Jukka Teräs

REGIONAL SCIENCE-BASED CLUSTERS

A CASE STUDY OF THREE EUROPEAN CONCENTRATIONS
JUKKA TERÄS

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A case study of three European concentrations

Academic dissertation to be presented, with the assent of the Faculty of Technology of the University of Oulu, for public defence in Kuusamonsali (Auditorium YB210), Linnanmaa, on October 3rd, 2008, at 12 noon

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Abstract

The aim of this thesis is to provide an improved understanding of the structural characteristics and the dynamic evolution of regional science-based clusters. The study is based on an in-depth comparison of three non-metropolitan science-based clusters: Oulu in Finland, Luleå in Sweden, and Pisa in Italy. This thesis is the result of a qualitative multiple-case study consisting of in-depth interviews with cluster decision-makers and experts in Finland, Sweden and Italy. The thesis is structured as follows: first the theoretical framework and research method are presented, then the case study regions and clusters are described, and finally, the data from the interviews are collated and discussed.

The results of the study suggest that regional science-based clusters are not isolated entities but are increasingly more connected to the external environments and global markets than before although the local cluster activities and the "social glue" between the cluster actors are still relevant. The current structures of the clusters should have more alternatives and allow more flexibility. The data from this case study, based not only on the current status of the case clusters but also on a more longitudinal approach, confirm the life cycle nature of regional science-based clusters, consisting of various stages. The results of the study show that a detailed analysis of the cluster components is more efficient than studying the cluster as an aggregate. Furthermore, the data indicate that critical mass plays an important role especially in the development of regional science-based clusters in non-metropolitan regions. This study suggests an optimal size for the non-metropolitan cluster, i.e. one which reaches the critical size of a cluster but avoids the problems related to metropolitan clusters. The study underlines the importance of cluster features, such as cluster leadership and strategic management.

The study identified similarities between the case study clusters in Oulu, Luleå, and Pisa, such as e.g. a strong research community, a high proportion of ICT companies, an insufficient number of growth-oriented enterprises, and some unease about the role of intermediaries of the cluster. Differences were found in e.g. the importance of cluster locomotive companies, the roles of technology parks, and the ability of the cluster actors to commit to joint actions.

Keywords: innovation system, regional cluster, regional development, regional science-based cluster
Tiivistelmä


Väitöstitelmän mukaan alueelliset tiedepohjaiset klusterit eivät ole ulkomaailmasta erityiset yksiköt, vaan yhä enemmän sidoksissa ulkoiseen ympäristöön ja globaaleihin markkinoihin – huolimatta siitä, että paikallisinlaisilla ja ”sosiaalisella liimalla” klusteritoimijoiden välillä on edelleen merkitystä. Tutkimuksessa ehdotetaan klusterirakenteen kuvaamiseen joustavuutta ja vaihtoesineistä. Tutkimuksessa esitellään alueellisten tiedepohjaisten klustereiden kehityksen elinkaarin eri vaiheineen. Klusterien analysoimisessa on tutkimuksen mukaan pelkkä kokonaistarkastelua tehokkaampaa klusterin komponenttien yksityiskohtaisen tarkastelun. Tutkimuksen perusteella on muita virakkaiden suurimmaksi osaksi on johtava teknologiakentän aloilla ja ”sosiaalisella liimalla” klusteritoimijoiden välillä on edelleen merkitystä. Tutkimuksen mukaan alueellisten tiedepohjaisten klustereiden kehityksen elinkaarin eri vaiheineen.

Asiassat: alueellinen klusteri, alueellinen tiedepohjainen klusteri, aluekehitys, innoativaatiojärjestelmä
Dedicated to my father and my mother
Acknowledgements

One of the significant paths in my life, the doctoral journey, is coming to an end. During that journey, I have had the opportunity to interact with a large number of people in the course of my research project and now it is time to convey my gratitude to those valuable contributors.

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The interviews with the decision-makers and other experts in the case study regions in Oulu, Luleå, and Pisa were extremely important from the viewpoint of my research. I would like to thank the interviewees for their valuable contribution.

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I want to thank my parents Unto and Iris for their unfailing support and nurturing down through the years in both my life and studies. Finally, I want to thank my loving wife Marianne, and our daughters Elisa and Julia, for being by my side throughout the journey.

And I would like to encourage anybody considering a doctoral research process: it is never too late, and the road, towards the doctoral thesis, is in itself well worth the effort!

Helsinki, August 2008

Jukka Teräs
## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASIC</td>
<td>Application-specific integrated circuit</td>
</tr>
<tr>
<td>CEO</td>
<td>Chief Executive Officer</td>
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<tr>
<td>CNR</td>
<td>National Research Council (Italy)</td>
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<tr>
<td>CPR</td>
<td>Consorzio Pisa Ricerche</td>
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<tr>
<td>ERIS</td>
<td>Entrepreneurial Regional Innovation System</td>
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<td>EU</td>
<td>European Union</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>GREMI</td>
<td>European Research Group on Innovative Milieux</td>
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<tr>
<td>HT</td>
<td>High technology</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communication Technology</td>
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<td>IT</td>
<td>Information Technology</td>
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<tr>
<td>IFC</td>
<td>Institution for Collaboration</td>
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<td>IRIS</td>
<td>Institutional Regional Innovation System</td>
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<tr>
<td>LTU</td>
<td>Luleå University of Technology</td>
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<tr>
<td>NIS</td>
<td>National Innovation System</td>
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<tr>
<td>NUTEK</td>
<td>Swedish Business Development Agency</td>
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<tr>
<td>OECD</td>
<td>Organisation for Economic Cooperation and Development</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
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<tr>
<td>RF</td>
<td>Radio frequency</td>
</tr>
<tr>
<td>RIS</td>
<td>Regional Innovation System</td>
</tr>
<tr>
<td>SIC</td>
<td>Standard Industrial Classification</td>
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<tr>
<td>SITRA</td>
<td>Finnish Innovation Fund</td>
</tr>
<tr>
<td>SME</td>
<td>Small and Medium Size Enterprise</td>
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<tr>
<td>SSSUP</td>
<td>Scuola Superiore Sant’Anna Pisa</td>
</tr>
<tr>
<td>SWOT</td>
<td>Strengths, Weaknesses, Opportunities, Threats</td>
</tr>
<tr>
<td>T &amp; E CENTRE</td>
<td>Employment and Economic Development Centre</td>
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<tr>
<td>TEKES</td>
<td>Finnish Funding Agency for Technology and Innovation</td>
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<td>VINNOVA</td>
<td>Swedish Governmental Agency for Innovation Systems</td>
</tr>
<tr>
<td>VTT</td>
<td>Technical Research Centre of Finland</td>
</tr>
</tbody>
</table>
# Table of contents

Abstract

Tiivistelmä

Acknowledgements

Abbreviations

Table of contents

1 Introduction

1.1 Background – motivation for the study

1.2 Research questions and objectives

1.3 Scope of the study

1.4 Research methodology

1.5 Overview of the study

2 Theoretical framework

2.1 Introduction to cluster literature

2.2 Regional science-based clusters

2.3 Structural characteristics of regional science-based clusters

2.3.1 Main categories of actors

2.3.2 Main cluster elements

2.4 Dynamic evolution of regional science-based clusters

2.4.1 Cluster life cycle

2.4.2 Technology/industry life cycle and clusters

2.4.3 Critical mass

2.4.4 Path dependence and lock-in

2.5 Regional clusters and strategic management

2.6 Conclusions on theoretical framework

3 Research method and process

3.1 Case study analysis

3.2 Rationales behind the choice of the case study regions

3.3 Units of analysis

3.4 Sources of evidence

3.5 Case study interviews

4 Empirical context and target

4.1 Case study countries and regions: an overview

4.2 Oulu HT cluster

4.3 Luleå HT cluster

4.4 Pisa HT cluster
4.5 Cross-case comparison of the regions ................................................... 109

5 Research findings 113
5.1 Definitions and contents of case study clusters ................................. 113
5.2 Structural characteristics .................................................................... 116
  5.2.1 Main categories of actors and cluster structure .......................... 116
  5.2.2 Main structural elements ............................................................ 132
5.3 Dynamic evolution ........................................................................... 146
5.4 Perceptions of future development and judgmental biases ............... 160
5.5 Summary of the findings of this study ............................................. 169

6 Conclusions 179
6.1 Answering the research questions ...................................................... 179
6.2 Contribution of the research .............................................................. 182
6.3 Validity and reliability ....................................................................... 184
6.4 The future of the regional science-based clusters.............................. 186
6.5 Suggestions for further research....................................................... 188

References 191
Appendices 203
1 Introduction

1.1 Background – motivation for the study

Clusters and clustering have become a key focus of discussion and analysis in contemporary debates on urban and regional economic development (Cumbers & MacKinnon 2004). The cluster concept attracts a broad range of interest groups from academics and consultants to policy-makers concerned with promoting regional growth. Examples of the tendency of firms to cluster range from high technology concentrations in Silicon Valley to the *maquiladora* electronics-and-auto parts districts in Mexico and Broadway theatre district in New York City (Florida 2005b). The cluster concept, although not without its critics, is still today one of the focus areas of regional development for both academics and practitioners around the world. Cluster-based policies have been adopted by a broad range of organizations, and the cluster policies have become an integral part of industrial and regional policies. The Aho Group Report (2006) states: “Clusters, and more generally, regional agglomerations are often at the core of innovative development.”

The dictionary definition of cluster is “a small close group”, and the definition of clustering as “to gather in a cluster” (Oxford Universal Dictionary 1981). Clusters and clustering activities have existed since the early history of economic activity; many goods have been produced cooperatively and in specialised regions, such as silk in China and trade services in the cities of Hanse (Steiner 1998). The idea of industrial localisation can be traced back to the late 19th century and Marshall’s observations in 1890 about industrial districts in the UK (Marshall 1961). Agglomeration has been a major theme of urban and regional studies for decades. The cluster phenomenon has attracted increasing attention during the last fifteen years (Maskell & Kebir 2005). One of the important milestones was the article on clusters by Porter (1998a), whose notion of industrial or business clusters has become a dominant concept in the research on clusters (Porter 1998a, Martin & Sunley 2003).

The research on clusters and policy-making around clusters are sub-themes of the dominant megatrends of globalisation. There is a parallel development in globalization and localization or “clusterization” of activities (Lehtimäki 2005). The role and importance of cities and regions is keenly debated in the research on clusters. Innovation and innovative environments belong to the key concepts of
the literature on clusters. According to Porter (1998a), clusters play a vital role in a company’s ongoing ability to innovate. Also concepts like the innovative milieux by the GREMI group (e.g. Maskell & Kebir 2005), the regional innovation system, the industrial district, have been developed, raising the questions: how can competitiveness or innovation in regional industries be stimulated, enhanced and maintained, and how can responsiveness to a rapidly changing environment be achieved? (Kautonen 2006) There is also criticism of cluster enthusiasts “assuming latent clusters out there everywhere if only their constituent businesses, institutions, and agencies realized it” (Martin & Sunley 2003).

There is abundant current research literature on clusters. There are, however, research areas within the research on clusters that have not yet been covered sufficiently. The question of cluster evolution over time is one of the issues largely neglected in the literature on clusters. Much of the recent literature on clusters focuses on the incremental processes of innovation and learning within selected growth regions and clusters, offering “snapshots” of regional success rather than considering the capacity of particular clusters to sustain growth over time by successfully adapting to economic change (Chapman et al. 2004). The current studies on innovation usually focus on highly urbanised metropolitan areas (Doloreux et al. 2007). Additionally, the current literature on clusters does not include many multiple-case studies on regional clusters located in different countries. Cumbers & MacKinnon (2004) rightly claim: “…the apparent divide between intensive research based on single-case studies, often interview-based, on the one hand, and extensive studies which deploy official statistics to measure the extent of clustering within particular economies, on the other, seems to have hindered understanding of agglomeration processes.” The need for a more in-depth analysis of the international linkages of regional clusters has been identified (e.g. Virtanen & Hernesniemi 2005).

Clustering, related to knowledge and knowledge-based innovations and high technology industries, has received a great deal of attention both from scholars and in the public policy arena (Breshanan & Gambardella 2004). A large and important amount of knowledge, defined as a cognitive capacity empowering its possessors with the capacity for intellectual and manual action, cannot be codified, or is too expensive to be codified, and remains tacit (Cooke et al. 2007). Geographical proximity is an important factor in creating a common understanding for tacit knowledge exchange, reflected in the highly uneven and polarized distribution of high-tech regions and knowledge-based city regions.
The innovation-dependent highly specialized firms need universities, research institutions, and specialised suppliers of goods and services which has increased the importance of science-based clustering in high-tech economies (Tichy 1998). The European Commission Report (2002) emphasizes the growing importance of the “new economy” in the process of regional clustering, the concept “new economy” refers to newly created industrial sectors based around new technologies. The number of studies focusing on the structural characteristics and evolution over time of these science-based, “new economy” regional clusters is, however, still rather limited.

The aim of this study is to provide an improved understanding of the structure and evolution of the regional industrial concentrations. The previous experience of the researcher in high technology, internationalization, technology transfer, and regional development issues combined with the interest in gaining more profound knowledge in the issues of regional clustering have been the catalyzing factors in choosing this field of research. The empirical material of this study was collected from three European regions: Oulu in Northern Finland, Luleå in Northern Sweden, and Pisa in Tuscany, Italy. All three case study regions – with a population of less than half a million people – are situated outside the metropolitan regions. The case study regions have created a multidisciplinary concentration of research, educational, and industrial activities in the field of advanced technologies. The case study regions all have a relatively high proportion of high technology industries.

The researcher has had the opportunity to work in the area of regional development in Northern Finland and Northern Sweden. The job assignments in Finland and Sweden fomented an interest in a more profound analysis and inter-regional comparison of the Finnish and Swedish regions. The increased importance of internationalization and globalization issues provided an additional motivation to include also a region outside the Nordic regions in the regional comparison. The literature of so-called “third Italy” in the Northeast and centre of Italy, marked by the concentration of firms clustered in specific localities according to industrial sectors (Andersson et al. 2004), contributed to the idea of including a region from Italy in the study. Pisa in Tuscany, Italy was identified during a preliminary review of the literature as a potential region with interesting similarities but also differences compared to the Oulu and Luleå regions, which encouraged the researcher to include Pisa as the third region to be analyzed in the empirical part of this study. The issue of generalization of the results is examined:
to which extent, if any, can the results of the comparison of the case study clusters be generalized?

The study was carried out in the years 2004–2008. The multiple-case study interviews were held between June 2007 and January 2008.

1.2 Research questions and objectives

The main objective of the study is to develop an improved understanding of the structure and evolution of the regional industrial, science-based concentrations. The existing knowledge related to the research topic is evaluated, and the empirical analysis of the three regions is presented. The major research task of this study is to test the relevance and applicability of specific parts of the regional cluster theory to three non-metropolitan industrial and scientific concentrations in Finland, Sweden, and Italy.

As the research objective is rather broad, it hinges on two research questions: RQ1 and RQ2. In tandem, they cover the general aim of the study to increase general knowledge of regional clustering. The research questions are presented below in more detail.

RQ1: How can the structural characteristics of regional science-based clusters be understood?

The main interest in research question RQ1 is to gain a deeper understanding of the question: what is the structure of the regional science-based cluster? The analysis of the cluster structure in this study involves the following sub-questions:

- How are the regional clusters structured?
- What kind of main elements of regional clusters can be identified?
- What are the specific features of regional science-based clusters?

The theoretical part of the study introduces the concepts of cluster, regional cluster, and regional science-based cluster based on the existing literature. In the study there is a review of the most relevant literature on the structural characteristics of clusters, especially from the point of view of regional science-based clusters. The empirical part includes an analysis of the structural characteristics of three non-metropolitan regional science-based clusters. The three regional clusters are examined using the method of case study analysis, including in-depth interviews with the key decision-makers in the chosen regions relevant to cluster analysis. The comparability of the case study clusters and the
applicability of the findings outside the empirical context regarding the structural characteristics are also evaluated. In the study, attempts are made to identify and analyze the specific structural features related to non-metropolitan clusters.

**RQ2: How can the dynamic evolution of regional science-based clusters be understood?**

The evolution of the regional science-based clusters over time is the major area of interest to be studied under the research question RQ2. The main aim is to gain a deeper understanding of the question: How does the evolution of the regional science-based cluster appear over time? The analysis of the dynamic cluster evolution focuses on the following sub-questions:

- What kind of models and concepts of the dynamic evolution of regional clusters can be identified?
- What kind of special characteristics of the dynamic evolution of regional science-based clusters can be identified?

The theoretical part of the study concentrates on reviewing the most relevant literature on the dynamic evolution of clusters, especially from the point of view of the regional science-based clusters. The empirical part of the study includes an analysis of the dynamic evolution of three non-metropolitan regional science-based clusters. The comparability of the case study clusters and the applicability of the findings outside the empirical context regarding the cluster evolution over time are also evaluated. The study also analyzes the features of the dynamic evolution of non-metropolitan clusters.

There are two main reasons to focus on the issues listed under research questions RQ1 and RQ2 in this study. Firstly, the work experience of the researcher has fomented an interest in gaining more knowledge on the issues presented. Based on the previous experience of the researcher, the issues related to RQ1 and RQ2 are constantly debated also by cluster practitioners in various countries. Secondly, the preliminary review of the literature on clusters in the beginning of the research process created an interest in gaining a deeper understanding of the issues related to research questions RQ1 and RQ2.

As a specific issue, in the study the relevant theories of strategic management in the decision-making of regional clusters are identified. In the study two areas of strategic management are examined: the perceptions of the decision-makers and the potential biases in decision-making. To what extent the strategic
management issues related to perceptions and biases apply to regional case study clusters is also discussed.

1.3 Scope of the study

The focus of the study is on regional clusters. The analysis of cluster initiatives with a larger geographic scope, e.g. national-level cluster programmes, falls beyond the scope of this study. This study concentrates on science-based clusters, as opposed to more traditional clusters (the European Commission Report 2002). The science-based clusters in three European regions: Oulu in Finland, Luleå in Sweden, and Pisa in Finland, consist of high technology industries, i.e. information and communication technology (ICT) as the dominant industry in Oulu and Luleå, and ICT and pharmaceutical industries in Pisa. The case study regions include science-based concentrations of economic activity where the scientific knowledge in R&D underlies innovation activity instead of relying more on traditional, local skills (Isaksen 2005). The study concentrates on analyzing regional clusters outside the metropolitan areas. The aim of the study is to better understand the challenges of the smaller regions (less than 500,000 inhabitants) in sustaining the viability of the science-based clusters. The majority of the previous cluster studies have focused on large metropolitan areas, to the neglect of those in non-metropolitan areas (ISRN 2003).

The empirical study covers cluster evolution over time but does not describe in full detail the entire historical development path of the clusters. The key issues and historical events of the case study clusters are analyzed but the focus is on contemporary events. The empirical part of this study compares the three case study regions, and examines their main characteristics and distinctive features. The interviews of the representatives of the relevant actors in the case study clusters form an essential part of the study, and focus on the past and current status of the regional science-based clusters. The interviews also include questions about the current perceptions of the informants regarding the future development of the clusters. The replies of the informants regarding the future development of the clusters provide additional information on the current strategic thinking of the informants, having an effect on today’s decision-making in the case study clusters. The cluster leadership is covered in this study but an in-depth analysis of the management practices of the regional clusters is not included. The in-depth analysis of individual companies and specific innovations
of the companies and research institutions in the case study clusters falls beyond
the scope of this study.

1.4 Research methodology

The general methodological points of departure of this study are in line with the
definitions of Niiniluoto (1980, 1983). He defines truth as the main objective of
science. According to Niiniluoto, science can be defined as information and
knowledge about reality collected in a systematic and critical way.

The division of research approaches into qualitative and quantitative is
common even if Alasuutari (1999) states that, in practice, it is almost impossible
to find any research that is purely quantitative or qualitative. This study is
predominantly in the field of qualitative research. A multiple-case study of three
European industrial concentrations: Oulu in the northern part of Finland, Luleå in
the northern part of Sweden, and Pisa in Tuscany, Italy was carried out to gain a
deeper understanding of regional clusters. The research questions primarily focus
on qualitative data; the focal point is in deepening the understanding of the
structural characteristics and the evolution over time of regional science-based
clusters. The primary data gathered from the interviews of the representatives of
the key actor groups of the regional clusters are, however, complemented by the
information gathered from other sources of evidence. This study applies a
research approach of systematic combining, grounded in abductive logic,
including a constant move between the theoretical framework of data sources, and
analysis (Dubois & Gadde 2002).

