so much private in the beginning but public money represent also private. Bring investors in the cluster
* The university has to move towards to become a Hub for robotic technologies parallel with the O.R startup hub that is a very good initiative but with small capacity. University has to benefit from its competitive advantage in knowledge resources and infrastructure and to promote entrepreneurship from inside the University. Companies can grow internally until a point investing on the collective advantages that a commercialized idea will have.
* Industry is open for collaboration. Integrators are the ones that match competences and demand more innovation in the cluster. Industry is active for entrepreneurship and collaboration through clusterpreneurs and partnerships or ‘support’ to younger companies.
* The shortage of human resources was mentioned as a major potential threat for the Odense Robotics. There will be increased demand for Robotic engineers that the cluster will not be able to support. At the moment none of the interviewees treat this problem but from the analysis I noticed that there are few players that absorb big quantities of human resources. This problem can be solved with a fair distribution of human capital in the cluster’s needs putting control in the demand. A strategic human resource plan can attract resources from abroad but also the scientists in the robotic technologies from SDU can maximize their utilities in the most profitable position in the cluster.
* The cluster has to cultivate talented and skilled human resources both in technical but also managerial spectrum of competencies. Robotics is a transformational technology that can turn an idea into application but also a technology that you can formulate. Polyphony of ideas will increase innovation both in product development but also in innovation management. University can provide a variety of human resources in Odense Robotics and the cluster should focus on letting people become familiar with robotics.
* The proximity maters in Odense Robotics due to the established infrastructure (the triangle University-Videnbyen-forskerparken but also the physiology of the Funen island support growth around a nucleus that is the city of Odense. The proximity is connected with the time that the idea is transformed into a final product that is reduced when the idea spinouts from the university. There are all the resources around at least to create a working prototype.
* Low level of competition can be explained of the socialistic function of the state and the developing stage of the cluster. At the moment few stakeholders are competing in the level of human resources. I predict that as the cluster is growing to the established cluster stage competition will raise from rivalry to accessing capital resources (Private venture capital) as the state’s initiatives will be stable or reduced. At a second level and probably in the maturation stage the cluster’s stakeholders may compete on the direct probuct competition.
* As a conclusion the cluster has to focus in the frictions that produce innovation as the structure and the environment are working efficiently. Robotics tranformed

# 6.1 Recommendations

* Make Odense Robotics frontier as the label. Odense Robotics as it used in the thesis has to represent the whole cluster. Robotics in Denmark begun and flourished in Odense and the cluster has to be known in the word with its full name. Also the city will be benefitted from the common brand policy increasing the reputation of the town.
* People form management can reduce the workload of technicians coping with administrative tasks. The engineers can focus on the development side and personnel with diversified backgrounds can be employed within organizations. These can regulate the human capital distribution on the cluster, letting young organizations work closely with scientific personnel to develop technologies.
* The cluster has to be open in innovations that create new markets as the Robotics is still an emerging technology. Robot workers can reduce the costs of labor bringing innovation in low tech industries with a target to raise productivity. As Robotics is a transformational technology, the potential applications are not discovered. Diversified personnel can identify new innovative applications for robotics without being educated in the technology but filling the gap of what the technology provides with what the market need.
* The university has to adopt a more active role in the cluster practices. The university has to participate in entrepreneurship acting as a hub that can houses young companies until they reach a certain side.
* Robotics can also have implications in the society part promoting social innovation to the whole social-political and economic ecosystem.
* Startups should work in diversified teams benefited from the cluster’s environment that can provide assistance. Interns can be employed in young robotic companies as to gain polyphony is a broad spectrum of skills such as the formulation of the value chain of the firm, drawing the business strategy and organization with the knowledge that they have gained from the academia. As robotics is a combination of technologies in can be also act as a combination of scientific fields bridging innovation both in product and in management.
* Search for talents not for the quantity. The quantity can be sustainable with the correct use. Robotics is a combination of technologies and as such it must be seen. According to (“ROBO Global,” 2016) the accelerating pace of technology diffusion will make robotics as ubiquitous as computers and has the potential to be as transformational as the Internet. Robotics can be a job market for candidates from both technical and theoretical bases. Robotics can be talent attraction from many different scientific competences.
* Companies should continue developing their product technology internally and to combine commercialization with research. The cluster in this notion has to support especially young companies to reach a certain size before they are able to survive by themselves. Multidimensional employees can also help companies to grow.
* Private venture capital can assist further growth for the cluster. Private money can unlock more potential for ideas to become commercialized products and will strength the investments atmosphere in the cluster. Parallel with public money venture capitalists can bring a stream of more intensive and rapid route for commercialization and international success. Those companies can also bring diversity in the procedures deviating from the strong role models in the cluster. The cluster in the development stage receives lot of public help but until the maturation private initiatives has to be equal.

Business models are not fixed and have to be flexibility in the company’s needs and future potentials. The matching with the environment is a factor that facilities the adoption of a future line. Companies should explore their full potentials as robots provide space to create.

Cultivate the Global linkages with hot spots in Robotic technology. Innovation center Denmark Silicon Valley.

# 6.2 Limitations & Future Research

* How to promote efficient collaboration
* The stemma stopped very early having the tension to drive in the suburbs of the cluster. For that reason the examination of the human resources future stagnation were not gone further.
* Not too much focus on the robot part. The potentials of robot technology as 5th industrial revolution(Steno, 2016) How robots are seen as roboworkers and robosociety.

Future research in the robotics Human capital pool should be done to show the distribution of personnel in IFCs, Industry, and University. Are they all needed there or it should be more productive

The role of Science Parks in Odense Robotics cluster.

**References**

# Appendices

# Appendix 1: Interview Transcriptions

# Appendix 2: Stylistic Notes

* **you know** need not be transcribed when used as a refrain
* **umm or hmm** need not be transcribed when this indicates thinking
* **umm or hmm** should be transcribed when it indicates an affirmative - "yes"
* **ah** should be transcribed when it indicates understanding or realization
* **yeah** should be transcribed verbatim
* **--.** indicates an interrupted sentence
* **--** indicates a false start. Although stammers need not be transcribed, false starts should be transcribed. For example: I thought--I was thinking—I thought that I should go . . .
* **. . .** indicates that the transcriber could not hear the word

**. . . .** indicates that the transcriber could not hear more than one word

# Appendix 3: Interview Guide

* What is your name, age, educational level?
* Describe your role in the organization.
* What is in your perception Innovation? How can you describe or define innovation?
* Difference between Innovation and Technology
* Any innovative processes in managerial aspect?(innovation management)
* How you see robots as a product? (costumer solution-functional)
* Key success factors over this intensive growth
* Key players in the cluster. Environment of the cluster.
* Mobility of resources. Knowledge spill.
* How Society how the community in Odense locally in the Danish nation help the development of the industry?
* What about the society in this 'key player' discussion
* Is it about networking
* In your opinion who is the most important key player that actually runs the flow of the cluster?
* Are there any flows of other resources that facilitate the development of cluster?
* Which interactions are having the most innovative results in the cluster?
* Have you seen any ideas to get lost in the meantime, that for example not having the right resources to go a step forward for commercializing their idea
* What about entrepreneurship?
* The people that get the innovative idea are also good entrepreneurs?
* How the cluster, for example, gives these solutions by itself.(for growth)
* Do you have any other examples of such intensive growth companies such as UR? Or potential
* What about trust? In the cluster?
* So they share information? Openly?
* Do you think of any disadvantages or space for improvement in the cluster?
* How you see the future of the cluster for example in the next 10 years

# Appendix 4 : Odense Robotics ecosystem