1.5 Overview of the study

The reporting of this study follows the linear-analytic structure (Yin 1994) of the
sequence of subtopics involving the issue being studied, a review of the relevant
literature, the methods used, the findings from the collected and analyzed data,
and the conclusions and implications from the findings. The report is a multiple-
case study version of the classic single case study. In Chapter 1, the background
and the motivation for the study are described. The research questions are
introduced. The scope and the positioning of the study are presented and the
research methodology is introduced. The theoretical framework is presented in
Chapter 2 where there is an introduction to cluster theory and an evaluation of the
cluster theory issues, most relevant to this study, such as the structural
characteristics of clusters, the characteristics related to the dynamic evolution of clusters, and strategic management related to the decision-making in clusters. Chapter 3 presents the research method and research process in more detail, including definitions of the units of analysis, sources of evidence, and case study setting. Chapter 4 describes the empirical context and target of the study and provides an analysis of the three regional science-based industrial concentrations: Oulu in Finland, Luleå in Sweden, and Pisa in Italy. In Chapter 5, the research findings of the in-depth interviews, held between June 2007 and January 2008, are presented. Additionally, the findings of the empirical part of the study are evaluated against the cluster theory presented in Chapter 2 and the analysis of the case study regions presented in Chapter 4. In Chapter 6, the conclusions of the study are set out along with the answers to the research questions. The last chapter also includes an assessment of the study and suggestions for further research. The outline of the study could be summarized as follows:

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction</td>
<td>Background, research questions, scope, research methodology, overview of the study</td>
</tr>
<tr>
<td>2</td>
<td>Theoretical framework</td>
<td>Definitions, structural characteristics, dynamic evolution, strategic management issues, conclusions on the theoretical framework</td>
</tr>
<tr>
<td>3</td>
<td>Research method and process</td>
<td>Case study analysis, rationales of choosing the case study regions and clusters, units of analysis, sources of evidence, case study setting</td>
</tr>
<tr>
<td>4</td>
<td>Empirical context and target</td>
<td>Overview of case study countries and regions, presentation and analysis of regional science-based clusters in Oulu, Luleå and Pisa</td>
</tr>
<tr>
<td>5</td>
<td>Research findings</td>
<td>Findings of the interviews, analysis of the results against theory and other sources of evidence</td>
</tr>
<tr>
<td>6</td>
<td>Conclusions</td>
<td>Answering the research questions, contribution of the study, validity and reliability, future of regional science-based clusters, suggestions for future research</td>
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Fig. 1. The outline of the study.
2 Theoretical framework

In this chapter, the theoretical framework of the study is presented. An introduction to the literature on clusters is provided, including cluster definitions, major advantages and disadvantages of clustering, and the relationship between clusters and innovation systems. Regional science-based clusters are defined. The structural characteristics of the regional science-based clusters are described and evaluated, including the main categories of cluster actors and structural elements: internal competition vs. co-operation, social capital and trust, leadership, and internal vs. external linkages. The dynamic evolution of regional science-based clusters is analyzed, including cluster life cycle models, technology/industry life cycles and clusters, and the concepts of critical mass, path dependence and lock-in. The strategic management issues of judgmental biases and perceptions related to regional cluster decision-making are discussed. Finally, the conclusions on the theoretical framework are presented.

2.1 Introduction to cluster literature

Development of cluster theory and cluster definitions

Clusters have dominated the theoretical discussion and the practical operations of the decision-makers in the field of regional development especially in the recent years. Maskell & Kebir’s (2005) study, of publicly accessible databases of scholarly journals within the social sciences with the term ‘cluster’ between the years 1953–2004, confirms that the cluster phenomenon has attracted a remarkably increased attention during the 1990s and 2000s evidenced by an avalanche of published academic papers. At the same time, confusion persists regarding the actual meaning and applicability of the term “cluster”.

The agglomerations of related industrial activities were first explained by Marshall in the year 1890, who discussed the industrial districts and the concentrations of specialized industries in particular localities (Marshall 1961). The framework established a link between co-location by firms and economic efficiency, as firms would cluster in order to benefit from positive externalities associated with their respective activities. The interest in industrial districts increased in the 1980s, inspired by observations on the “third Italy” concept (e.g. Brusco 1982). The term ‘industrial district’ – defined as a local system with an
active co-presence of people and of a primary industry consisting of small, independent firms specialised in the different phases of a single production process (Sforzi 2003) was introduced by Becattini in 1977 (Becattini 2003). The existence of mutual trust and an ‘industrial atmosphere’ are essential ingredients of ‘industrial districts’ (the European Commission Report 2002). The firm structures in the northeast and centre of Italy contrasted with the poor development of the south (‘second Italy’) and a recession in the traditionally rich northwest (“first Italy”). The firms in traditional industry branches e.g. shoes, furniture, tiles, clustered in specific localities and gained a position in world markets. The strong local networks of mainly small firms also improved the spreading of new ideas and technical innovation (Sengenberger & Pyke 1992).

Porter (1990) introduced the “diamond model” to explain industrial dynamics, consisting of four sets of interrelated forces: factor conditions (input), demand conditions, related and supporting industries, and context for firm strategy and rivalry. He argued that the intensity of interaction within the “competitive diamond” is enhanced if the firms concerned are also “geographically localised” or “clustered”. The “diamond model” was followed by the definition of clusters by Porter (1998a): “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. They include, for example, suppliers of specialized inputs such as components, machinery, and services, and providers of specialized infrastructure. Clusters also often extend downstream to channels and customers and laterally to manufacturers of complementary products and to companies in industries related by skills, technologies, or common inputs. Finally, many clusters include governmental and other institutions – such as universities, standards-setting agencies, think tanks, vocational training providers, and trade associations – that provide specialized training, education, information, research, and technical support.”

According to Porter, a “geographically localised” cluster consists not only of firms, but also of an institutional environment. Geographically concentrated firms and institutions inside a certain technological proximity or common “theme” are relevant. Porter states that clusters reveal the mutual dependence and collective responsibility of businesses, government, and institutions, requiring fresh thinking on the part of leaders and a willingness to abandon the traditional ways of thinking about who does what in the economy. Porter links the diamond theory and the idea of clusters together, stating that the idea of clusters is a derivative of
the diamond theory, emphasizing the productivity of the firms as the metric of competitiveness (Snowdon & Stonehouse 2006).

Porter (2008) argues that a cluster is not an industry but a series of related industries. He states that in terms of understanding productivity, industry as a unit of analysis is too narrow, and sector, such as manufacturing or services, is too broad. Porter argues that clusters should be regarded as being positioned between industry and sectors. He states that clusters take a long time to grow, to accumulate skills and technology.

Sölvell et al. (2003) define a more comprehensive notion of cluster compared to Porter (1998a): “Clusters consist of co-located and linked industries, government, academia, finance and institutions for collaboration.” Andersson et al. (2004) describe the change in the focus of the cluster concept over time, stating that the focus of policymakers, researchers and cluster practitioners was clearly on firms when the cluster concept was introduced. As more attention was paid to the challenges arising in the sharing of knowledge and skills, a systems approach underlining the interplay and interdependence of actors gained ground.

Bergman & Feser (1999) define regional industry clusters as industry clusters that are concentrated geographically, normally within a region that constitutes a metropolitan area, labour market shed, or other functional economic unit. They also note that industry clusters identified in practice often bear little resemblance to Porter’s ideal type. “It is not uncommon for local and regional agencies to designate clusters for policy attention that are actually very poorly developed or that constitute the only viable industry in the given region.” Rosenfeld (2002) makes a distinction between networks and clusters. According to him, networks are closed organizations generating external economies for members willing to share costs of resources, expertise, or information, whereas clusters, being more open, derive external economies because the market delivers it to them as a result of the scale of demand.

Martin & Sunley (2003) state that Porter has taken the influential and even dominant role in the literature on clusters not only by promoting the idea of clusters as an analytical concept, but also as a key policy tool. The Porter definition of clusters has thus become a standard definition especially among the practitioners despite the critics’ claimed shortcomings of the definition. Martin and Sunley (ibid.) claim that Porter’s definitions of clusters are vague in terms of geographical scale and internal socio-economic dynamics, allowing different analysts to use the idea in different ways to suit their own purposes. According to them, Porter regards competitiveness as the dominant and overarching element of
clusters. “Just how far can the full complexity of economic, social, and institutional factors and processes alleged to underpin cluster formation, development, and success, be reduced to or subsumed within an overarching concept of competitiveness?” They state that clusters vary considerably in type, origins, structure, organisation, dynamics, and developmental trajectory, yet Porter’s theory is supposedly intended to fit all. According to Martin and Sunley (ibid.), the cluster concept has acquired such a variety of uses, connotations and meanings that it has, in many respects, become a “chaotic” concept, in the sense of “conflating and equating quite different types, processes and spatial scales of economic localisation under a single, all-embracing universalistic notion”.

In spite of the relatively dominant role of Porter, the terminology and the perceptions of the clusters vary significantly as illustrated in Table 1.

Table 1. Examples of cluster definitions.

<table>
<thead>
<tr>
<th>Author</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>Porter (1998a)</td>
<td>A cluster is a geographically proximate group of interconnected companies and associated institutions in a particular field.</td>
</tr>
<tr>
<td>Sölvell et al. (2003)</td>
<td>Clusters consist of co-located and linked industries, government, academia, finance and institutions for collaboration.</td>
</tr>
<tr>
<td>Rosenfeld (1997)</td>
<td>A cluster is very simply used to represent concentrations of firms that are able to produce synergy because of their geographical proximity and interdependence, even though their scale of employment may not be pronounced or prominent.</td>
</tr>
<tr>
<td>Rosenfeld (2005)</td>
<td>Clusters are geographic concentrations of interrelated companies and institutions of sufficient scale to generate external economies.</td>
</tr>
<tr>
<td>Bergman &amp; Feser (1999)</td>
<td>An industry cluster is a group of business enterprises and non-business organizations for whom membership within the group is an important element of each member firm’s individual competitiveness.</td>
</tr>
</tbody>
</table>

Cortright (2006) states that the multiplicity of interests in clustering, coupled with the widely varying perspectives different actors bring to its use, have created an ongoing debate about clusters: what are they, do they matter, and who “owns” them. There are, also, differences in the data used to discern the existence of clusters and to measure their effects. Cortright claims that academics tend to rely on secondary data, usually looking to simplify, to abstract, and to generalize, while the practitioners are more pragmatic, looking for something that works and
that helps explain the changing and challenging economic context in which their communities or organizations are competing. Cortright argues that both (cluster) academics and practitioners must continue to tolerate some ambiguity. He concludes that rather than working to prove (or disprove) that clustering generally is a benefit to economic performance, research would be better directed to discovering the specific characteristics of clusters that lead to such performance.

Besides individual clusters, there are also national and regional cluster programmes and initiatives e.g. the Finnish Centre of Expertise Programme and the Vinnväxt programme in Sweden (European Cluster Observatory 2008). The national and regional cluster programmes and initiatives have spread over a large quantity of countries. Ylä-Anttila (2007, 2008) states that the internationalisation has changed cluster thinking. “Clusters are not similar to what they used to be. It is not any more possible to build up national projects based on clusters. Today, there are small, regional clusters or international, big clusters.”

Regional cluster

The concept “region” has its origin in Latin from “regere” meaning to govern (Cooke 2005). The geographical scope of a regional cluster differs between the various definitions of regional clusters presented in the literature. The European Commission Report (2002) defines regional cluster as “a concentration of ‘interdependent’ firms within the same or adjacent industrial sectors in a small geographical area”. Rosenfeld (2005) defines the geographic boundaries of clusters to be set by the distances those in the firms and the entrepreneurs are willing to travel for informal face to face meetings, and by how far employees are willing to travel to work. Andersson et al. (2004) define a regional or localized cluster as a spatial agglomeration of similar and related economic activity that forms a basis of a local milieu that may facilitate knowledge spill-over and stimulate various forms of learning and adaptation. These clusters commonly consist of SMEs and the core of their success is centred on strengths in social capital and geographical proximity. Menzel & Fornahl (2007) argue that the (regional) cluster is at the interface between industrial and local dynamics. The elaboration of this interface requires the elaboration of its constituent rationales, namely industrial and local dynamics.

Enright (2001) suggests the following dimensions as relevant to characterize regional clusters: geographic scope, density, breadth, depth, activity base, geographic span of sales, strength of competitive position, state of development,
nature of technological activities, innovative capacity, and ownership structure. His categories of clusters are illustrated in Table 2.

**Table 2. Cluster categories characterizing the state of development (Enright 2001).**

<table>
<thead>
<tr>
<th>Cluster category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working clusters</td>
<td>Those in which a critical mass of knowledge, expertise, personnel, and resources create agglomeration economies that are used by firms to their advantage in competing with those outside the cluster.</td>
</tr>
<tr>
<td>Latent clusters</td>
<td>Having a critical mass of firms in related industries sufficient to reap the benefits of clustering, but having not developed the level of interaction and information flows necessary to truly benefit from co-location.</td>
</tr>
<tr>
<td>Potential clusters</td>
<td>Having some of the elements necessary for the development of successful clusters, but where these elements must be deepened and broadened in order to benefit from the impact of agglomeration.</td>
</tr>
<tr>
<td>Policy driven clusters</td>
<td>Those chosen by governments for support, but which lack a critical mass of firms or favourable conditions for organic development.</td>
</tr>
<tr>
<td>Wishful thinking</td>
<td>Policy driven clusters that lack, not only a critical mass, but any particular source of advantage that might promote organic development.</td>
</tr>
</tbody>
</table>

According to Enright, the characterizations of clusters are useful in determining the focus of the cluster promotion policies. For working clusters, one should help them further develop export markets. For latent clusters, one should help them reach a level of self-realisation that will allow for development of inter-firm links. Potential clusters should be assisted in developing or attracting a sufficient critical mass to become a working cluster. Finally, for wishful thinking clusters, Enright proposes either more creative approach or “exclusion from resource constrained programmes”.

**Advantages and disadvantages of clusters**

Before delving deeper into the cluster theory, the key benefits of clustering based on the literature on clusters are now discussed. The rationales for the geographic concentration of industries in regional clusters have been explored by a number of authors, including the presence of unique natural resources, economies of scale in production, proximity to markets, labour pooling, the presence of local input or
equipment suppliers, shared infrastructure, reduced transaction costs, and other localized externalities (Enright 2001).

According to Porter (1998a, 1998b), clusters affect competition in three broad ways. First, they increase the productivity of companies. Second, they drive the direction and pace of innovation. Finally, clusters stimulate the formation of new businesses. Porter states that a cluster allows each cluster member to benefit as if it had greater scale or as if it had joined formally with others – without requiring it to sacrifice its flexibility.

DTI (2004) lists the key benefits of clustering, for both business and the wider economy, as follows:

- increased level of expertise;
- the ability of firms to draw together complementary skills;
- the potential for economies of scale;
- strengthening social and other informal skills;
- improved information flows within a cluster;
- enabling the development of an infrastructure of professional, legal, financial and other specialist services.

Clustering may also bring disadvantages to cluster participants. Swann (1998) argues that clusters face the risk of congestion: the cluster may become overcrowded, resulting in an increased number of competitors reducing per-firm sales, prices, per-firm profits, and per-firm growth on the demand side, and an increased competition on the supply side e.g. the cost of real estate or labour. He adds that the cluster benefits may be most important at an early stage of the cluster’s life cycle, while the cluster disadvantages build up at a later stage. The analysis on optoelectronics industry at the company and regional level (Hendry & Brown 2006) shows that clustering itself grants no particular performance benefits when comparisons are made of companies not in clusters. Kuah (2002) notes that co-location itself does not imply clustering when the associated clustering benefits like innovation, productivity, growth or other superior competitiveness cannot be shown or described.

Clusters and innovation systems

The analysis of clusters is closely related to the analysis of innovation systems. The term “innovation” originates from a Latin verb “innovare” which means doing something new. Schumpeter (1939) states: “We will simply define
innovation as the setting up of a new production function. This covers the case of a new commodity as well as those of a new form of organization such as merger, the opening up of new markets, and so on.” He stresses the role of technological change in industrial development and introduces the significance of innovation and the significance of the entrepreneur as an agent of change playing an important role for creative destruction, an evolutionary process dismantling obsolete industrial structures. According to Tichy (1998), innovation needs an integrated and interactive approach blending scientific, technological, socioeconomic, and even cultural aspects with organisational capabilities. He adds that geographical proximity and face-to-face contacts are facilitated by cluster in order to blend firm-specific knowledge with generally accessible knowledge. The link between innovation performance and the interconnectedness of various actors has been one of the mainstream topics of the cluster discussion, closely related to the literature on Innovation Systems. Malmberg & Maskell (2002) state that a local industrial infrastructure with competing and/or collaborating firms triggers processes which create dynamism, flexibility, learning and innovation. “In such an environment, chances are greater that an individual firm will get in touch with actors that have developed or been early adopters of new technology.”

The Oxford Universal Dictionary (1981) defines system as a set of connected things or parts that form a whole or work together. Then the question can be posed: what is an innovation system? Moreover, what is the relation of clusters to innovation systems? Laestadius (2007) defines an innovation system as a structure of institutional/cultural/actor concentration in an economic space, with specific industrial/innovative characteristics in relation to its environment. He points out that there is a family of innovation systems, the core family includes the national, regional, and sectoral innovation systems, adding that innovation system per se is not limited to a geographical context. He states that a system may be more or less openly related to its environment; however, a totally open system would be meaningless because it could not be identified any more.

Miettinen (2002) explains that there are two sources of the notion National Innovation System (NIS). The first main source is the attempt in the 1980s to understand the reasons for the difference in economic growth rates between industrialized countries. The second source is the attempt to explain economic development in terms of capital and accumulation. According to Metcalfe (1995), a National Innovation System is a set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and
which provides the framework within which governments form and implement policies to influence the innovation process. “As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies.” According to Oinas & Malecki (2002), the NIS approach generally focuses on institutional characteristics of innovation systems on a national scale and favours those at the expense of other scales. The involvement of the public sector is recognized by the NIS approach both directly (i.e. universities, government laboratories) and indirectly (i.e. by creating incentive structures, education and training systems, and promoting exports through fiscal, monetary, and trade policy packages).

Cooke (2004) defines a regional innovation system: “A regional innovation system consists of interacting knowledge generation and exploitation of sub-systems linked to global, national, and other regional systems for commercialising new knowledge.” The geographical limitation is one of the key issues of the RIS debate. Cooke (2005) specifies “regional” as nested territorially beneath the level of the country, but above the local or municipal level adding that in objective terms, this is generally how the conceptual level will align with the real. Doloreux & Parto (2004) argue that the diversity of the units of analysis employed in studies of regional innovation systems, ranging from “city” and “the local” to supra-regional or even sub-national level, presents a major problem in developing a unified conceptual framework towards a construct of “the region” as a theoretical object of the study. Doloreux & Parto (ibid.) state that the concept of regional innovation systems is usually understood as a set of interacting private and public interests, formal institutions and other organizations that function according to organizational and institutional arrangements and relationships conducive to the generation, use and dissemination of knowledge.

Cooke (2004, 2007) defines two different types of regional innovation systems: the IRIS (Institutional Regional Innovation System) and ERIS (Entrepreneurial Regional Innovation System). The IRIS, more familiar in Europe, is research and development driven and technology-focused whereas the ERIS, more familiar in the USA, is more venture capital driven and market-focused. Cooke (2007) states that regional innovation systems are not isolated “islands” but more like “icebergs”, swiftly affected by their global environment, immediate external conditions and internal dynamics. He argues that Western regional innovation systems are less and less concerned with routine manufacturing and private services (e.g. branch plants and call centres) and more focused on relatively untraded services (e.g. healthcare), local traded services
(e.g. transport, cuisine), and knowledge intensive exploration (research), examination (testing and trialling) and exploitation (innovation) activities.

The relationships between clusters and the various concepts of innovation systems have been subjects for a number of studies. Cooke et al. (2007) present the main structure of a regional innovation system (see also Tödtling & Trippl 2005). According to them, an RIS consists of two subsystems embedded in a common regional socioeconomic and cultural setting. The knowledge application and exploitation subsystem comprises of the companies, their clients, suppliers, competitors, and industrial co-operation partners. The knowledge generation and diffusion subsystem consists of various institutions that are engaged in the production and diffusion of knowledge and skills (public research organisations, technology mediating organisations, and educational institutions). A regional policy dimension includes policy institutions and regional development agencies. Cooke et al. (2007) argue that clusters and RISs can, and often do, coexist in the same territory. “But whereas the regional innovation system by definition may host several clusters, a cluster is never isomorphic with an RIS.” Tödtling & Trippl (2005) state that clusters are central elements of the knowledge application and exploitation subsystem, whilst the RIS is a wider concept in the sense (1) that there are usually several clusters and many industries in an RIS and (2) that institutions play a larger role, institutions in this context referring to innovation relevant organisations, rules and behavioural characteristics of forms and actors. Fig. 2 illustrates the regional innovation system. The clusters of the region, marked in grey, are located inside the knowledge application and exploitation subsystem, consisting of “leading firms in a particular industry, vertically and horizontally related companies, service providers and supporting institutions” (Cooke et al. 2007).
According to Wolfe & Gertler (2004), clusters can be seen as nested within, and impacted by, other spatial scales of analysis, including regional and national innovation systems, as well as global relationships and forces. Andersson et al. (2004) argue that clusters and regional innovation systems are closely related but with fundamentally different ideas: while a cluster is regarded as an industry specific phenomenon, an innovation system is a broader framework affecting the innovative capacity of firms in a variety of sectors. They state that the cluster concept is narrower than the concept of innovation systems: an innovation system may contain several clusters, but a cluster is not a necessary ingredient in an innovation system.

Bellini & Landabaso (2005) make a difference between the “US cluster a la Porter” and regional innovation policies in Europe mainly because of the different role attributed to public policies. They argue that regional innovation system approaches do not concentrate solely on firms and factor conditions. According to them, it is more appropriate to talk about localized public-private networks which
may have a sectoral, technological or thematic nature in Europe rather than of clusters in a strict sense.

The Triple Helix concept was introduced by Etzkowitz & Leydesdorff in the late 1990’s. The Triple Helix model includes three key actors of the innovation system: the government, industry, and university, or State, Industry, and Academia. The objective is to realize an environment with innovativeness, consisting of university spin-offs, tri-lateral initiatives for knowledge-based economic development, and strategic alliances between the Triple Helix actors (Etzkowitz & Leydesdorff 2000). Westerberg et al. (2007) state that the Triple Helix concept, a specific type of innovation system, promises profound progress for an ageing European industry, emphasizing the role of the universities. They argue, however, that the empirical proof supporting the promises is not that convincing, one of the problems being the different time perspectives of actors.

Besides national and regional innovation system concepts, there is also the concept of sectoral innovation systems. Sectoral innovation systems are based on the understanding that innovations develop in or with an application for a specific line of industry or industry sector. For example, new process technology may be related primarily to the process industry, new ICT to the ICT industry and new biotech innovations to the biotech industry (Laestadius 2007). These industries normally operate under global competition and are often to a significant degree represented by global multinational corporations. While the concept of national innovation systems has its main focus on the nation as the primary unit of analysis, advocates for the sectoral innovation system approach state that national boundaries are not always the most appropriate ones to examine the structure, agents, and dynamics of sectoral systems (Malerba 2005).

As a conclusion to the discussion of the relation between clusters and innovation systems, it can be stated that most of the literature on clusters regards clusters as nested within innovation systems. Firms are regarded as core elements of clusters. There are differences in the comprehensiveness of the regional cluster concept in the cluster and innovation system literature, ranging from a narrow definition (firms only) to broader definitions (firms, research organizations, governmental organizations, research organization, financial institutions, and institutions for collaboration). Laestadius (2007) states that even Porter, without using the expression ‘innovation system’, bases the analyses on research settings and sources of evidence in many aspects similar to innovation system research. As Porter (1998a) claims: “What happens inside companies is important, but
clusters reveal that the immediate business environment outside companies plays a vital role as well.”

### 2.2 Regional science-based clusters

The general cluster concept includes a wide range of possible companies and industrial sectors. The main interest in this study focuses on clusters related to advanced technologies and research-based activities. Pavitt (1984) divides innovative firms into three major categories: supplier dominated, production intensive, and science-based. In the science-based category, the main sources of technology are the R&D activities of firms in the sectors. Paniccia (2006) provides a typology of industrial districts and clusters, using Pavitt’s categories. The classification includes science-based or technology agglomerations, characterized by e.g. locations for important scientific and communication knowledge infrastructures, rich technological opportunities, the very active role of knowledge institutions, and products with short life cycles. Examples of science-based agglomerations given by Paniccia include e.g. Silicon Valley in US and Sophia-Antipolis in France.

The report by European Commission (European Commission Report 2002) presents the results of a cluster survey where 34 regional clusters in 17 European countries were analyzed, dividing the 34 clusters into two categories: science-based clusters and traditional clusters (relying more on traditional, local skills). Table 3 demonstrates the major characteristics of science-based clusters and differences between science-based and traditional clusters.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Science-based clusters</th>
<th>Traditional clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Young</td>
<td>Young and old</td>
</tr>
<tr>
<td>Dominant forms of transaction</td>
<td>Market based relationships, temporary coalitions and long-term relationships</td>
<td>Long-term market relationship</td>
</tr>
<tr>
<td>Important local collaborators</td>
<td>R&amp;D institutions and public authorities</td>
<td>Service suppliers and public authorities</td>
</tr>
<tr>
<td>Typical innovation activity</td>
<td>Technology generators (mainly product development and changes in the organisation of the production process)</td>
<td>Incremental innovators (mainly product development and new methods of marketing and distributions)</td>
</tr>
</tbody>
</table>
Besides the categorization of science-based and traditional clusters, there are other categorizations of research and technology oriented regional clusters. Fallah (2005) defines a technological cluster as a geographical concentration of related technology firms to include competitors, suppliers, distributors, and customers; usually around scientific research centres and universities. According to him, a functioning technological cluster consists of a number of players that work in concert to create a highly innovative and productive environment for the growth of the existing and creation of new businesses in the cluster. Dalum et al. (2002) use the term “regional high-tech cluster” featuring a regional cluster, where the economic development patterns are quite closely related to the emergence of new key technologies. Pouder & St. John (2006) state that the clusters such as “the original Silicon Valley” have evolved a technology identity, rather than an industry identity. In these clusters, new technologies, often developed with the participation of university researchers, provide radical innovations that are often competence-destroying, giving rise to whole new industries and firms.

The cluster discussion has largely concentrated in so-called high-tech industries. The problem of defining high technology and high technology industries causes difficulties in the analysis of clusters related to so-called high technology industries. There is not a widely accepted definition of high technology or high technology industry available. The American Electronics Association (AeA 2005) defines high technology industries using 45 Standard Industrial Classification, or SIC, codes falling into three broad categories: high-tech manufacturing, communication services, and software and computer-related services. The SIC classifications have a considerable drawback from the viewpoint of clusters: the definition does not include many related industries such as biotechnology, and engineering services. Cortright (2006) states that clusters are not always contained with a single industry classification. Some clusters cut across a wide swath of industry classifications. Porter (1998a) argues that the term high-tech, normally used to refer to fields such as information technology and biotechnology, has distorted thinking about competition, creating the misconception that only a handful of businesses compete in sophisticated ways. He claims that in fact, there is no such thing as low-tech industry. There are only low-tech companies – that is, companies that fail to use world-class technology and practices to enhance productivity and innovation. A vibrant cluster can help any company in any industry compete in the most sophisticated ways, using the most advanced, relevant skills and technologies. Enright (2001) argues that the
distinction between high innovation and low innovation clusters is far more useful than that of high technology and low technology clusters.

2.3 Structural characteristics of regional science-based clusters

The research question RQ1 focuses on the analysis of the structural characteristics of regional science-based clusters. The following review of the literature on clusters provides a presentation and analysis of the most relevant issues from the viewpoint of research question RQ1 of this study: i.e. the main categories of cluster actors and the main structural cluster elements.

2.3.1 Main categories of actors

There are different ways of presenting the actors and the relationships between different groups connected to clusters. Stakeholder analysis is a practical tool for analyzing the actions and relationships. The main ideas of stakeholder analysis can be traced back to Barnard in the year 1938, defining an organization as a system of consciously coordinated personal activities or forces (Barnard 1976 and Simon 1957). Stakeholder mapping (Freeman 1984) includes the basic identification of different stakeholder groups as the starting point of the stakeholder analysis. Fig. 3 presents an example of a stakeholder map.
Stakeholder concept has also been used in the regional cluster analysis. Wolfe & Gertler (2001) present the cluster analysis within a set of 22 regional clusters in Canada. They categorize the stakeholder groups of the regional clusters as follows:

- Lead firms (large, technologically-dynamic, export-oriented)
- Smaller and mid-sized firms, including suppliers
- Industry associations, chambers of commerce
- Labour organizations
- Government agencies (federal, provincial, local)
- Technology transfer organizations
- Universities: offices of technology transfer; relevant departments and faculties
- Colleges and other training institutions
- Financial sector (venture capitalists, bank, other)
- Local political leaders and “civic entrepreneurs”.

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). Andersson et al. (2004) present the cluster structure by Sölvell et al. (2003) as illustrated in Fig. 4.

Fig. 4. Categorization of cluster actors (Andersson et al. 2004, adopted from Sölvell et al. 2003).

The cluster figure presented by Andersson et al. (2004) is almost similar to the Sölvell et al. (2003) cluster figure, the visual difference being the size of the IFC “balloon”. Andersson et al. (ibid.) illustrate the IFC as having approximately equal size compared to other cluster actors, whereas Sölvell et al. (2003) illustrate the IFC “balloon” as considerably smaller at size compared to other cluster actors.

Companies, being central to cluster actions and policies, are directly involved in technical, business and market processes. According to Andersson et al. (2004), companies need to be viewed as pursuing their own interests. Their participation in a cluster initiative should be recognised as a tool to improve sales and profit growth, not as a socially beneficial public service contribution for PR purposes. Firms may even have valid reasons to keep away from co-operation, such as fears of disclosing their assets to competitors through collaborative ventures. Andersson et al. (ibid.) argue that many successful clusters have at least one large company functioning as an anchor company. The cluster firms in science-based clusters are based on new technology and knowledge, and to some extent they are spin-offs from universities and research institutions (European Commission Report 2002).
Governments/policymakers are divided into international, national, and regional/local. The international level consists of actors such as the EU, allocating funds to regional actors, supporting a broad-based modernisation of infrastructure and trans-national R&D co-operation. The national government is considered to have the overview and the coordinating capacity but lacking the proximity to local clustering processes (Andersson et al. ibid). The local/regional level policymakers tend to have a better understanding of the potentiality of specific local assets. The government is often expected to “see the big picture” and provide the infrastructure to support growth and competitiveness. The role and intensity of public sector actors in supporting regional cluster initiatives is being frequently debated. Porter (1998a) states that governments – both national and local – should not choose among clusters, because each one offers opportunities to improve productivity and support rising wages, adding that market forces – not government decisions – should determine the outcomes. Martin & Sunley (2003) state that even cluster enthusiasts find it enormously difficult to point to any examples of deliberate cluster promotion programmes that have been unambiguously successful.

Research community (universities, public laboratories, research institutes) is generally characterized by in-depth knowledge and analytical competencies. The research community, however, has in many countries few incentives to engage in commercial undertakings, limited experience of entrepreneurship, and insufficient abilities to communicate directly to the business community (Andersson et al. ibid.). According to Sölvell et al. (2003), few cluster initiatives are started by universities and even fewer financed by them. Breshanan & Gambardella (2004) emphasize the importance of highly skilled labour as a precondition for the growth of an ICT-based entrepreneurial cluster. They do not, however, support the simple ‘recipe’ view of universities and higher education in starting a cluster, stressing that a university per se is not essential to the emergence of a successful cluster. They suggest that regions can look for the most appropriate way of acquiring skilled labour, from universities to larger firms and other local as well as more distant institutions. Baptista (1998) argues that location depends on the type of research to be carried out in the region: applied research tends to be scattered in smaller units attached to production facilities, the development work is primarily attached to manufacturing plants, and basic research tends to be concentrated in core metropolitan regions.

Financial actors – banks, insurance companies, public pension funds, investment funds, business angels, venture capitalists – all have their objectives,
limitations, and preferred portfolios (Andersson et al. ibid). Although government and industry are identified as the main sources of financing for cluster initiatives (Sölvell et al. 2003), the financial actors, especially professional venture capitalists can play a vital role not only in channelling financial resources but also providing human capital, notably in risk management complemented by organisational, production, management, marketing, and/or sales knowledge in a particular niche where they are managing risk and business development. Andersson et al. (ibid.) argue that in times of crisis, the risk aversion nature of the financial actors threatens to make them the ‘weakest of the links’. They add that there is also a need for public venture capital for early stages in the commercialisation of new technology.

Institutions for Collaboration (IFCs) are formal or informal actors promoting interest in the cluster initiative among the actors involved (Andersson et al. ibid). The IFC may consist of several diverse actors that can complement each other. Rosenfeld (2002) states that cluster intermediaries stand for organisations with certain knowledge and interests enabling them to match the supply to the demand, whether it is about labour, information, knowledge, or technology. The role of IFCs may vary considerably. Their capabilities and roles may evolve over the course of the cluster life cycle (Andersson et al. ibid.).

Hybrid organisations include incubators (university-industry hybrid), trade associations or chambers of commerce (government-industry hybrid), and government councils e.g. research/science, innovation, etc., comprised of representatives from all three elements of the Triple Helix structure: government, industry, and the research community. Hybrid organisations can make contributions in linking and helping to integrate the roles and functions of others (Andersson et al. ibid.). Laestadius & Nuur (2007) warn, however, that there are some elements of risk embedded into Triple Helix including e.g. resistance of the academic community to co-operation with the SMEs, the overestimation of the role the regional universities can play, and the relatively slow engagement of the companies to participate in Triple Helix type co-operation.

2.3.2 Main cluster elements

The literature on clusters introduces a number of cluster elements which have an effect on the dynamics and viability of the cluster. Andersson et al. (2004) list the following main elements of clusters commonly found in the cluster literature:
- Geographical concentration, due to hard factors, such as external economies of scale, as well as soft factors such as social capital and learning processes;
- Specialisation: clustering around a core activity to which all actors are related;
- Multiple actors: clusters consisting not only of firms, but also involving public authorities, academia, members of the financial sector, and IFCs;
- Competition and co-operation;
- Critical mass required to achieve inner dynamics;
- Cluster life cycle;
- Innovation: processes of technological, commercial and/or organisational change.

The list includes both structural cluster elements and elements related to the dynamic evolution of clusters. Many of the main elements are related to other cluster main elements. The main elements sometimes include both structural characteristics and features related to the dynamic evolution of clusters.

The analysis of the structural characteristics of the regional science-based clusters in this study focuses on the following main elements of clusters (the cluster life cycle and critical mass will be introduced later in this study under the analysis of dynamic evolution):

- internal competition vs. co-operation: how do the cluster participants compete with each other? What kind of co-operation exists inside the cluster?
- social capital and trust: what kind of “social glue” and trust exist inside the cluster? What kind of “industrial atmosphere” could be identified?
- leadership: how is the cluster leadership organized – or is it spontaneous, without formal governance?
- internal vs. external cluster linkages: what is the relation between the internal cluster activities and links with partners outside the cluster?

The selection of the cluster elements to be analyzed in this study reflects the attempt to provide a broader and deeper understanding of the structural characteristics of regional clusters. The specific features related to regional science-based clusters will be highlighted where appropriate. The selection of the cluster elements reflects the qualitative approach of this study and the case study method emphasizing “how and why” type of questions instead of e.g. “how much” questions. The chosen cluster elements are also frequently discussed by cluster practitioners.
Clusters carry features of both competition and co-operation. As the competition between firms tightens, pressures for improvement are generated. Local rivalry extends even to individuals. Porter (1998a) states that peer pressure amplifies competitive pressure within a cluster. “Pride and desire to look good in the local community spur executives to attempt to outdo one another.” Enright (2001) states that paradoxically, regional clusters appear to entail both greater cooperation and greater competition among direct competitors than geographically dispersed industries. For firms, co-operation with direct competitors involves a trade-off between access to greater resources and the potential for loss of proprietary information or the creation of stronger competitors. According to Enright, co-operating with local direct competitors can be beneficial if such co-operation helps the cluster compete against outside competitors.

Porter (1998a) states that the companies must participate actively and establish a significant local presence. Tapping into the competitive valuable assets within a cluster requires personal relationships, a sense of common interest, and “insider” status. Maskell & Kebir (2005) argue that the local coordinated action is usually a blessing to the local community. Often, however, closely knitted local power groups are an unquestioned evil when uncomfortable decisions have to be made. Malmberg & Maskell (2002) state, that in reality, many empirical studies have produced disappointing results in trying to document the abundance of inter-firm collaboration in localized clusters. They add that suppliers and customers in a vertically organized production chain need to interact with each other in order to do business, whereas competitors do not.

The European Commission report (2002), based on the European survey of regional clusters, states that cluster firms rarely collaborate intensively with competitors. There are, according to the report, some differences between firms in science-based clusters and firms in traditional clusters regarding co-operation. Firms in traditional clusters co-operate especially with service suppliers and public authorities, whereas firms in science-based clusters co-operate mostly with public organizations and R&D organizations.
Social capital and trust

Besides the techno-commercial aspects, there are “soft aspects” related to clusters concerning the interaction between the cluster actors. Sölvell et al. (2003) list three types of 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. Social capital is embedded in local cultures and institutions, consisting of e.g. personal networks and institutions for collaboration. Putnam (2000) defines social capital, “your extended family”, as social networks and the associated reciprocity. Andersson et al. (2004) define social capital as intangible aspects of the social organization or region or cluster, facilitating collaboration among economic actors. They link the technical efficiency of a region to the ability to build up social capital. “If you have or can build social capital, technical innovations can thereby be made more efficient.” There are, however, indications of a decreasing trend in the amount of social capital, as Putnam (2000) argues, stating that community life declined significantly over the last half of the 20th century, and that people have become increasingly disconnected from each other and from their communities.

Porter (1998a) states that the social glue binds clusters together, adding that reaching the competitively valuable assets within a cluster requires personal relationships and contacts, a sense of common interest, and “insider” status. Cortright (2006) argues that economic systems are embedded in social systems, not separate from them. “People are not simply workers or managers; they are also consumers, citizens, church-goers, kin, and community members.” The challenge of sustaining the social capital in the region and its clusters is essential in the development of competitive innovation environments, related to the quality of life, cultural issues, and the ability of the regions and clusters to attract talented people.

Saxenian’s (1994) analysis of high technology regions in Boston (Route 128) and California (Silicon Valley) highlights cultural differences, attributing the superior economic performance of California partly to its openness and networking abilities compared to the more closed industrial system in Boston area where the process of technological change is limited within corporate boundaries. According to her, 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. Malmberg & Maskell (2002) argue, however, that a “nice” and collaborative atmosphere might not characterize most relations...
between companies in an industrial concentration. “Firms may dislike each other and refuse to talk but can still, indirectly, contribute to each other’s competitive success in the global market. “

Florida (2003, 2005a) states that both economic and lifestyle considerations matter in attracting talented workforce to locate and cluster in certain places. The chances to attract “creative class” to certain places are better if the “3T” combination of factors can be provided; “3T” refers to tolerance, talent, and technology. Tolerance is defined by Florida as openness, inclusiveness, and diversity to all ethnicities, races and walks of life. Talent refers to workforce with bachelor’s degree and above. Technology is a function of both innovation and high technology, concentrated in the region. Florida (2005b) states that the creative economy is highly concentrated in about 10 leading regions in the USA and some tens of regions outside the USA. The concentration has, however, resulted in e.g. higher costs of housing, inequality, traffic problems, threatening to dampen the innovation and growth created by the regions.

Doloreux et al. (2007) state that metropolitan regions have a high population density, demographic diversity, and an environment where innovation is most likely to occur. They argue, however, based on the analysis of non-metropolitan regions in Canada, Belgium, and France, that smaller regions may have the ability to devise and lead big operations on local, regional, and national scales, creating e.g. support structures specifically devoted to entrepreneurship. Also, the regional public bodies are involved in promotion of a local economy based on innovation and technological transfer.

Social capital is closely tied to the concept of trust. Maskell & Lorenzen (2006) define trust as a relationship between firms when each is confident that the other’s present value of all foreseeable future exchanges exceeds the possible benefits of breaking the relation. They state that trust is an efficient lubricant to economic exchange, diminishing the friction for interaction, co-operation, or exchange. The notion of trust is discussed e.g. in the literature of the Italian industrial districts, characterized by common culture and social embeddedness, where trust is based on “custom” (Dei Ottati 2003). Sabel (1992) argues that the proper question should not be how to create trust from mistrust but how and whether particular persons or relations come to be seen as trustworthy, concluding that trust is a precondition of social life.

Cooke & Morgan (1998) state that trust is ‘neither an outcome derived from calculation nor a norm traced to culture’. They claim that effective, trust-based relationships require ‘rich consultative structures which allow the participants to
monitor their interactions’. They add that monitoring minimizes problems that may result not from a breakdown of trust but from a lack of competence’. Maskell (2001) states: “The only requirement is many firms with similar bodies be placed in circumstances where they can monitor each other constantly, closely and almost without effort or costs.”

**Leadership**

DTI (2004) states that successful clusters are often associated with strong leadership, either from individuals or institutions. Leaders are typically people committed to a local area, perceived as having a high degree of influence and able to cultivate interactions between cluster stakeholders. The national study of cluster development in Canada reveals the cluster leadership as one of the dominant themes (Wolfe & Gertler 2004). According to the Canadian study, the cluster leadership can differentiate one region from another. The “civic 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 ibid). According to Cooke et al. (2007), clusters may have some kind of ‘governance’ but it is likely to be informal or a private ‘cluster association’ rather than more formally governmental in character. Harmaakorpi (2004) states that the actions of leadership give direction to the organisation, and groups of people, motivating and inspiring activity, and bringing positive, sometimes even dramatic changes. The actions of management produce plans and budgets, organising and controls. According to Harmaakorpi (ibid.), the actions of both leadership and management are needed in regional innovation systems. Sölvell et al. (2003) state that clusters are often initiated by a “clusterpreneur”, with leadership later taken over by a hired cluster facilitator.

Sotarauta (2007) argues that the relationships between influential individuals and institutions are reciprocal. Individual actors shape their institutional environment but at the same time they are shaped by the institutions. He states that people who can “see the entire playing field” and make sense of many complementing and conflicting issues, instruments, and actors simultaneously are of importance. According to Sotarauta (ibid.), individual organizations or human beings are usually not strong enough to make a difference alone from regional economic development point of view, which suggests shared leadership.
Hallencreutz et al. (2002) state that the “cluster motor” of the majority of the Swedish clusters is not one single individual but several persons sharing the leadership task. In several cases, the other “cluster motor” individuals come from the public sector and some from the private sector. Rosenfeld (1997) emphasizes that one should empower the companies to take charge of the cluster initiatives. “Regions that let the companies take charge of their efforts have the most to show for their investments.”

Molina & Kinder (2000) analyze industrial clustering with a particular emphasis on the governance dominating its evolution. They apply the sociotechnical constituencies approach, drawing attention to the processes of networking, negotiation, and conflict underpinning technological processes, to industrial clustering. They state that a cluster is a large-scale sociotechnical constituency consisting of a variety of specific and interrelated technical, organizational, and commercial factors. According to Molina & Kinder (ibid), the organization, projects, and formal and informal working arrangements between players is an outcome of the process of a sociotechnical alignment: something to be created and shaped in a large and complex process of accommodation. They state that the cluster governance needs a careful approach due to “different blends of expertise, perceptions, imperatives, and expectations” of the cluster actors.

Westerberg et al. (2007) analyze the roles of various actors at different stages of the innovation system development in a Triple Helix based innovation system. They argue that the leading role at the initial stage is often assumed by a public sector actor. The scientific development stage, following the initial stage, gives the actors from the university sector a natural leading role. Finally, during the commercialization stage it would be natural to private companies to assume the leading role while university and the governmental sector actors could step back.

**Internal vs. external linkages**

Keroack et al. (2004) state that the concept of clusters highlights the importance of inter-organizational linkages in the development of complementary capabilities and exchange of knowledge. They indicate, after studying the networking in the Quebec optics/photonics cluster, that 44% of the actors involved in optics/photonics in the region said “yes” without hesitation when asked if they perceived themselves as belonging to an informal network or cluster. At the same time, the sociometric analysis showed that numerous linkages exist between all the actors in the Quebec region, indicating that actors in small science-based,
export-oriented industries may not have the full view of their environment and local contributions to innovation.

In order to avoid stagnation, the regional clusters not only need favourable local conditions but also free and substantial mobility between the cluster and the world around it (Sölvell et al. 2003). Wolfe & Gertler (2004) argue that the complex technologies require the support of sophisticated organizational networks providing the key elements of the overall technology. Increasingly, the elements are situated across a wide array of locations. They note that skills required when dealing with the local environment are substantially different than the ones needed to generate the inflow of capital and people and utilization of codified knowledge produced elsewhere, and these different tasks must be managed by the cluster. Hendry et al. (2000) studied optoelectronics clusters and found out that national and international relationships are more important than localized ones due to highly diversified nature of the end-user markets and the complexity of the technologies involved. The cluster firms shared their common linkage to the leading firm or institution and their common interest in maintaining the highly skilled labour.

Bathelt et al. (2002) refer to two kinds of knowledge: local buzz and global pipelines. According to them, buzz consists of specific, continuously updated information, intended and unanticipated learning processes in organised and accidental meetings, the application of the same interpretative schemes and mutual understanding of new knowledge and technologies, as well as shared cultural traditions and habits within a particular technology field, which stimulate the establishment of conventions and institutional arrangements. Buzz arises from the fact of physical co-presence, facilitating the circulation of information in a local economy or community. The local buzz is, however, of little relevance if firms are not ‘tuned in’. Pipelines refer to channels of communication used in distant interaction, between firms in network pipelines. Bathelt et al. (ibid.) state that a well-developed system of pipelines connecting the local cluster to the rest of the world is beneficial for each individual firm due to knowledge-enhancing relations to actors outside the cluster. Also, the information acquired by a firm through its pipelines will spill over to other firms in the cluster through local buzz. The more the cluster firms build up trans-local networks, the more information and news about markets and technologies are pumped into internal networks, increasing even the local buzz of the cluster. (Bathelt et al. ibid.)

Bathelt et al. (ibid.) argue that, in contrast to communication within the cluster, cost-considerations tend to make the knowledge flows and interaction in
global pipelines targeted towards a certain, often pre-defined goal, which makes the global pipelines usually more focused and narrow. Cooke (2005) makes a difference between “channels” and “pipelines”. According to Cooke, channels, being “open” and “leaky”, offer more opportunity for knowledge capability enhancement than pipelines, being “closed” and offering more capable means of proprietary knowledge transfer based on contractual agreement. Laestadius (2007) argues that the communities of researchers in the globalised world of today can be created without physical closeness, possibly even outdating the traditional “Marshall industrial district” concept in that aspect.

Maskell & Kebir (2005) state that co-located firms are often less well equipped to monitor and grasp new knowledge. They suggest widening the horizon and extending the reach of local actors instead of only promoting the local buzz. Rosenfeld (2002) states, that a continuous inflow of information into the cluster from research institutions, competitors, and customers around the world, provides the cluster with cutting edge ideas. Social capital then transfers that knowledge from firm to firm and from individual to individual. He argues that clusters that focus exclusively on internal linkages cut themselves off from sources of new knowledge and technology. Rosenfeld (2005) argues that the geographic boundaries of the cluster must be porous: the best thinking should be absorbed into the cluster and cluster firms should be well aware of benchmark practices and changing markets.

The European Commission Report (2002) argues, based on the European survey of regional clusters, that globalisation and regionalisation seem to occur simultaneously. Firms having presence in several countries increase their importance in clusters, and cluster firms find their major components increasingly outside their clusters. Clusters find, however, their applied R&D, to some extent basic research, and supporting services inside the cluster boundary. Isaksen (2005) indicates that cluster firms may to some extent replace their local networks with more far-reaching networks enabled by the distance-transcending capabilities of new technologies. Tödtling & Tripl (2007) argue that informal relations (milieu or buzz) are not exclusively local and that formal networks (pipelines) are not predominantly global. They state that face-to-face contacts and the exchange of knowledge by e-mail and telephone have their relevance both with local and remote partners.
2.4 Dynamic evolution of regional science-based clusters

The research question RQ2 focuses on the analysis of the dynamic evolution of regional science-based clusters. The following review of the literature on clusters provides a presentation and analysis of the most relevant issues to research question RQ2: i.e. the cluster life cycle model and the specific features of dynamic evolution of regional science-based clusters.

2.4.1 Cluster life cycle

Clusters are dynamic and have a recognisable life cycle that can be represented as a cyclical process containing four stages. Embryonic clusters are the clusters in the early stages of growth. Established clusters are the clusters perceived as having room for further growth. Mature clusters are those that are stable or will find further growth difficult. Declining clusters are those that have reached their peak and are failing or declining. Clusters in a declining stage are sometimes able to reinvent themselves and enter the cycle again. (DTI 2004)

![Fig. 5. The stages of the cluster life cycle (DTI 2004).](image-url)
According to DTI (2004), moving between different cluster life cycle stages may be simply a function of the industry life cycle reflecting the product cycle for a particular cluster. They argue that, in some cases, a shift may occur towards a new form of working or new market areas to prevent the cluster decline and re-establish the cycle. They also state that, in practice, clusters are likely to develop and mutate in more complex ways than the simplistic presentation of the four major stages of the cluster life cycle.

Porter (1998a) states that a self-enforcing cycle promotes the growth of a regional cluster, especially when local institutions are supportive and local competition is vigorous. The success stories of a growing cluster help attract the best talent. According to Porter, numerous case studies suggest that clusters require a decade or more to develop depth and real competitive advantage. Porter (ibid.) states that clusters can and do, however, lose their competitive edge due to both external and internal forces.

Fig. 6 by Waelbroeck-Rocha (2001) illustrates the cluster development including the possibility of transformation. During the emerging phase, a number of the actors in the region start to co-operate around the core activity. As new actors in the same or related activities emerge or are attracted to the region, new links develop between all these actors. Moreover, formal or informal IFCs may enter the field (i.e. a developing cluster). A mature cluster has reached a certain critical mass of actors and internal dynamics of e.g. new firm creation. Finally, the cluster has to innovate and adapt to changes, undergoing transformation into one or several new clusters.

Fig. 6. The cluster life cycle (Waelbroeck-Rocha 2001).
Rosenfeld (2002) affirms that clusters, because they are associated with certain classes of products or services, have life cycles including incubation, takeoff, maturity, or declining stages. According to Rosenfeld, areas dominated by mature clusters with declining sales should not panic but should assess their strengths, determine whether the downturn is temporary or structural, and, if the latter, look for alternative markets and products. He states that the main ways to forestall and even reverse the effects of cluster decline are by rejuvenating the cluster through innovation (e.g. new design, markets, and products), taking advantage of core competencies to transition into new products, and looking for elements of the value chain that can be built into self-sustaining clusters. According to Rosenfeld (ibid.), it is probably too late to rejuvenate the cluster if it has already reached a late maturation stage without prior planning or preparation.

Pouder & St. John (1996) contend that cluster evolution contains a deterministic element as the movement of a cluster through its whole life cycle results in a decline. Wolter (2003), however, states that the cyclic development of regional clusters from set-up to adaptation is not a predetermined one. Virtanen & Hernesniemi (2005) support the possibility of cluster transformation, including also a possibility to merge with other cluster initiatives.

Menzel & Fornahl (2007) state that it can be difficult to assign a cluster to a concrete stage if the cluster is in transition. According to them, a cluster consists of many diverse protagonists who develop differently, the heterogeneity implicating that the cluster does not develop evenly and as a whole. Parts of the cluster can stay in an earlier stage while others already move to a later one.

Bergman (2005) states that the sustainability of a cluster has not been considered much of an issue so far, perhaps because “sustainability is an obvious side-benefit simply of having a successful cluster”. He claims that the predominance of success stories in the literature on clusters offers a misleading impression that one needs only emulate the set of “best practices” of these clusters and success is possible, bringing with it a sustainable future. He claims that the best time to consider cluster sustainability is during their period of greatest success. “However, it is at precisely these moments human nature and local institutions seem least-capable of dealing with issues more comfortably delayed for later attention or by one’s successors.” Bergman (2007) adds that the vast majority of clusters may experience life cycles that never pass to the succeeding phase.
Chapman et al. (2004) focus on the strategies to sustain the cluster, drawing a distinction between renewal – radical change of direction – and adjustment, referring to extension of existing trends. They conclude that in policy terms, it makes sense to build on establishing strengths by encouraging diversification and innovation rather than simply allowing an existing cluster to decline.

2.4.2 Technology/industry life cycle and clusters

The specific characteristics of the life cycle of science-based clusters are related to the evolvement of the technologies and industries relevant to the science-based cluster. In understanding the cluster evolution over time, it is important to analyze the development of the technological process and product life-cycle over time. Improvement of performance in technology follows the S-curve described in Fig. 7 (Khalil 1999). Technology progresses through a three-stage technology life cycle: (1) the new invention period, also known as the embryonic stage, (2) the technology improvement period, also known as the growth stage, and (3) the mature technology period. The technology finally becomes vulnerable to substitution or obsolescence when a new or better-performing technology emerges. The mature technology period starts when the upper limit of the technology is approached and progress in performance slows down. Technology can consist of multiple technologies and derive from different generations of innovation.

![Fig. 7. The S-curve of technological progress (Khalil 1999).](image)
A product life cycle closely resembles the profile of the technology life-cycle. When scientific and engineering advances lead to the introduction of new technology, turbulence is created in existing systems. New products emerge and many product innovations occur. Process innovation follows new product designs and continues throughout the technology life cycle in support of both radical and incremental product innovations (Utterback & Abernathy 1975, Khalil 1999). For a single product, the technology life cycle and the product life cycle coincide as illustrated in Fig. 8.

![Fig. 8. Technological progress (Khalil 1999).](image)

As with a product, also an industry follows cyclical development patterns. Klepper (1997) distinguishes the different stages of an industry life cycle: embryonic, growing, and mature. In the initial stage, the market volume is low and unspecialized machinery is used to manufacture the product. In the growth stage, output growth is high, product innovation declines, and the production process becomes more refined. In the mature stage, output grows slowly, innovations are less significant, and management, marketing, and manufacturing techniques become more refined.
This study has a specific interest in gaining a better understanding of the life cycle of science-based clusters, including the links between a technology life cycle, an industry life cycle, and a cluster life cycle. The technological component has been emphasized by Porter (1998a) as a factor affecting a cluster’s success. He states that while external threats to cluster success arise in several areas, technological discontinuities are perhaps the most significant, because they can neutralize many cluster advantages simultaneously. Dalum et al. (2002) illustrate the technological life cycles of the mobile communication industry, using the S-curve model to illustrate the technology life cycle, where the evolution of the technology, industry, or product follow an S-shaped curve over time (see Fig. 9). The significant changes in the basic technology from the first generation (1G) Nordic Mobile Telephony (NMT) technology to the second generation (GSM) and likewise to the third system (UMTS) constitute shifts of technological life cycles. They note, however, that the path of the cycles is not as predictable as the diagram may indicate. The life cycle of an established technology may be prolonged by sustaining innovations or may be disrupted by emergence of a new technology. A disruptive technology is new and creates a new technological life cycle. Likewise a new technological life cycle offers new opportunities for existing or emerging regional clusters.

Fig. 9. The technological life cycle of the mobile communication industry (Dalum et al. 2002).
Dalum et al. (ibid.) conclude that different congestion effects appear during cluster evolution and the internal dynamics of networks and organisations may become less flexible. The stages of evolution are, however, not deterministic and revitalisation may – or may not – occur.

The characteristics of different industries need to be taken into account in the analysis of the dynamic evolution of science-based clusters. For example, the ICT industry is characterized by much shorter product cycles than the biotechnology industry. Cooke et al. (2007) state that a typical duration of the product life cycle in the ICT industry is 2–3 years. In the biotechnology industry, the process of research, development, examination and testing may exceed 10 years.

The convergence of technologies is closely related to the life cycle of science-based clusters. Swann (1998) defines that two technologies are assumed to be converging if the strength of industry A in cluster X has a positive effect on the growth rate and entry into industry B of the same cluster – or vice versa. Swann & Prevezer (1998) argue, based on simulations of clusters in the US computing industry, that single-technology clusters outperform the multi-technology clusters when technologies have not converged because in a multi-technology cluster, congestion starts to restrain growth in one sub-sector earlier than in the single-technology cluster. When technologies converge, the multi-technology cluster outperforms the single-technology cluster because of the intersectoral spillovers that a single-technology cluster cannot have. They conclude that the most successful clusters in the early stage of the cluster life cycle, with little convergence, may be single-technology clusters; whereas at a later stage the most successful clusters may be multi-technology.

Gartner, the Market Analyst firm, has launched the idea of the Hype Cycle as a proposed pattern of human response to technology (Linden 2002, Fenn & Linden 2005). They note that technologies generally follow a certain pattern of hype and time: enthusiasm, followed by disillusionment, and finally a gradual improvement in the technology that could lead to maturity. Fig. 10 illustrates the Gartner Hype Cycle. Gartner has applied the Hype Cycle model to a large number of technologies especially in the ICT fields in recent years.
The hype cycle by Gartner comprises five steps:

- **Technology Trigger**: breakthrough, product launch or other event that generates significant press and interest;
- **Peak of Inflated Expectations**: the publicity generating over-enthusiasm and unrealistic expectations;
- **Trough of Disillusionment**: technologies fail to meet expectations and quickly become unfashionable. Consequently, the press abandons the topic and the technology;
- **Slope of Enlightenment**: some businesses continue and experiment to understand the benefits and practical applications of the technology;
- **Plateau of Productivity**: the benefits of a technology become widely demonstrated and accepted.

Fenn & Linden (2005) state that Gartner Hype Cycle may also be applied to technology adoption across geographic regions. Many technologies depend on the existence of an ecosystem that develops differently around the world. According to Bellini (2002), the attitudes and expectations of the regional actors may change over time, resulting in the pressure to modify and mutually adjust the perceptions and expectations concerning the proposed policy action. Henten & Skouby (2004) argue that e-business solutions and e.g. broadband penetration are in actual fact developing again after the hype and the dot-com crash experienced in late 1990’s and early 2000’s. The dot-com crisis, however, affects investments in the area and the diffusion of technologies. Wolfe & Gertler (2004) mention that e.g. the post-
2000 meltdown in the telecom and information technology provides a laboratory for studying how individual clusters in city-regions respond to external shocks.

2.4.3 Critical mass

Critical mass is a concept used in a variety of concepts, including e.g. physics, technology, and group dynamics. Critical mass is a size, number, or amount large enough to produce a particular result (Merriam-Webster 2008). In nuclear physics, critical mass refers to the minimum amount of a given fissile material necessary to achieve a self-sustaining fission chain reaction. Porter (1998a) describes clusters as critical masses of unusual competitive success in particular fields. Rosenfeld (2002) defines critical mass of cluster as “sufficient to attract specialized services, resources, and suppliers”. According to Andersson et al. (2004), a cluster needs to engage numerous actors and reach some sort of critical mass in order to achieve inner dynamics. The presence of critical mass may serve as a ‘buffer’, making a cluster resistant to exogenous shocks, including losses of companies, as long as a critical threshold of remaining players is not exceeded. They admit, however, that the notion of critical mass is a fluid one and subject to change, adding that in some industries and technologies, achieving the critical mass is likely to be very demanding.

Swann (1998) provides a quantitative estimate of critical mass in his study of clusters in the US computing industry. According to Swann, the critical mass or the take-off point of computing employment in a cluster is usually between 2,000 and 10,000. Temple (1998) argues that critical mass should be thought not only as a matter of size but also as a concentration of the kinds of information exchanged. He mentions also the difficult role of government in a democracy in concentrating – and diverting – resources to achieve critical mass through procurement policy or other means by which economic activity could be located. Brenner (2007) states that regional clustering is linked with the notion of critical mass. There are some regions which have reached the critical mass enabling the formation of a cluster, whereas the majority of the regions have not reached the critical mass needed. Brenner links critical mass also to the policy issues: he advises locations to be supported only if the region is able to reach the critical mass with the help of policy actions.

DeBernardy (1999) states, based on the analysis of Grenoble high technology region, that critical mass is a necessary but not sufficient element of success. “Critical mass in a specific technological field is becoming a necessary condition...
for sustaining new innovative activities. If, however, links with other milieux are weak, critical mass alone will be insufficient and dynamic entrepreneurs and researchers may move away from the area.”

The concept of critical mass is related to the discussion of clusters and regional innovation systems in metropolitan vs. non-metropolitan regions. Doloreux et al. (2007) state that a fundamental characteristic of non-metropolitan regions – as opposed to metropolitan regions – is that the elements required for an innovation system to function efficiently are weakly developed and the network dynamics and innovation support much less apparent. They list the ingredients necessary for the development of an innovation region (i.e. knowledge, human capital, collaborations, critical mass of an innovation system’s constituent elements, etc.) which are often absent in non-metropolitan regions, and add that companies in non-metropolitan regions appear to innovate less and “find it difficult to expand and export or to integrate global chains of production”.

The regional science-based clusters in non-metropolitan regions with limited size and resources might face the problematics of two-sided cluster trap (Tichy 1998) between full specialisation, with deep knowledge in a very small field, on the one side, and non-specialisation on the other side, with a consequent skill and knowledge deficit. Dalum et al. (2002) contend that the central dimension for evaluation of the potential of a cluster is its depth, i.e. the range of vertically related industries within the cluster. Deep clusters, containing an almost complete supply chain, are more likely to succeed when comparing to the “shallow” ones relying on input from outside the region. They also argue that the risks are spread in a broader cluster, consisting of several horizontal related industries. The dynamics of both the depth and breath can be further enhanced by appropriate educational organisations e.g. university R&D and education supporting industries. Cortright (2006) states that industry diversity is generally correlated with urban size: i.e. larger metropolitan areas generally have more industrial clusters than smaller metropolitan areas. He adds that few analyses have examined whether concentration or diversity results in better economic results for similarly sized metropolitan areas. “All else equal, regional leaders would prefer a diverse range of specializations rather than just one or a few.”
2.4.4 Path dependence and lock-in

Britton (2007) states that an industrial cluster is “the product of time-dependent processes of locational concentration, progress in industrial technologies, market development, and infrastructural and other policy choices in the past regardless of time”. Bergman & Feser (1999) indicate that the concept of path dependence refers to the general notion that technological choices – sometimes even suboptimal ones – can assume a dominant lead over alternatives and be self-enforcing, though not necessarily irreversible given a significant enough shock. Because technology can be path dependent, also regional development trajectories can become path dependent. Cortright (2006) states that the independent but complementary decisions of a range of economic actors regarding clusters all converge to reinforce growth in initially successful places. Small, even chance events can play an important role in triggering the formation of industries and their clustering in particular locations. There may be, according to Cortright, substantial opportunity to influence a cluster’s location in the early stages of its development and almost no ability to affect it once it becomes set in place. Britton (ibid.) states that unanticipated events may challenge the evolution of clusters. He affirms that local observers usually perceive the failure of highly visible firms as a setback instead of noticing the potential positive local effects such as new business formation.

The concept of path dependence is closely related to the concept of lock-in. Bergman (2007) describes cluster lock-in as an inwardly-spiralled layering of events and decisions that steadily shrink “protectively isolated” clusters, thereby progressively insulating them from external influences or internal impulses for change. Grabher (1993) applies the industrial district lock-ins to clusters, identifying factors resulting in a reduced competitiveness of the clusters. He concludes, after studying the reasons for the industrial decline of Ruhr area, especially the iron, steel, and shipbuilding regions, that Ruhr area “fell into the trap of rigid specialization”. Grabher identifies three kinds of lock-in categories. Functional lock-in refers to locally-tied connections. As an example, personal ties to a few client firms were given preference over the supplier’s own marketing. Cognitive lock-in refers to inward orientation and group-think – a specific view of the world was developed on the basis of social reinforcement. Political lock-in refers to overdependence upon non-firm actors and subsidies to support the industry. “The politico-administrative system kept the region effectively on course, even when this course became a dead-end.” (Grabher 1993)
Boschma (2005) contends that localized path dependent processes may cause lock-in situations that result in sub-optimal outcomes. The local environment may stimulate innovative behaviour along existing trajectories but tends to hinder the development of something completely new. He claims that the prospects for public policy to avoid lock-in may not be too promising because the public authorities are often sensitive to the interests of the representatives of the “old” technologies. “In such circumstances, the local government is expected not to be much interested in pursuing a policy of change and solving the problem of lock-in.” Isaksen (2007) adds, referring to Bathelt et al. (2002), that external connections to the global economy can play an important role in bringing in ideas and knowledge to sustain a competitive advantage and avoid a lock-in situation.

Maskell & Kebir (2005) state that cluster policies, assisting communities when faced with the need to unlearn previously successful routines, provide cognitive and economic space for new waves of entrepreneurial activity that might help put the cluster on a new and promising track. They also claim that the ability to unlearn varies significantly between clusters.

Tödtling & Trippl (2005) analyze the potential deficiencies in regional innovation systems, combining both structural issues and dynamic evolution issues. They state that there are three main deficiencies in regional innovation systems. Peripheral regions may often face “organisational thinness”: important RIS prerequisites are weakly developed, there is a lack of dynamic clusters, often the critical mass for a dynamic cluster is not reached. Old industrial regions often face a “lock-in”: i.e. too strong clustering as the regions are overspecialized in mature industries experiencing decline, resulting in a loss of regional competitive advantage and innovation capacity. Metropolitan regions, regarded as centres of innovation, often face the problem of “fragmentation”: a lack of networks and interactive learning representing an innovation barrier, resulting in the development of new technologies and the formation of new firms below expectations. (Tödtling & Trippl 2005). Fig. 11 illustrates the various deficiencies in regional innovation systems.
Tödtling & Trippl (ibid.) suggest that there might be predominant innovation problems in each of the types of regions described above, which require more attention than others. They emphasize, however, that regions in reality face a mix of these RIS deficiencies, and conclude that policy makers in each region should possess a detailed knowledge about the RIS specificities and the factors undermining its dynamics in their region, and they warn about the pitfalls of an innovation policy inspired in “ideal type” innovation systems.

Fig. 11. RIS deficiencies and types of problem regions (Tödtling & Trippl 2005).
2.5 Regional clusters and strategic management

Strategic management has not been in the focus of the literature on regional clusters. However, the decision-makers of the regional clusters constantly face strategic issues in their work.

Mintzberg et al. (1998) remark that strategic management differs from other fields of management in its very focus on strategic choice. They list the major schools-of-thought in strategy formation as follows: the Design School, the Planning School, the Positioning School, the Entrepreneurial School, the Cognitive School, the Learning School, the Power School, the Cultural School, the Environmental School, the Configuration School. The Configuration School is of specific interest from the viewpoint of regional clusters. This is because of the nature of regional clusters: strategic decision-making based on information and the life cycle pattern of development of the regional clusters, divided into stages of development. According to Mintzberg et al. (ibid.), the configuration school groups the various elements of the strategy-making process into distinct stages or episodes, for example, of entrepreneurial growth or stable maturity, sometimes sequenced over time to describe the life cycles of organizations. They state that, most of the time, an organisation can be described in terms of stable configuration of its characteristics. These stable periods are interrupted occasionally by some process (“a quantum leap”) towards another configuration in contrast to “piecemeal” changes.

The aspects of specific interest in analyzing the regional clusters from a strategic viewpoint include the judgmental biases which have obvious consequences for strategy decisions. The categories of judgmental biases (Mintzberg et al. ibid.) are presented in Table 4.
Table 4. Biases in decision-making (Mintzberg et al. 1998).

<table>
<thead>
<tr>
<th>Type of bias</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Search for supportive evidence</td>
<td>Willingness to gather facts which lead toward certain conclusions and to disregard other facts which threaten them</td>
</tr>
<tr>
<td>Inconsistency</td>
<td>Inability to apply the same decision criteria in similar situations</td>
</tr>
<tr>
<td>Conservatism</td>
<td>Failure to change (or changing slowly) one’s own mind in light of new information/evidence</td>
</tr>
<tr>
<td>Recency</td>
<td>The most recent events dominate those in the less recent past, which are downgraded or ignored</td>
</tr>
<tr>
<td>Availability</td>
<td>Reliance upon specific events easily recalled from memory, to the exclusion of other pertinent information</td>
</tr>
<tr>
<td>Anchoring</td>
<td>Predictions are unduly influenced by initial information which is given more weight in the forecasting process</td>
</tr>
<tr>
<td>Illusory correlations</td>
<td>Belief that patterns are evident and/or two variables are causally related when they are not</td>
</tr>
<tr>
<td>Selective perception</td>
<td>People tend to see problems in terms of their own background and experience</td>
</tr>
<tr>
<td>Regression effects</td>
<td>Persistent increases (in some phenomenon) might be due to random reasons which, if true, would (raise) the chance of a (subsequent) decrease. Alternatively, persistent decreases might (raise) the chances of (subsequent) increases</td>
</tr>
<tr>
<td>Attribution of success and failure</td>
<td>Success is attributed to one’s skills while failure to bad luck, or someone else’s error. This inhibits learning as it does not allow recognition of one’s own mistakes</td>
</tr>
<tr>
<td>Optimism, wishful thinking</td>
<td>People’s preferences for future outcomes affect their forecasts of such outcomes</td>
</tr>
</tbody>
</table>

The different biases in decision-making are closely related to the decision-making process of regional clusters. The decision-makers of the regional clusters are individuals, processing information to make decisions with an effect on the evolution of the cluster. Enright (2000), after analyzing a survey on a total of 160 regional clusters, suggests that it is not surprising that only a few informants were willing to characterize the clusters they reported as “wishful thinking” clusters. Enright concludes, based on his experience, that both “policy-driven” and
“wishful-thinking” clusters are underreported in his sample of 160 regional clusters.

The perceptions of the cluster decision-makers is another area of specific interest related to strategic management. Lehtimäki (2005) analyzed the development of Hermia Technology Centre in Tampere, Finland in the years 1983-2004. The main interests of the Lehtimäki study were the human phenomena: individual actors as processors of knowledge and strategy makers, and their perceptions. Lehtimäki analyzed the perceptions – or beliefs – of the most important individuals involved in the Hermia Technology Centre. Fig. 12 illustrates the Lehtimäki approach. The actual events – what has really happened – are described by realized processes. The perceptions of the key actors – how they have understood the process – are described by the perceptions of the key actors. The interpretations of the researcher, Lehtimäki, were compiled throughout the process based on the document analysis, interviews with the key actors about their perceptions, and analysis of the generated material.

Fig. 12. Perceptions of key actors (Lehtimäki 2005).

2.6 Conclusions on theoretical framework

The main purpose of Chapter 2 is to provide answers to the research questions RQ1 and RQ2 in this study from the research literature. The following evaluation summarizes the review of the literature on clusters focusing on the issues in research questions RQ1 and RQ2.
Cluster definitions

The review of literature on clusters has shown that confusion persists about the meaning and applicability of the term “cluster”. There is an ongoing debate about what constitutes a cluster, both among academics and among policymakers, which includes diverse understandings of the kinds or categories of clusters which exist. Based on the literature review, there is not one generally accepted definition of clusters available. There are also different interpretations regarding the relationship between clusters and innovation systems.

The Porter (1998a) cluster definition is used as the general point of departure in this study. The “standard” nature of the Porter cluster definition (Martin & Sunley 2003) supports the selection of the Porter (1998a) cluster definition as the general point of departure. The literature review confirms that the term “regional cluster” is widely used in the literature on clusters despite the slightly different interpretations of the term. The scope of the empirical part of the study is to analyze three regional industrial concentrations with a high amount of research and technology know-how. There is no widely-used, universally accepted definition in the literature on clusters to describe the sub-group of regional clusters of this study. The term “regional science-based cluster” described in the European Commission Report (2002) describes in an adequate manner the regional, research-intensive industrial concentrations. The term “regional science-based cluster” is used to describe the case study clusters of this study.

The main interest in this study is to analyze regional science-based clusters, especially those with a research community and governmental institutions as important collaborators (European Commission report 2002), and financial institutions in a vital role. The comprehensive notion of cluster by Sölvell et al. (2003), including the major categories of cluster actors (companies, research community, government, financial institutions, and institutions for collaboration), matches the key features of the regional science-based clusters. It also provides an opportunity to position the units of analysis of this study between the narrow “firms only” definition of regional cluster, and the broad concept of RIS by e.g. Cooke et al. (2007). The notion of cluster by Sölvell et al. (2003), together with the illustration of the regional cluster by Andersson et al. (2004), are used in the empirical part as a lens through which the case study clusters will be examined. The applicability of the Triple Helix concept to regional science-based clusters is also discussed.
**Structural characteristics**

Based on the literature review, the evaluation of the main structural elements of regional clusters in this study focuses on the issues of:

- intensity and nature of internal rivalry and cooperation, the amount of greater co-operation and competition inside the clusters;
- social capital and trust, especially the issues of “social glue”, non-metropolitan regions and social capital, and the nature of trust;
- leadership, especially the role of individuals and the shared leadership;
- internal vs. external linkages of regional science-based clusters, especially local buzz and global pipelines.

Table 5 summarizes the results of an examination of the literature on structural characteristics of clusters from the viewpoint of this study.

**Table 5. Conclusion of the literature review: structural characteristics of clusters.**

<table>
<thead>
<tr>
<th>Structural characteristics:</th>
<th>Focus of the interest</th>
<th>Key theories, models, and concepts to be scrutinized in the empirical part</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key actors and the overall structure</td>
<td>Models describing the cluster structure, the balance between the actors, and the roles of cluster actor groups</td>
<td>Description of five key categories of cluster actors (Sölve et al. 2003, Andersson et al. 2004)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Triple Helix (Etzkowitz &amp; Leydesdorff 2000)</td>
</tr>
<tr>
<td>Competition vs. co-operation</td>
<td>Internal rivalry vs. internal co-operation</td>
<td>Intensity and nature of cluster co-operation and competition (Enright 2001)</td>
</tr>
<tr>
<td>Social capital and trust</td>
<td>Quantity and quality of “social glue”, non-economic factors (e.g. quality of life, culture), trust</td>
<td>Amount and nature of “social glue” (Putnam 2000, Andersson et al. 2004, Porter 1998a), Non-metropolitan regions and social capital (Doloreux et al. 2007), Nature of trust (Cooke &amp; Morgan 1998)</td>
</tr>
<tr>
<td>Leadership</td>
<td>Roles of various cluster actors</td>
<td>Civic entrepreneur or clusterpreneur (Wolfe &amp; Gertler 2004, Sölve et al. 2003), Shared leadership (Sotarauta 2007, Hallencreutz et al. 2002)</td>
</tr>
<tr>
<td>Internal vs. external linkages</td>
<td>Internal cluster co-operation vs. co-operation with partners outside the cluster</td>
<td>Local buzz and global pipelines (Bathelt et al. 2002)</td>
</tr>
</tbody>
</table>
**Dynamic evolution**

Based on the literature review, the evaluation of dynamic evolution of clusters in this study focuses on the issues of:

- the general cluster life cycle model, using the DTI (2004) cluster life cycle model as the point of departure for the empirical part;
- technology/industry life cycle and clusters, especially the life cycle of high technology industries;
- critical mass, especially the relation between size and critical mass and critical mass related to non-metropolitan clusters;
- path dependency and lock-in, especially related to industrial regions and non-metropolitan regions.

Table 6 summarizes the analysis of the research literature on the dynamic evolution of clusters, and the key theories and models of interest from the viewpoint of this study.

**Table 6. Conclusion of the literature review: dynamic evolution of clusters.**

<table>
<thead>
<tr>
<th>Characteristics related to dynamic evolution of clusters: focus of the interest</th>
<th>Key theories, models, and concepts to be scrutinized in the empirical part</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology/industry life cycle and clusters</strong> Specific features related to science-based clusters</td>
<td>Hype cycle (Linden 2002)</td>
</tr>
<tr>
<td><strong>Critical mass</strong> Development trajectory and critical mass Non-metropolitan regions and critical mass</td>
<td>Sufficient size to reach critical mass (Swann 1998), Organizational thinness (Tödtling &amp; Trippl 2005, Doloreux et al. 2007)</td>
</tr>
<tr>
<td><strong>Path dependency and lock-in</strong> Role of path dependency in regional science-based clusters Lock-in related to non-metropolitan science-based clusters</td>
<td>Regional clusters and path dependency (Britton 2007), Industrial regions lock-in (Grabher 1993) applied to regional science-based clusters Lock-in and non-metropolitan regions (Tödtling &amp; Trippl 2005)</td>
</tr>
</tbody>
</table>
Strategic management and regional clusters

From the perspective of strategic management, this study focuses on the decision-makers of the regional clusters, processing information to make decisions with an effect on the evolution of the cluster. The empirical part of this study focuses on the past and current status of the case study clusters. The current decision-making in the clusters is closely related to the perceptions of the cluster decision-makers of the future development of the clusters. The empirical part assesses the strategic decision-making situation in the case study clusters against the perceptions and possible biases introduced in this theoretical part.

Based on a review of the literature on strategic management, the strategic management analysis of clusters in this study focuses on two major issues:

- perceptions of the key decision-makers concerning the information to be processed (Lehtimäki 2005), applied to case study clusters
- judgmental biases (Mintzberg 1998) which have obvious consequences for strategy decisions, applied to case study clusters.
3 Research method and process

In this chapter, the research method and research process of this study is presented in more detail. The case study method is introduced, along with abductive logic as a research approach. The rationales behind the choices of high technology clusters in Oulu, Luleå, and Pisa as case study clusters are discussed. The units of analysis and the sources of data are described. Finally, the practical implementation of the case study interviews is presented.

3.1 Case study analysis

Yin (1994) defines a case study as an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and context are not clearly evident. The case study method is not the only research strategy used in research on clusters. Other potential research strategies include e.g. surveys, archival analyses, history analyses, and evaluation by the Delphi method. Also, combinations of different research strategies can be found in the literature on clusters. The usability of the case study method in cluster analysis depends on the type and nature of the research problems or propositions.

Bergman & Feser (1999) recommend the two-stage process to conceive of regional cluster analysis: 1) an initial scan of the regional economy, using detailed quantitative sources, and 2) a detailed, perhaps painstaking, investigation of specific industrial features/groupings identified in the scan. Cortright (2006) claims that case studies provide a more balanced view of the various factors that produce clusters by addressing many of the different dimensions of the industry simultaneously. He warns, however, not to give the reader of the case study the impression that copying the institutions or tactics that worked in one place at one time will produce similar results elsewhere at some very different time. Yin (1994) notes that the case study method adds two sources of evidence not usually included in the historian’s repertoire: direct observation and systematic interviewing. He adds that the relevant field contacts depend upon an understanding – or theory – of what is being studied. Yin (ibid.) warns the researchers using case study method not to give disproportionate attention to the early events. Instead, one should focus on the later events.

The basic guideline in choosing the proper method could be derived from the research questions. Yin (1994) states that in some situations, a specific research
strategy has a distinct advantage. For the case study, this is when a “how” or “why” question is being asked about a contemporary set of events over which the investigator has little or no control. The research questions RQ1 and RQ2 in this study meet the Yin (1994) criterion, also with a focus on contemporary events. The evolution of the regional science-based clusters over time is analyzed, too, but the focus on analyzing the past development examines how and why the clusters experienced the development, and is not an in-depth analysis of the historical events as such. The researcher, currently living in Helsinki, Finland, has little or no control over the set of events in non-metropolitan regional science-based clusters. The researcher, although familiar with the regional industrial concentrations in e.g. Finland and Sweden, has not had any leading position in any of the case study clusters.

Pouder & St.John (1996) suggest multiple parallel case studies including longitudinal data collection for different hot spots as they move through phases at different paces, as one alternative way of studying the evolution of fast-growing or hot-spot regions. The recommendations of some of the previous studies on industrial concentrations that have applied case study method (e.g. Lehtimäki 2005, Hyry 2005) suggest additional case studies to be implemented. Lehtimäki proposes a larger multiple-case study of innovation environments addressing the cultural and environmental differences between distant locations. Hyry (2005), after studying the Oulu high technology development, suggests further comparative international research. The multiple-case study setting of this study thus adopts the suggestions of Lehtimäki and Hyry.

The arguments presented above indicate that the case study method is a suitable way to proceed with this research. In this study, the focus of the analysis is on regional science-based clusters. Besides the research questions, other relevant issues are the budget, the time available for the study, and the previous skills of the researcher including the network of contacts and sources of evidence on the regional science-based clusters (Remenyi et al. 1998).

According to Cortright (2006), there are two basic approaches in cluster analysis: top-down analyses, which generally rely on quantitative data of a regional economy, and bottom-up analyses, which examine the inner workings and inter-firm connections of a particular cluster in a particular location. Cortright states that the best way to understand clusters is to balance between top-down and bottom-up approaches and use them “in tandem” to fuel an interactive discussion and analysis of clusters in a regional economy.
As already indicated in Chapter 1, the research approach of this study includes both inductive and deductive elements. According to Dubois & Gadde (2002), the abductive approach is about investigating the relationship between “everyday language and concepts” having a framework successively modified, partly as a result of unanticipated empirical findings, but also of theoretical insights gained during the process. Dubois & Gadde (ibid.) introduce the concept of systematic combining efforts of the researcher, including a constant move between asking questions, generating hypotheses, and making comparisons. They state that systematic combining, grounded in abductive logic, is closer to the inductive than the deductive approach, and creates “fruitful cross-fertilization where new combinations are developed through a mixture of established theoretical models and new concepts derived from the confrontation with reality”.

The systematic combining approach, grounded in abductive logic, is the research approach followed in this study. The preliminary analytical framework is developed through the empirical fieldwork, as well as through analysis and fieldwork. The confrontation between the evolving framework and the evolving case continues by matching, going back and forth between framework, data sources, and analysis. Finally, when the case turns into a “product”, there should be no confusing pieces of data left. Systematic combining builds more on refinement of existing theories than on inventing new ones (Dubois & Gadde ibid.).

The steps in designing the multiple-case study of Oulu, Luleå, and Pisa regions follow, to a large extent, the Yin (1994) procedure (see Fig. 13). The findings of the study interviews in Chapter 5 are presented in an order more convenient to the readers to compare the findings between the case study regions, instead of writing complete individual case reports first and drawing cross-case conclusions only after the individual case analyses.
3.2 Rationales behind the choice of the case study regions

The case study clusters of this study come from the following regions: Oulu in Northern Finland, Luleå in Northern Sweden, and Pisa in Tuscany, Italy (see map, Appendix III). The case study regions have a priori similarities: including a population of less than 500,000 inhabitants, a regionally and even nationally important university, and an industrial structure combining the traditional industries and high-tech industries. Clearly, there are also a priori differences between them, including cultural differences.

According to Porter (1998a), numerous case studies suggest that clusters require a decade or more to develop depth and real competitive advantage. All the chosen case study regions – Oulu, Luleå, and Pisa – have a history of regional development long enough in the fields of advanced technologies to meet the criterion of Porter regarding the life time of clusters.

Most of the regional science research concentrates on success stories only – at the expense of stories about the failures. It is difficult for both practitioners and researchers to learn from a large number of success— or self-defined success-stories (Cooke & Piccaluga 2004). The three case study regions – Oulu, Luleå,
and Pisa – have not been chosen for the criterion of being a complete success story although at least some of the chosen regions have been cited as success regions. E.g. Hosper (2005) lists Oulu as an example of “best practices” of regional clustering together with California, Bavaria, and the French Sophia-Antipolis. Cooke (2005) states that in Italy, disappointment with traditional universities as regional development engines has led to the diffusion of the Pisa model of Scuola Superiore or Advanced Study Institutes to five laboratory regions (Puglia, Umbria, Marche, Lombardia, and Campania) to emulate Pisa’s Institute-Corporate –Spinout system, judged a success by OECD.

The case study regions are non-metropolitan regions. Doloreux et al. (2007) state that studies of regional innovation systems “neglect the study and analysis of the emergence and consolidation of such systems in non-metropolitan regions”. This study contributes to filling the research gap by providing a multiple-case study analysis of three regional science-based clusters in non-metropolitan European regions.

3.3 Units of analysis

Before entering the case study analysis, it is necessary to define what the “case” is in this study. Yin (1994) indicates that the selection of the appropriate unit of analysis arises from accurately specified research questions. In this study, the research questions RQ1 and RQ2 refer to regional science-based clusters. This study focuses on regional science-based concentrations of science, industry and other economic activity in Oulu, Luleå, and Pisa regions. Table 7 shows the specific units of analysis of this study.

<table>
<thead>
<tr>
<th>Region</th>
<th>Geographical scope</th>
<th>Contents</th>
</tr>
</thead>
</table>
| Oulu   | Inner circle: City of Oulu  
        | Entire region: Oulu region (City of Oulu and nine surrounding municipalities) | ICT cluster  
        | Wellness cluster  
        | Biocluster  
        | Environment cluster  
        | Content and Media cluster |
| Luleå  | Inner circle: City of Luleå  
        | Entire region: Luleå region (Norrbotten county) | ICT cluster |
| Pisa   | Inner circle: City of Pisa  
        | Entire region: Pisa Region (Province of Pisa) | High technology cluster including ICT and pharmaceutical concentrations |
In Oulu, the unit of analysis of this study consists of the regional science-based family of five clusters defined in the Oulu Growth Agreement Programme (2002): Information technology, Wellness, Biocluster, Environment, Content and Media. In Luleå, the unit of analysis of this study consists of the ICT cluster defined by the Regionfakta (2007), not including call centre activities. In Pisa, the unit of analysis of this study consists of the Pisa High Technology cluster defined by the Observatory of Scuola Superiore Sant’Anna (Osservatorio 2007), with ICT and Pharmaceutical sectors as the dominant sectors. The core of the units of analysis consists of the companies in the cluster. Other categories of cluster actors presented by Sölvell et al. (2003) and Andersson et al. (2004) will be introduced and evaluated, too. The geographical area of the unit of analysis in each case consists of the city (inner circle), and the surrounding region, represented by the surrounding or adjacent municipalities. In all the case study regions, there is a major university in the city.

The units of analysis are defined as above for the following reasons. Firstly, the units of analysis cover the large majority of all high technology activities in the case study regions. The units of analysis include activities which match the description of regional science-based clusters by the European Commission Report (2002). Secondly, there is relevant information available concerning the status and the development of the activities of the chosen units of analysis. Thirdly, the choice of the units of analysis enables a comparison between the three case study regions. The geographical definition including the city as the inner circle, and region as the outer circle, is relevant given the spread of high technology activities in Oulu, Luleå, and Pisa into surrounding or adjacent municipalities, too. Finally, it is important to divide the regional HT clusters into sub-clusters. As Kautonen (2008) claims, the descriptions of innovative regions are often too simplified and overhomogenized – for example, when statements are made that the entire “Oulu region” or “Silicon Valley” or “Third Italy” is like this or that – as such statements may in fact cover only the most visible part of the company structure in the region.

The terms “Oulu HT cluster”, “Luleå HT cluster”, and “Pisa HT cluster” in this study are used synonymously with the terms “Science-based cluster in Oulu”, “Science-based cluster in Luleå”, and “Science-based cluster in Pisa”, respectively, to describe units of analysis defined in table presented above, HT refers to “high technology”. The notion “HT cluster” has previously been used to describe the research-intensive scientific and industrial concentration in Pisa.
(DiMinin et al. 2003, 2006) and Oulu (Oulu Growth Agreement Programme 2002).

It is important to evaluate the extent to which the case study units of analysis meet the regional cluster criteria set out in the literature on clusters. It is also of importance to raise the question: how do we know whether these industrial concentrations are really regional clusters or not? According to Martin and Sunley (2003), it may happen that “what are claimed to be clusters often turn out to be only loosely connected collections of similar or related firms, and sometimes have more to do with local policy aspirations than with realities on the ground.” Wolfe & Gertler (2004) advise researchers to treat the existence of a local cluster as a hypothesis to be verified throughout the investigation. In this study, the case study units of analysis are called “clusters”. In this study, to what extent the definition of units of analysis, i.e. clusters, of the empirical part of the study is valid is examined. The aim of the study is to analyze e.g. to what extent the chosen case study units of analysis geographically meet the definitions of regional clusters, and also to what extent it is possible to define the case study units of analysis as “regional science-based clusters”. The notion “cluster” used to describe the units of analysis is tested after the presentation of the information gathered from the case study regions.

3.4 Sources of evidence

Yin (1994) lists the following major sources of evidence for case studies: documents, archival records, interviews, direct observation, participant-observation, and physical artefacts. Yin also emphasizes the importance of using multiple sources of evidence to develop converging lines of inquiry – a process of triangulation. Table 8 summarizes the methods used in this study to collect data.
Table 8. The sources of evidence of this study (adapted from Yin (1994)).

<table>
<thead>
<tr>
<th>Sources of evidence</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Documents</td>
<td>Formal studies or evaluations</td>
</tr>
<tr>
<td></td>
<td>Newspaper articles, web site information</td>
</tr>
<tr>
<td></td>
<td>Administrative documents: proposals, progress reports, other internal documents, written reports on events</td>
</tr>
<tr>
<td>Archival records</td>
<td>Maps and charts</td>
</tr>
<tr>
<td></td>
<td>Organizational records: charts and budgets</td>
</tr>
<tr>
<td>Interviews</td>
<td>32 in-depth interviews: 11 in Oulu region, 10 in Luleå region, and 11 in Pisa region</td>
</tr>
<tr>
<td>Direct observation</td>
<td>Visits to the case study sites in Oulu, Luleå, and Pisa</td>
</tr>
<tr>
<td>Participant-observation</td>
<td>Job/research assignments in the case study regions</td>
</tr>
</tbody>
</table>

The analysis of documents and archival records in this study serves to gain a deeper understanding of the regional clusters in the Oulu, Luleå, and Pisa regions. The document analysis also completes the information obtained from other sources e.g. interviews. The in-depth interviews are an essential part of this study. The informants are supposed not only to provide insights into the cases but also to suggest sources of corroboratory evidence and initiate access to such sources (Yin 1994). The interviews of the study include 32 in-depth interviews in the three case study regions, more informal interviews in the case study regions, and discussions with regional policy experts and cluster experts especially at conferences and seminars.

Opportunities for direct observation were created by field visits to case study sites in Oulu, Luleå, and Pisa. In Oulu and Luleå regions, the researcher has not been merely a passive observer but also participated in some of the events being studied. The job assignments of the researcher in Oulu and Luleå regions have included consultancy work with clients representing regional and local companies and collaborative institutions. In Pisa, the researcher acted as a visiting researcher in June-July, 2006 at Scuola Superiore Sant’Anna Pisa. The direct observations and participant-observations have served as yet another source of evidence in this study.
3.5 Case study interviews

The interviews of the key decision-makers and other relevant persons in the case study clusters form an essential part of this study. Interviews were conducted over the period of 7 months between June, 2007 and January, 2008. A snowball sampling method (Scott 1991) was selected to identify the relevant people in the three case study regions: Oulu, Luleå, and Pisa. The first informants in each region were chosen during the document and literature review. Their contribution to the respective regions was easily perceived. During each interview the informants were asked to suggest other persons who could provide added-value insights into the research subject. The informants were urged to propose additional informants so that a reasonable balance between the cluster actors (companies, research community, financial institutions, government, and institutions for collaboration) could be reached.

A total of 32 people were interviewed. The interviews lasted for 45–120 minutes. All the interviews were recorded and transcribed. Additional interviews were continued until they did not provide any significant information to the research subject. After 32 interviews, the collected information together with additional information from other sources of evidence of this study was considered sufficient for a final analysis.

The interviews followed the same agenda in all three countries. First, the researcher gave a 10–15 minutes introduction of the research and presented the written questionnaire. The questionnaire was modified for each country in order to present the region-specific questions, otherwise the questionnaire was similar in each country. The interview questions were posed to the informants under the following categories:

- The structure and key actors of the regional cluster
- The cluster life cycle
- Perceptions on the cluster development.

The interview questions were sent to the informants before the interview. The list of informants in alphabetical order and the list of interview questions (summary) can be found in Appendix 1 and Appendix 2. The text, however, refers to informants using codes (e.g. O2, L4, P8) based on the chronological order of the interviews. The procedure follows the suggestion by Yin (1994), naming the individuals but avoiding the attribution of any particular point of view or
comment to a single individual. The procedure allows the case itself to be identified accurately.

The questionnaire was in English in each country. The language of the interviews was Finnish in Finland, Swedish in Sweden, and English in Italy. In Pisa, an interpreter attended three interviews. All interviews were recorded and transcribed. Table 9 presents the informants and the cluster actor groups based on their present primary job assignment as follows:

**Table 9. Informants 2007–2008.**

<table>
<thead>
<tr>
<th>Region</th>
<th>Research</th>
<th>Government</th>
<th>Financial</th>
<th>Companies</th>
<th>IFC</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oulu</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>Luleå</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Pisa</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>8</td>
<td>3</td>
<td>4</td>
<td>9</td>
<td>32</td>
</tr>
</tbody>
</table>

It can be seen from the table above that all the major cluster actor groups have been represented in the interviews. The university representatives were slightly overrepresented in Pisa region. It became evident already during the first interviews that several informants represented and/or were connected to more than one category of cluster actors. For example, a professor from a university was also on the board of a high technology company, or was a leading person at some technology transfer, or IFC organisation. Or, a consultant was the chairman of the board of a high technology company. Moreover, several informants had changed their job positions and the cluster actor categories during their career, many of them several times, making it possible for them to analyze the cluster with personal experience in two or several cluster categories. The number of informants and the balance between the informants and the categories of cluster actors should be evaluated by also taking into account this cumulative experience of a large amount of informants in several cluster actor groups.
4 Empirical context and target

This chapter introduces the empirical context and target of this study. First, an introductory overview of the case study countries and regions is provided. The national innovation policies including the regional links are set out. The case study clusters in Oulu, Luleå, and Pisa are uncovered, including the key actors and statistics and a description of the evolution of the clusters over time. At the end of the chapter, a cross-case comparison of the three regions is presented.

The research literature on the development of high technology industry in Oulu is more abundant than the respective literature on Luleå and Pisa. The material presented in this chapter somewhat reflects the differences in the amount of research literature on the case study clusters and regions. Instead of shortening the description of the Oulu case in line with the length of descriptions of the Luleå and Pisa cases, the report covers the Oulu case in slightly more length compared to Luleå and Pisa cases, following the Yin (1994) advice of showing all the relevant data available.

4.1 Case study countries and regions: an overview

The following presentation includes the basic demographic and economic facts of the countries of the three case study regions: Finland, Sweden, and Italy, and provides an introduction of the national innovation systems in the three countries. That is followed by an introduction to the case study regions: Oulu, Luleå, and Pisa.

Basic demographic and economic facts: Finland, Sweden, and Italy

The empirical target of this study consists of concentrations of scientific and industrial activity in three regions: Oulu in Finland, Luleå in Sweden, and, Pisa in Italy. Finland, Sweden and Italy are all member states of the European Union. All three countries are almost similar in size but the population density is much higher in Italy compared to that in Finland and Sweden. The growth of the GDP in the years 1996–2006 has been moderate in Italy when compared to Finland and Sweden (see Table 10).
Table 10. Finland, Sweden and Italy: Basic demographic and economic facts (OECD 2007).

<table>
<thead>
<tr>
<th></th>
<th>Finland</th>
<th>Sweden</th>
<th>Italy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (million) 2005</td>
<td>5.2</td>
<td>9.0</td>
<td>58.1</td>
</tr>
<tr>
<td>Population density (people/sq km) 2005</td>
<td>16</td>
<td>20</td>
<td>193</td>
</tr>
<tr>
<td>GDP, current exchange rates (billion USD) 2006</td>
<td>210.6</td>
<td>384.7</td>
<td>1850.9</td>
</tr>
<tr>
<td>GDP per capita, current exchange rates (USD) 2006</td>
<td>40 000</td>
<td>42 400</td>
<td>31 400</td>
</tr>
<tr>
<td>GDP growth (Average annual % volume change) 1996–2006</td>
<td>3.8</td>
<td>3.1</td>
<td>1.4</td>
</tr>
<tr>
<td>Unemployment rate (% of civilian labour force 2005)</td>
<td>8.4</td>
<td>7.8</td>
<td>7.8</td>
</tr>
</tbody>
</table>

**National innovation policies in Finland, Sweden, and Italy**

The following introduction presents the structure, key actors, and challenges of the national innovation systems in Finland, Sweden, and Italy. The regional innovation policies in three countries are briefly introduced.

In Finland, the innovation policies of Finland are coordinated under the Science and Technology Policy Council which works in relation with the parliament and different ministries and is chaired by the Finnish Prime Minister. The key organisations within the National Innovation System include the government and legislative bodies, private sector organisations and entrepreneurship promotion, knowledge institutes (i.e. universities, polytechnics, and public research institutes), industrial research centres and innovation intermediaries, and financial system. The major innovation supporting organisations in Finland include TEKES (Finnish Funding Agency for Technology and Innovation), the Academy of Finland, and SITRA (The Finnish Innovation Fund). VTT Technical Research Centre of Finland concentrates on producing new technologies and creating and promoting new innovations in Finland. The regional employment and economic development centres (T & E Centres) were established in the mid-1990s. In Finland, the municipalities enjoy wide-ranging powers of self-government, but in practice, the majority of the tasks are set by national legislation. The Finnish administration system is divided into state, province, and municipality levels. The Centre of Expertise Programme set up by the Ministry of the Interior, and the Regional Centre Programme are the two major regional development programmes promoted by the Ministry of the Interior. The Science and Technology Policy Council made a decision in 2006 to establish SHOKs, International Strategic Centres for science, technology and innovation, the first phase consisted of the founding of five SHOKs. The strategic
centres coordinate dispersed research resources in Finland. (European Trend Chart of Innovation 2006, Tekes 2008)

Boschma & Sotarauta (2007) describe the development and present status of the Finnish innovation policy. They state that the basic pillars of the Finnish national technology and science policies of the 1990s were mostly built in the 1970s and 1980s, with the goal of lifting the technological level of Finnish industries and reducing the dependence on raw-material-driven production and exports. The National Technology agency TEKES was founded in 1983 to fulfil these tasks, with information technology as one focus area. In 1990, the concept of the national innovation system was introduced to accentuate the systemic nature of innovation. The national centre of expertise programme was initiated and launched in 1994. Finland experienced a rapid shift towards a knowledge-based economy adopting a culture open to new technologies, favourable conditions and decisions especially in relation to the ICT sector development. At that time, the Porterian cluster approach was adjusted to Finnish policymaking purposes. More recently, internationalisation and global networking have become a key aspect of Finnish technology programmes. The Finnish innovation model is challenged by e.g. being too focused on technology, and being inefficient in attracting immigrants. (Boschma & Sotarauta 2007).

Sotarauta & Kautonen (2007) state that regions, and especially city-regions, have influenced the national science policies. The national and local efforts have co-evolved and influenced each other. They argue that in Finland, science, and especially educational policy, has traditionally had a strong regional policy dimension.

In Sweden, most of the innovation policy guidelines at the national level are formulated by the Ministry of Industry, Employment and Communications and the Ministry for Education, Science and Culture. The key organizations within the national innovation system include the government and legislative bodies, the employers’ organization and labour union, universities and colleges, industrial research centres and innovation intermediaries, the major innovation supporting organizations, and financial system. The major innovation supporting organisations in Sweden include NUTEK (Swedish Business Development Agency), and VINNOVA (Swedish Governmental Agency for Innovation Systems). The regional development policy in Sweden in 1970s and 1980s was mainly focused on the development of Sweden as a manufacturing industrial nation. The new regional development policy, started in the late 1990s, is concentrated on Regional Growth Programmes, aiming to give more
responsibility to regional and local levels. In 2002, VINNOVA introduced an alternative programme, VINNVÄXT, focusing on functional regions rather than administrative regions. (European Trend Chart of Innovation 2006, Vinnova 2008)

The report by Regeringskansliet (2004) identifies four challenges that the Swedish innovation strategy has to meet: investment is becoming increasingly mobile internationally, international competition is more challenging, the public sector is making new demands, and initiative and skills are increasing in importance. Marklund et al. (2004) report that the Swedish national innovation system has shown a relatively weak long-term competitiveness in terms of innovation, economic growth, and job creation, despite large investments in the production, diffusion and use of knowledge and top rankings in the OECD country assessments. They state that the reasons for the relatively poor development are due to the Swedish paradigm of stimulating growth in large R&D intensive multinational groups, the lack of incentive for renewal through knowledge-intensive SMEs, the strong focus on curiosity-driven basic research in the Swedish research system, and problematic features in the Swedish labour market. They further state, however, that the Swedish national innovation system has great potential due to an internationally strong macroeconomic situation and public finance, substantial R&D resources, and a highly-developed university system.

In Italy, the innovation system at the national level is coordinated by three ministries: The Ministry of Education, University and Research, the Ministry of Productive Activities, and the Ministry for Innovation and Technology. The key sectors within the national innovation system include the government and legislative bodies, universities and knowledge institutes (77 universities, public research institutes e.g. National Research Council CNR and Italian Institute of technology IIT), public innovation agencies, private sector associations, industrial research centres (including e.g. 24 Technology Districts, 30 Science and technology parks), and the financial system. Italy consists of 20 regions, of which 15 are ordinary regions and 5 regions have a special statute. In addition, Bolzano and Trento are self-governing provinces. As far as R&D and innovation policies are concerned, Italian regions have a considerable autonomy in planning their innovation support programmes. Most regions have formulated their innovation strategies in regional innovation plans. Research and innovation policies at regional or local levels are carried out by a regional R&D and innovation
department alone or in collaboration with the regional innovation agencies. (European Trend Chart of Innovation 2006)

In the analysis of the Italian innovation policy, the European Trend Chart of Innovation (2006) states that Italy’s prolonged economic stagnation is partly due to insufficient business innovation in terms of products, processes, and organizational innovation. They state that the perception of innovation by SMEs is more as a modernisation process than a strategic activity. The report lists three major challenges for the Italian innovation policy: the creation of an environment favourable to innovation (especially for the SMEs), improvements in innovation financing (especially for the SMEs), and improvements in educational attainment and skills of the population. (European Trend Chart of Innovation 2006)

The in-depth comparison of the national innovation systems in Finland, Sweden, and Italy is not included in this study. It is, however, of interest to consult the international comparisons of the effectiveness of the national innovation systems. The European Innovation Scoreboard is an instrument developed at the initiative of the European Commission to provide a comparative assessment of the innovation performance of EU Member States (EIS 2008). The assessment divides the EU Member States into four categories based on the innovation performance and innovation efficiency: the innovation leaders, the innovation followers, the moderate innovators, and the catching-up countries. Sweden and Finland were categorized in the European Innovation Scoreboard survey in 2007 under the “Innovation leader” category, whereas Italy was categorized as a “Moderate innovator”. The comparison shows that Italy’s economic growth measured against the growth of the GDP and exports in the past years has been quite slow, when compared to the leading countries of the European Union.

**Basic facts: Oulu, Luleå, and Pisa regions**

The city of Oulu is located on the shores of the Gulf of Bothnia in Northern Finland with 130 000 inhabitants. Oulu has the sixth largest population amongst Finnish cities. Oulu was founded by the order of King Carl XIV of Sweden in 1605. Oulu has always been a centre of trade and communications in the north. The sailing fleet of Oulu grew in the 1860s to be the largest in Finland, and the most important exports from Oulu were furs, salmon and tar which were used throughout the world to protect wooden chips. The Oulu region, consisting of the city of Oulu and 9 surrounding municipalities, has a population of 209 000, and
the area known as Northern Ostrobothnia has a population of 381 000 inhabitants (City of Oulu 2007a, Ylinenpää & Lundgren 1998).

The city of Luleå is located on the opposite side of the Gulf of Bothnia at a road distance of 260 km from Oulu. Luleå is the capital of Norrbotten County. The city has 73 000 inhabitants. Norrbotten County has a total of 251 000 inhabitants. Luleå was granted city charters in 1621 by the state government. The growth of the region started in the second half of the 18th century when a dynamic regional economy emerged based on exploitation and international trade of wood products. Further expansion started during 1940s linked to the establishment of an iron ore steel mill, a rail road to Narvik (Norway) and an expanding mechanical and saw mill industry (City of Luleå 2007, Ylinenpää & Lundgren 1998).

The city of Pisa is located in the Tuscany region in Italy. Pisa is a medium-sized university city in Tuscany. The province of Pisa is the second largest province of Tuscany. The city of Florence is the administrative capital of the Tuscany region, located 108 km from the city of Pisa. The city of Pisa is 8 km from the Tirrenic Sea and 20 km from the commercial harbour of Livorno. Pisa hosts an international airport, Galileo-Galilei. The city of Pisa is described as a middle-sized city and is not one of the metropolitan areas on a national or international scale. The region has been known for its research and education resources throughout the 20th century. Pisa’s regional economy has been based on tourism and traditional manufacturing industries: e.g. leather, shoes, the light motorcycle industry (around the Piaggio Company in Pontedera near Pisa), wood and furniture, etc. (DiMinin et al. 2006). The local economy has generated a new high technology based industry in the fields of ICT and pharmaceuticals. The region also hosts foreign industrial and research groups. The city has 88 000 inhabitants, whereas the Province of Pisa has 397 000 inhabitants.

Table 11 presents some basic demographic and geographic facts on the three regions.

<table>
<thead>
<tr>
<th>City/region</th>
<th>Population (2006)</th>
<th>Land area (sq km)</th>
<th>Road distance (km) to country capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>City of Oulu</td>
<td>130 178</td>
<td>373</td>
<td>611 to Helsinki</td>
</tr>
<tr>
<td>Oulu region</td>
<td>209 786</td>
<td>3 639</td>
<td>611</td>
</tr>
<tr>
<td>Northern Ostrobothnia</td>
<td>381 000</td>
<td>37 000</td>
<td>611</td>
</tr>
<tr>
<td>City of Luleå</td>
<td>73 313</td>
<td>2110</td>
<td>907 to Stockholm</td>
</tr>
<tr>
<td>Norrbotten County</td>
<td>251 886</td>
<td>98 249</td>
<td>907</td>
</tr>
<tr>
<td>City of Pisa</td>
<td>87 737</td>
<td>185</td>
<td>334 to Rome</td>
</tr>
<tr>
<td>Pisa Province</td>
<td>396 792</td>
<td>2 448</td>
<td>334</td>
</tr>
</tbody>
</table>

The land area of the Pisa Province is smaller compared to the land area of Oulu Region in Finland, which is in turn smaller than Norrbotten County in Sweden. The economic and industrial activity in science-based activities is, however, largely concentrated in the city of Oulu in Northern Finland, and in the city of Luleå in Norrbotten in Sweden.

4.2 Oulu HT cluster

Key actors and statistics of the Oulu HT cluster

Table 12 presents the key actors of the Oulu HT cluster as defined in 3.3 Units of analysis, using the Andersson et al. (2004) categories of actors.

Table 12. Key actors of the Oulu HT cluster.

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Companies</td>
<td>Information technology (Nokia the leading company), Wellness technology (Polar the leading company), Content and media, Environment, Biotechnology 18,400 jobs in Oulu region 2005 (Oulu Growth Agreement Report 2006)</td>
</tr>
<tr>
<td>Government</td>
<td>City of Oulu, Council of Oulu region, Northern Ostrobothnia T&amp;E Centre, TEKES regional office</td>
</tr>
<tr>
<td>Financial Institutions</td>
<td>Banks, regional venture capital companies</td>
</tr>
<tr>
<td>Research Community</td>
<td>University of Oulu, VTT Technical Research Centre of Finland, Oulu University of Applied Sciences</td>
</tr>
<tr>
<td>Institutions for Collaboration</td>
<td>Oulu Innovation, Technopolis / Technopolis Ventures, various public and private IFCs</td>
</tr>
</tbody>
</table>
The companies of the Oulu HT cluster as defined in this study consist of companies in five high technology branches defined in the Oulu Growth Agreement 2002: information technology, environmental sector, biotechnology, wellness technology, and content production and media. The most important company of the Oulu HT cluster is Nokia with two major units in Oulu: Nokia Mobile Phones and NSN Nokia Siemens Networks. In February 2007, Nokia employed 4,500 people in Oulu region (Kaleva 2007 b). The Oulu HT cluster includes several companies listed on OMX Helsinki Stock Exchange e.g. EB Group, formerly Elektrobit, which is specialised in demanding embedded software and hardware solutions for automotive and wireless industries, the net sales of EB Group for the year 2007 totalled EUR 144 million (EB Group 2008). The leading wellness technology company is Polar, manufacturing e.g. heart rate monitors. The Oulu HT cluster employed 18,400 people in the Oulu region in the year 2005 (Oulu Growth Agreement Programme 2006).

The major regional governmental authority is the Council of Oulu region. TEKES (the Finnish Funding Agency for Technology and Innovation) has a regional office in Oulu. The T & E Employment and Economic Development Centre office in Oulu provides regional services of e.g. the Ministry of Employment and the Economy. The City of Oulu provides services to businesses directly and via special units such as the Oulu Region Business Agency.

Financial institutions include banks and venture capital companies (public and private). Oulu hosts e.g. the regional office of Finnvera Plc., a specialised financing company owned by the State of Finland, providing loans, guarantees, venture capital investments, and export credit guarantees (Finnvera 2008).

The major actors of the research community in Oulu include (University of Oulu 2008, VTT 2008, Oulu University of Applied Sciences 2008):

- the University of Oulu, operates in eight major fields: Humanities, Education, Economics, Natural Sciences, Technology, Medicine, Dentistry, and Health Care, distributed in six faculties. More than 13,000 students study at the University of Oulu;
- the state-owned independent research organisation VTT (Technical Research Centre of Finland), is one of the key actors in Oulu region. At present, the role of VTT is significant in Oulu region in developing expertise and know-how also in the relative new fields e.g. printable electronics;
- the University of Applied Sciences of Oulu, formerly known as Oulu Polytechnic, with approximately 8,000 students and a staff of 700 people.
Institutions for Collaboration include (Oulu Innovation 2008, Technopolis 2008)

- Oulu Innovation Ltd, a development company which promotes high technology related businesses in the Oulu region. The city of Oulu owns 42% of the shares. The shareholders include nine municipalities around Oulu, the major research organizations in the Oulu region, the technology park company Technopolis Plc, Finnvera and the Oulu Chamber of Commerce;
- Technopolis /Technopolis Ventures. Technopolis Plc is the technology centre operating company and Technopolis Ventures Ltd is the business incubator and business service provider company;
- public and private IFCs including e.g. internationalization associations such as Finpro, consultants.

Fig. 14 illustrates the ICT cluster in Oulu region using Porter (1990) diamond theory (Pikka 2007). The focus area in the cluster is wireless technology. According to Pikka, the main difference between the national ICT cluster in Finland and the ICT cluster in Oulu is the role of public organisations in the Oulu region.
The City of Oulu Planning Department’s report on the development of jobs in Oulu region (City of Oulu Planning Department 2007) describes the ICT sector, or ICT cluster, as follows:
The report by the Oulu City Planning Department defines the ICT cluster in Oulu as consisting of companies in three categories: the first category includes ICT companies producing electronics for information and communication technology, e.g. companies such as Nokia, Scanfil, Jutron, and Aspocomp; the second category includes ICT companies producing services such as software and databases, e.g. companies such as Nethawk, Tietoenator, TeliaSonera, Oulu Telephone Ltd.; the third category includes ICT content production, with companies such as e.g. Kaleva media company.

The evolution of the Oulu HT cluster 1958–2007

Oulu is a peripheral region located in northern Finland and a city of some 130 thousand residents. Up to the 1970s, the development of the Oulu Region followed a typical path in Finnish terms, with an industrial structure based on the development of traditional industries. How did this region become a high technology region? What is the story behind the so-called “Oulu phenomenon”?

Hyry (2005) identifies the following stages in the high technology development of Oulu: the formative stage in the 1970s, consolidation stage in the 1980s, fast growth stage in the 1990s, and diversification stage in the 2000s. The starting point towards a city of high technology was the establishment of the University of Oulu in the year 1958. The Department of Electrical Engineering was founded in 1965. The professors of the University were active in promoting the idea of electronics and other high technology industries and were accelerators for industrial growth and job creation in the region. (Hyry 2005, Hyry et al. 2003).
Nokia Electronics started its activities in the Oulu region in 1972 with the production of U.S. military radio equipment by license for the Finnish military forces. Hyry notes that the University of Oulu was not the reason for Nokia’s presence in Oulu in the early stages. Nokia was interested at that time in Oulu, according to Hyry, due to the lower competition for a workforce compared to other locations such as Helsinki. Hyry reports that the Regional Planning Office of Northern Ostrobothnia already referred to the idea of the “Silicon Valley in the north” in 1978. The regional plan of the area proposed a “high technology area” near the university and the Research Centre VTT in 1981. The City Council of Oulu decided in 1981 to set up a committee to launch the technology park project. The technology park, called Oulun Teknologiakylä Oy, was founded in 1982; the first partners were the city of Oulu, the University of Oulu, the Regional Development Fund KERA, and 18 private firms.

In the 1990s, as Finland went through a deep recession, the Oulu region’s progress towards knowledge based high technology was strengthened. In 1993, a new development strategy for the Oulu region was created by company managers and other key people of the region, focusing on telecommunications, optoelectronics, biotechnology, and medical technologies. According to Hyry, it took a decade for the city authorities of Oulu to enthuse about the idea of job creation in the electronics industry. The city of Oulu generated publicity with the technology city campaign, there was discussion and doubts rose about whether the strategy was fruitful for the city’s long-term development. The goodwill towards new growth industries increased in the late 1980s with the plant closures in pulp and food industries.

Hyry states that the technology park Technopolis contributed directly not only to growth in its immediate region but became later in the 1990s and 2000s a dynamic factor in other parts of Finland, including the listing on the Helsinki Stock Exchange. Hyry argues that in recent years, much of the responsibility for regional development in technology intensive areas in Finland has fallen into the realm of Technopolis Plc. Much of the increase in employment of companies in the Technology Park in 1982–2000 was, however, due to Nokia’s local and global expansion in the late 1990s. The Nokia arrival, according to Hyry, brought new radio technology to the area, developed itself into a world leader in telecommunications through base stations and mobile phone technology, provided a significant number of jobs, enabled co-operation with relevant departments of the University of Oulu and VTT establishing a networking culture, created a
catalytic impact on subcontracting and outsourcing activities, and with its global status enhanced region’s expertise in the fields of digital communications.

The Nokia-driven ICT cluster experienced a rapid growth in the 1990s. Table 13 illustrates the development of ICT cluster jobs in the city of Oulu and in the Oulu region in the period 1997–2004 (City of Oulu Planning Department 2007):

Table 13. ICT Cluster jobs 1997–2004, City of Oulu and Oulu region (City of Oulu Planning Department 2007).

<table>
<thead>
<tr>
<th>City/region</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>City of Oulu</td>
<td>9,008</td>
<td>9,724</td>
<td>11,183</td>
<td>12,776</td>
<td>12,258</td>
<td>11,508</td>
<td>11,570</td>
<td>11,437</td>
</tr>
<tr>
<td>Oulu Region</td>
<td>11,294</td>
<td>12,082</td>
<td>13,503</td>
<td>15,227</td>
<td>14,897</td>
<td>13,912</td>
<td>14,032</td>
<td>14,184</td>
</tr>
</tbody>
</table>

The rapid conversion of the Oulu region from a traditional industrial region into an internationally-known centre of advanced technologies and world-class companies, the Oulu Phenomenon, has been analyzed by several researchers. Männistö (2002) identifies four development stages that partly overlap like a spiral: the legitimating phase in the 1960s, enthusiasm phase in the 1970s, entrepreneurship phase in the 1980s, and the core competence phase in the 1990s. He lists in chronological order the following path dependent milestones that have facilitated the appearance of additional resources to strengthen the development of the Oulu region: the foundation of the University of Oulu, the birth of the cable industry, the redirection of the education and research towards electronics, the diversification of the traditional industry in the region to the electronics industry, the foundation of VTT Electronics Research Centre in Oulu, the foundation of the Technology Park, the Oulu City of Technology City project, the strong investments of Nokia in the region, the expansion of the markets of the telecommunication companies in Oulu, and the Oulu Centre of Expertise programme.

Tervo (2004) identifies the following development stages of the high technology concentration in Oulu region: the 1960s as the stage of “cables and engineers”, the 1970s as the decade of electronics, the 1980s as the stage of the establishment of city of technology, the 1990s as the stage of the growth of the mobile communications, and the beginning of the 2000s as the stage of “the IT concentration in action”. Nummi (2007), analyzing the university-industry collaboration in medical devices development in the Oulu region, identifies three major roles played by the University of Oulu in local university-industry collaboration. The first role is that of a promoter of academic research in
university-industry research projects. The second role is its role as knowledge sharer, and the third role is as a trainer of specialists. In addition to the University of Oulu, the University of Applied Sciences plays an important role in the medical devices network.

Hyry (2005) claims, that the establishment of the University of Oulu in 1959 was perhaps the most significant decision in the regional development policy of Finland. The priorities changed to examining how modern electrical-related/electronic industries could meet the wider needs of the region and bring about industrial and structural diversification. He summarizes the most important elements in the Oulu Phenomenon process: the active and strategic role of national government, the contributions of University of Oulu, VTT and Tekes, a joint development path, the central role of Nokia, and the roles of specific key individuals. According to Hyry, Oulu has become a clear example of a place where university research and needs of industry have become intertwined with each other in a complementary fashion to meet the requirements of the telecommunications industry. He states, however, that the software and electronics groups in Oulu have not experienced the same growth as the telecommunications group. Oulu has developed as a research and development centre in these fields rather than one simply providing manufacturing or assembly jobs. Hyry adds that the growth in investment and the emergence of newer industrial structures has failed to create a strong long-term manufacturing base in Northern Finland. The majority of firms are small, especially in the software and biotechnology sectors. Many of the firms concentrate almost entirely on R&D projects.

Hyry et al. (2003) discuss the role of social capital in the development of the Oulu high technology environment. They state that proximity has played a role in facilitating the diffusion of knowledge between the various actors, based on a common industrial culture and geographical area in which they have become embedded over time and has been facilitated through social interaction. Hyry et al. (ibid.) state that a high number of the people working in Oulu high technology industries are graduates from local higher educational institutes, sharing a great deal in common in relation to the regional culture. Kostiainen (2002) concludes, based on the comparison of the Finnish cities Helsinki, Tampere and Oulu in 1989–97, that the Oulu region has good co-operation in its business policy and the quality of its processes, and a visible local networking at least among the software product companies.
The Oulu Growth Agreement 2006 programme was launched in the year 2002 to further improve the competitiveness of the Oulu Region and to strengthen Oulu’s position as an internationally renowned centre of expertise (Oulu Growth Agreement Programme 2002). The foundation of the Growth Agreement was based on the five clusters of high technology: information technology, the environmental sector, biotechnology, wellness technology, and content production and media, supported by logistics and business development programmes (see Fig.16).

![Fig. 16. Oulu Growth Agreement clusters (Oulu Growth Agreement Programme 2002).](image)

According to The Oulu Growth Agreement programme report (2006), the total turnover of the high technology enterprises in Oulu region reached five billion Euro for the first time in 2005, with information technology representing more than 80 % of the total revenue. High technology enterprises employed slightly over 18 400 people in 2005 in the Oulu Region. The development of the breakdown of the jobs in five clusters in the period 2001–2005 is shown in Table 14, which illustrates the dominant role of the Information Technology cluster.

<table>
<thead>
<tr>
<th>Jobs</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information Technology</td>
<td>10913</td>
<td>11028</td>
<td>11084</td>
<td>11360</td>
<td>10870</td>
</tr>
<tr>
<td>Bio</td>
<td>254</td>
<td>279</td>
<td>283</td>
<td>263</td>
<td>265</td>
</tr>
<tr>
<td>Environment</td>
<td>1309</td>
<td>1309</td>
<td>1333</td>
<td>1397</td>
<td>1354</td>
</tr>
<tr>
<td>Wellness</td>
<td>3908</td>
<td>4047</td>
<td>4212</td>
<td>4571</td>
<td>4767</td>
</tr>
<tr>
<td>Content and media</td>
<td>1331</td>
<td>1331</td>
<td>1220</td>
<td>1171</td>
<td>1170</td>
</tr>
<tr>
<td>Total</td>
<td>17,715</td>
<td>17,994</td>
<td>18,132</td>
<td>18,762</td>
<td>18,426</td>
</tr>
</tbody>
</table>

Oulu HT cluster: recent development and discussion

The Oulu Growth Agreement Programme 2002–2006 did not reach the expected results, i.e. creating e.g. 150 new businesses and 6,000 new jobs (Oulu Growth Agreement Programme 2002). According to Mr. Mikko Karvo, the director of Business Activities of the City of Oulu, the business outlook was different in 2002 when the Growth Agreement programme was launched. Karvo states that the Growth Agreement turned out to be an instrument to fight against the job losses. “Without Oulu Growth Agreement, things could have turned even worse.” (Kaleva 2007a). Mr. Matti Pennanen, the Mayor of Oulu, stated in 2007 that Oulu currently experiences a zero growth of jobs instead of rapid growth as experienced in the 1990’s (Kaleva 2007e). Kaleva, the leading newspaper in Oulu, published special issues on the Oulu high technology development in 2002 and 2007. The title of one special issue in 2002 was: “Oulu experienced a rapid and intensive growth.” Five years later, the special issue “What now, Oulu?” discussed the possible measures to continue to success story of high technology in Oulu region. (Kaleva 2002, Kaleva 2007 d).

Mr. Pertti Huuskonen, the president of Technopolis Technology Park in Oulu, argued in the year 2007 that the mental state of the local innovation system in Oulu, including the hunger to success, should be turned back to the state of the 1970s, 1980s, and part of the 1990s (Kaleva 2006). According to Huuskonen, the Oulu innovation system has been driven into a false state of satisfaction. Mr. Pertti Korhonen, the CEO of Elektrobit company, one of the flagship companies of Oulu high technology, stated in 2007 that Oulu has to change from an R&D city to international, innovative business city. According to Korhonen, technology alone is not a business idea; the business model needs also strategy and
implementation including marketing and business logic (Kaleva 2007c). The expertise of the Oulu region is, however, still recognized by international experts. For example, Mr. Bob Ianucci, the head of Nokia research centre, stated in 2006 that Oulu has the best know how of radio technology in the world (Kauppalehti 2006).

In the year 2006, the new strategy “Oulu Inspires Innovation Strategy 2007–2013” was launched (Oulu Inspires 2006). According to the strategy document, the intention in choosing the name of the strategy was to pinpoint and emphasize the importance of human enthusiasm as a source of innovation. Contrary to the Oulu Growth Agreement Programme, the “Oulu inspires” strategy did not contain any measurable targets e.g. enterprise and job creation although it was stated that the outcomes are to be defined during the planning of each action.

The City of Oulu Planning Department study (2007) included 11 expert interviews on the strengths and weaknesses of Oulu from the viewpoint of business development. The informants concluded that Oulu is too dependent on the success of the ICT sector especially in view of the fact that production is moving to countries with cheaper production costs. The renewal of the ICT sector in Oulu and the better utilization of the strong expertise and know-how in other branches were seen as possibilities for the Oulu region. The threshold of entrepreneurship in the Oulu region was considered to be high.

The Board of the City of Oulu nominated a Triple Helix Committee in June, 2007 to further develop the innovation system in Oulu. The short term goal set by the Triple Helix Committee is to develop a model for the Oulu Triple Helix Alliance. The Triple Helix Committee final report (City of Oulu 2007b) identified the following focus areas for the Oulu region to be further strengthened by joint actions of the City of Oulu, the industry, and the research community:

– the strong ICT sectors, especially wireless communication, data security, software, wellness technology, machine vision technology and the new areas to be develop: new internet architecture (4G generation), intelligent systems, and new sensor technologies;
– research on biotechnology and areas combining biotechnology and information technology, biosensors, steel, and environmental issues;
– international business development and commercialization of innovation.

Mr. Matti Pennanen, the Mayor of Oulu, stated in 2008 that ICT sector is still important for Oulu but new growth sectors need to be identified. “One era, the era of the mobile phones, has anyway come to an end. Nobody knows what the future
brings up but we are searching for it now." Pennanen mentioned research and business opportunities related to e.g. natural resources and raw materials, mining industry and the Barents Sea oil fields (Tekniikka&Talous 2008).

4.3 Luleå HT cluster

**Key actors and statistics of the Luleå HT cluster**

Table 15 presents the key actors of the Luleå HT cluster defined in Section 3.3 Units of analysis using the Andersson *et al.* (2004) categories of actors.

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Companies</td>
<td>ICT sector (consult, service offices, telecommunication, electronics, trade)</td>
</tr>
<tr>
<td></td>
<td>2,855 jobs in Norrbotten region 2006, out of which 1,818 in the city of Luleå (Regionfakta 2007)</td>
</tr>
<tr>
<td>Government</td>
<td>City of Luleå, Norrbotten county council</td>
</tr>
<tr>
<td>Financial Institutions</td>
<td>Banks, regional venture capital companies and special funds</td>
</tr>
<tr>
<td>Research Community</td>
<td>Luleå University of Technology</td>
</tr>
<tr>
<td>Institutions for Collaboration</td>
<td>Internet Bay, Aurorum, LTU Innovation, LNAB, IUC</td>
</tr>
</tbody>
</table>

In the year 2006, the number of ICT sector jobs in Norrbotten companies was 2,855, out of which 1,818 were in the city of Luleå. ICT consultancy and services represented 41%, telecommunication 32%, electronics industry 15%, and ICT trade and renting 12% of the ICT jobs in the Norrbotten companies (Regionfakta 2007). The Luleå HT cluster does not have any major locomotive companies such as Nokia in Oulu. The companies can be divided into four major categories:

- units of nationally or internationally operating ICT companies e.g. TeliaSonera Ab, Tietoenator, CapGemini
- government-owned companies e.g. Tullidata with 165 employees in Luleå in the year 2006 (SR 2006), Metria
- niche companies having already experienced rapid development e.g. Avantra, Marratech, NordNav, Upzide
- new spin-off companies.
Norrbotten County Council is the major regional authority in Norrbotten. The City of Luleå promotes business development directly and via the business development company LNAB.

Besides banks, there are several financial institutions in Luleå active in the field of high technology including e.g. ALMI, Norrlandsfonden, Emano, Lunova, Längmanska.

Luleå University of Technology has 12,000 students and a staff of 1,600. The research profile of the university includes customer-oriented construction engineering, materials engineering, mining engineering and metallurgy, process IT (or process ICT), product development, and sustainable use of resources. There are several research centres and knowledge centres connected to the university, such as CDT (Centre for Distance-Spanning Technology) aiming at increased collaboration between ICT companies and researchers. Centek (International training and development centre) is a foundation promoting technology-based business development and consultancy. (LTU 2008a)

The IFCs (Institutions for Collaboration) in Luleå include numerous public and private organisations. Internet Bay is an industrial network established in Luleå in 1999 to promote ICT-based business and co-operation activities in Northern Sweden. Internet Bay has also co-operation with North Finland. Process-IT is an initiative launched by Internet Bay in the year 2003 to develop new products and services based on the needs list of the process industry, with the focus on measurement technology, mobile workplace, optimization of automated processes, and maintenance systems (Internet Bay 2008). Other IFCs in Luleå include e.g. the Chamber of Commerce, IUC, Export Development Norrbotten, Innovationsbron, and Företagarna. Aurorum Science Park was established in 1985 and welcomed its first tenants in 1989. Aurorum Science Park is located near the Luleå university campus area and there are 690 people employed in the Aurorum Science Park companies (Aurorum 2007). Until August 2007, the Aurorum Science Park was owned by the municipally-owned company Aurorum Teknikbyn AB. In August 2007, however, the Aurorum Science Park reported that the company will be sold to a privately-owned Swedish company Diös AB. Aurorum Science Park is the first Swedish science park totally owned by private investors (Diös 2007).

Olofsson et al. (2006) analyze the prerequisites of regional growth in Sweden. They define the Norrbotten region to include the following coastal or “near–coastal” municipalities of Northern Sweden: Luleå, Haparanda, Kalix,
Piteå, and Älvsbyn. Olofsson et al. (ibid.) illustrate the actors for growth in the region as follows:

The evolution of the Luleå HT cluster between 1971–2007

The economy of Luleå and Northern Sweden has traditionally been based on the exploitation of the natural resources. Mining and steel, forestry and wood manufacture, hydroelectric power and transportation of heavy goods have been the traditional pillars of the economy. (Nilsson et al. 2003)

The establishment of a technically oriented higher education and research institution was agreed after a discussion of more than 20 years, giving rise to the Luleå University of Technology established in the year 1971 with a marked orientation towards the need for research and future employees for the region’s historically important industries. The high technology industry in Luleå region did not enter the rapid growth phase until the late 1990s when the first spin-off companies, especially Arctic Software, took off. The number of high technology jobs in Norrbotten in 1996 was 700, a decrease of 9% from the year 1987 (Ylinenpää & Lundgren 1998, Nilsson et al. 2003).
The high technology sector in Norrbotten grew rapidly in the end of the 1990s into the early 2000s. In 2001, Information Technology, Data and Telecom industries in Norrbotten hosted over 200 companies. The leading ICT companies in Luleå were Ericsson Erisoft, Telia Research, Frontec Norr, and Tulldata. The research conducted at CDT at the Luleå University of Technology resulted in several start-up companies e.g. Effnet, Marratech, and Operax (Ohinmaa et al. 2001). Also, the umbrella organization Internet Bay was established with a plan to gather actors from Northern Sweden and even Northern Finland to co-operate in the field of wireless applications and Internet services.

The rapid growth of the ICT sector in Luleå peaked in the year 2001. The international downturn of the ICT industry in the beginning of 2000s hit Luleå relatively hard. The recovery of the ICT sector started to be visible in the year 2004 (see Table 16).

<table>
<thead>
<tr>
<th>Year</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICT jobs, companies in Norrbotten</td>
<td>3800</td>
<td>3100</td>
<td>2700</td>
<td>2800</td>
<td>2800</td>
</tr>
</tbody>
</table>

**Luleå HT cluster: recent events and discussion**

Ylinenpää et al. (2003) examined established or potential clusters in Norrbotten. Based on their analysis, they proposed the following prioritizing of the clusters in Norrbotten to be further developed: Process-IT cluster, combining the competencies of the traditional process industries and the new ICT competence in Norrbotten, winter car testing, to be extended into other related branches such as e.g. the aircraft industry, mobile communications, and military training, e-health or wellness cluster, and media, experience, and distance spanning learning.

The magazine Ny Teknik (2004) evaluated Luleå region using four criteria: competence, creativity, capital, and business and culture climate. The evaluation was based on written material and interviews with some of the key actors in the Luleå region. The category “capital” was evaluated to be the weak link of the Luleå innovation environment. Luleå achieved its highest grade in university research and education related to technology fields. The lowest grade was given for the number of employees in high tech companies, the number of patents, and the entrepreneurial climate. The magazine listed the major challenges of the Luleå
high technology region as follows: too few students, too few companies, too remote location, and too few wealthy persons.

Process IT Innovations is a concept initiated in 2003 to support research projects in the process industry. The traditional process industry in Northern Sweden is well-established with big companies, such as LKAB (mining) and SSAB (steel). The know-how and expertise is especially present in the application of wireless technologies in Sweden and Norrbotten. The main objective of the Process IT initiative is to contribute to the creation and growth of the process industry companies by developing new ICT-based products and services based on the process industry’s needs. The Swedish Government Agency for Innovation Systems VINNOVA made a decision in 2004 to include the Process IT programme in the national VINNVÄXT programme, guaranteeing an annual co-funding of 6 M SEK (approximately 630 000 EUR) over a period of 10 years to complement the regional and local support for the programme. The work method of the Process IT is illustrated in Fig. 18. The work method could be described as the Triple Helix development of new products and services based on the needs of the companies (Process IT 2008, Johansson et al. 2007).
The co-operation between the ICT companies in Norrbotten has intensified in recent years in order to provide joint services to larger customers. As an example, the joint co-operation efforts resulted in an order in 2008 to deliver ICT services to a public sector organization, Verva, in the Stockholm region. 11 ICT companies from Norrbotten were chosen to participate in the winning consortium of 55 companies, to deliver ICT services to the Stockholm region (Norrbottens Kuriren 2008).

Luleå University of Technology established, in the beginning of 2008, LTU Innovation, an effort aimed to assist the researchers and students of the university to commercialize research ideas. LTU Innovation is organized in co-operation with the Aurorum Business Incubator, the incubator of the Aurorum Science Park (LTU 2008b).
4.4 Pisa HT cluster

Key actors and statistics of the Pisa HT cluster

Table 17 summarizes the key actors in the Pisa high technology environment in 2007:

Table 17. Key actors of Pisa high technology environment.

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Companies</td>
<td>Information technology and Pharmaceutical industry</td>
</tr>
<tr>
<td></td>
<td>7,046 jobs in 226 companies in the Province of Pisa in 2006 (Osservatorio 2007)</td>
</tr>
<tr>
<td>Government</td>
<td>City of Pisa, Province of Pisa, Region of Tuscany</td>
</tr>
<tr>
<td>Financial Institutions</td>
<td>Banks, regional venture capital companies</td>
</tr>
<tr>
<td>Research Community</td>
<td>University Of Pisa, CNR National Research Council, Scuola Normale, Scuola Superiore Sant’Anna</td>
</tr>
<tr>
<td>Institutions for Collaboration</td>
<td>Consorzio Pisa Ricerche, Qualital, Polo Navacchio Technology centre, Pontedera Technology Centre</td>
</tr>
</tbody>
</table>

The Pisa area in 2005 was composed of more than 226 high technology companies and employed 7,046 people (Osservatorio 2007). Table 18 presents the high technology industries in the Province of Pisa. In 2006, 96 high technology companies in Pisa Province were located in the city of Pisa.

Table 18. High technology industries in Pisa region (Osservatorio 2007).

<table>
<thead>
<tr>
<th>Industry</th>
<th>Jobs</th>
<th>% of total high-tech jobs 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pharmaceutical</td>
<td>1790</td>
<td>25.4</td>
</tr>
<tr>
<td>Communication equipment</td>
<td>941</td>
<td>13.4</td>
</tr>
<tr>
<td>Software and IT consulting</td>
<td>889</td>
<td>12.6</td>
</tr>
<tr>
<td>Office machines</td>
<td>612</td>
<td>8.7</td>
</tr>
<tr>
<td>Electrical</td>
<td>567</td>
<td>8.0</td>
</tr>
<tr>
<td>Telecommunication</td>
<td>544</td>
<td>7.7</td>
</tr>
<tr>
<td>Chemical base products</td>
<td>438</td>
<td>6.2</td>
</tr>
<tr>
<td>Total of 10 other categories</td>
<td>1265</td>
<td>17.9</td>
</tr>
<tr>
<td>Total</td>
<td>7046</td>
<td>100%</td>
</tr>
</tbody>
</table>
The largest high technology sector in Pisa region is the pharmaceutical sector, dominated by big companies such as, e.g. US Abiogen Pharma, established in Pisa in 1917 as Gentili Institute and acquired in 1997 by Merck Sharp& Dohme. Another example of a foreign company investing in Pisa in the pharmaceutical sector is Spanish company, Grifols, set up in 1994. However, the pharmaceutical sector consists of only five companies in Pisa Province. The ICT sector also includes foreign groups located in Pisa e.g. Engisanita, previously part of the Olivetti Group, set up as a joint venture between the French GFI and the Italian Ingegneria Informatica. There are also companies with a high level of exports and special expertise e.g. Yogitech company. The Pisa HT sector is mainly dominated by small firms. Of all high technology companies in Pisa Province, 75% employ less than 30 people. The ICT sector employs an average of 12 people per company, while the average in the pharmaceutical sector in the year 2003 was 208 employees per firm (DiMinin et al. 2006).

DiMinin et al. (ibid) divide the Pisa HT firms into the following four main categories:

- established innovators: medium and large firms with significant R&D and operating on large national and international markets;
- technology integrators, specialized in the adaptation and integration of technologies already available on the market, with local and national clients;
- technology labs: investing in R&D but mostly with local clients only;
- emerging innovators and research spin-offs: young firms with a strong R&D orientation based on recent academic research.

Regione Toscana is the regional authority in Tuscany. The Province of Pisa is an administrative organization of Pisa Province, one of its aims being business promotion in the province. Comune di Pisa, the city of Pisa, promotes the business development of the city of Pisa.

Besides banks, Pisa region has a special funding institution, i.e. Fondo Rotativo, Rotating Fund ASSEFI.

Pisa has a strong public research system, with three universities. The University of Pisa is the largest, enrolling 7,000 students a year and employing about 1,500 researchers. The University of Pisa is considered to be the birthplace of Information Technology in Italy. In the year 1955, a team of professors built the first Italian computer CEP, Pisa Electronic calculator (Martinez 2006). Two other universities in the region are the Scuola Normale Superiore and the Scuola Superiore Sant’Anna. The region includes several public research centres such as
the National Research Council CNR, the National Institute for Nuclear Physics INFN, and the laboratory of the National Institute for Energy and Environment ENEA. The establishment of seven CNR departments to Pisa in 2000–2001 was an important infrastructure investment with long-term effects (CNR 2008).

The IFCs in Pisa include technology transfer institutions e.g. Consorzio Pisa Ricerche and Consorzio Qualital. Consorzio Pisa Ricerche CPR was established in 1987 to create consortia between research institutions and local companies. CPR is owned by industry, research organizations, and public bodies. Consorzio Qualital, the University Consortium of Quality Engineering, was set up in 1989, on the initiative of the University of Pisa (DiMinin et al. 2006, CPR 2008). The region of Pisa has two major technology parks: Polo Tecnologico in Navacchio and Pont-Tech technology centre in Pontedera. Navacchio Technology Park – Polo Tecnologico di Navacchio – is located 10 km from the Pisa airport, towards Florence. The first tenant started in Navacchio Technology Park in 1999, and the technology park hosted 60 companies in the year 2006. The number of employees of the Park has risen from 237 employees in 2003 to 430 employees in 2006 (Polo Tecnologico di Navacchio 2007b). The biggest sector of activity among the tenants at Navacchio Technology Park is Information and telematics (Polo Tecnologico di Navacchio 2007a). Pont Tech (Pontedera Tecnologia) is a consortium for industrial research and technological transfer with SSSUP, Scuola Superiore Sant’Anna as the leading scientific partner in Pontedera, 26 km from Pisa towards Florence, where the Piaggio motorcycle production facilities in Europe are located. Pont Tech is a result of a common initiative of local institutions, universities and industries to promote technology transfer from research towards industrial application. Pont-Tech and SSSUP collaborate especially in the fields of robotics, mechatronics, micromechatronics and microsystem technologies. A total of 18 spin-off companies were set up in the Pont Tech business incubator between 1991–2005 (Pont-Tech 2008).

The evolution of the Pisa HT cluster between 1955–2007

Sforzi (2003) describes the territorial pattern of Tuscany from 1951–71 including the steel and chemical industry located along the coastline, and industries producing goods, especially textiles, geographically concentrated in the valley of the river Arno. Tuscany is divided into “four Tuscanies”: the urbanised countryside, the touristic-industrial areas, the urban areas, and the countryside. Sforzi states that scientific research and university centres in Florence, Siena, and
Pisa are considered as assets in competition with other urban areas in Italy, and globally, through the stimulation of local entrepreneurs or attracting entrepreneurs from abroad.


In the birth and innovative growth phase, Pisa was in the favourable position to exploit the investment in IT by the local public research system. The Centre of Electronic Calculation (CSCE) started in 1955, and the first Italian computer CEP was built by a team of professors. Large companies, such as Olivetti and IBM, invested in Pisa to have privileged access to the scientific results of local academics: IBM opened their research centre in Pisa in 1972 and Olivetti in 1978. These investments, as well as new company formation in high technology fields, remained rather isolated phenomena, not linked to the rest of local manufacturing activities.

The consolidation and stability phase (1980–1995) was characterised by a consolidation of competencies in the IT field and by a diversification of research and private industrial actors in other scientific and technological fields, such as mechatronics and life sciences. Hewlett-Packard opened the Pisa Research Centre in 1990. Various initiatives and consortia, e.g. Consorzio Pisa Ricerche in 1987 and Consorzio Qualital in 1989, were launched without a widely accepted plan for the development of high technology activities in the area. Furthermore, Scuola Superiore Sant’Anna was founded in 1987. At the regional level in Tuscany, a regional network Rete Regionale dell’Alta Tecnologia to promote high-tech activities in Tuscany, especially in Pisa, Firenze, and Siena, was started in 1993. (Bellini et al. 1998)

During the clustering and restart phase (1995–2003), Pisa was recognized as an important high-tech cluster, with a diversified high technology community opening up to sectors such as medical-pharmaceutical, electronic, micro-electronics, and telecommunication. The growth of the high technology sector was rapid despite the downturn of the ICT sector at the end of 1990s due to the dot-com crash. The new technology parks and incubators were established in Navacchio and Pontedera, leading to spatial diffusion of high technology activities.

development in the private sector jobs in the Pisa HT cluster in the period 2001–2005 is shown in Table 19.


<table>
<thead>
<tr>
<th>Year</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>HT jobs in Pisa Province</td>
<td>5,801</td>
<td>6,731</td>
<td>7,043</td>
<td>6,915</td>
<td>7,046</td>
</tr>
</tbody>
</table>

The HT jobs in the province of Pisa as an aggregate did not suffer from the downturn of the ICT sector in the beginning of the 2000s. Delfino et al. (2005) report that the ICT sector did not lose many companies in the beginning of the 2000s. The average number of employees in the Pisa ICT sector companies, however, decreased from 16.1 to 8.5 during the period 2001–2003.

Present status of Pisa HT cluster development

DiMinin et al. (2006) propose categories for high technology based development in the non-central, emerging regions in Italy. They suggest that the Pisa region falls into the category of non-metropolitan areas, often medium-sized university cities, where the public sector has heavily invested in scientific research. According to DiMinin et al. (ibid.), the high technology firms in this category are likely to be set up in many cases as spin-off initiatives from public research centres. Moreover, established firms may be attracted to the area by the abundance of qualified human resources. They argue that the lack of innovative financial instruments, networking activities and technology transfer initiatives represent grey clouds which “darken the high technology sky over the city”. DiMinin et al. (ibid.) make three recommendations for policy makers in mid-sized cities such as Pisa. Firstly, the high quality university system and research community needs to be coupled with adequate links to industry. Secondly, the public intervention, focusing on professional training activities, coordinated initiatives, and territorial marketing should promote the local high technology industry. The lack of leadership might, according to DiMinin et al. (ibid.) cause short-termism in technology policies, and industrial and market strategies. Finally, learning from the intense networking, typical of the Italian industrial districts, is recommended through the facilitation of personal contacts among the entrepreneurs, technological partnerships, and labour mobility. (DiMinin et al. 2006)
The concentration of the research community and high technology companies in the Pisa region has gained national attention in Italy. According to the weekly magazine Panorama Economy (2005), Pisa has devised a winning recipe of investments and innovation which is due to the agreement between the public and private sector actors. The magazine also draws a profile of a typical high technology entrepreneur in Pisa, based on the Sant’Anna Osservatorio statistics: “The typical entrepreneur is young, he got his degree in Pisa, and he has found his partners and often also the necessary financing in his academic environment. He is driven by the will to do business and by the desire to carry out an innovative project or idea, rather than purely by the will to be in business.”

4.5 Cross-case comparison of the regions

The key events of the regional HT clusters in Oulu, Luleå, and Pisa between 1955–2005 introduced earlier in this chapter can be illustrated, see Fig. 19:

**Fig. 19. Pisa, Luleå, Oulu 1955–2005, Key events.**

Despite the slightly different time scales of the case study analyses, the dominant trends of the HT development in the case study regions can be identified. In Oulu, the Oulu HT cluster experienced a long rapid growth period from 1980s until the early 2000s, when the growth stagnated. There has not been any significant slowdown period in Oulu HT cluster between 1958–2006. The Luleå HT cluster
experienced the rapid growth period only in the late 1990s, followed by a downturn in early 2000s caused by turbulence in ICT sector, and a gradual recovery in recent years. In Pisa, the HT cluster grew slowly until the late 1990s, followed by a period of more aggressive growth between 1996–2002, after which the number of HT jobs has remained practically at the same level. The HT development paths in the Oulu, Luleå, and Pisa HT clusters between 1995–2005 are illustrated in Fig. 20.

![Fig. 20. HT development curves, Oulu-Luleå-Pisa 1997–2006 (Oulu Growth Agreement Programme 2006, Regionfakta statistics 2007, Osservatorio 2007).](image)

The figure illustrates the job development curves in the three case study clusters. The curves suggest that Oulu and Pisa, despite the downturn of the ICT sector in late 1990s and early 2000s, were able to maintain the level of HT jobs, whereas Luleå was hit harder by the dot-com crash. DiMinin et al. (2006) confirm that the overall employment statistics of the Pisa HT cluster shows a small increase even in the beginning of the 2000s, but the IT sector experienced some negative fluctuations. The figure also raises the question about the different levels of critical mass in Oulu, Luleå, and Pisa HT clusters, and about the clusters’ resistance to exogenous shocks, including losses in companies, as long as a critical threshold of remaining players is not exceeded (Andersson et al. 2004).

Ylinenpää & Lundgren (1998) compare the development of high technology activities in Luleå region (i.e. the city of Luleå and the county of Norrbotten) and in Oulu region (i.e. the city of Oulu and the county of Northern Ostrobothnia) in the period 1987–1996. In the study four main actors were identified behind the notably more favourable development of the Oulu region. Firstly, the role of the Oulu region in the national context in Finland was found to have higher hierarchy than the role of the Luleå region in Sweden. Secondly, the co-operation between the key actors in the Oulu region was regarded as more intensive than the co-
operation between the key actors in Luleå region. Thirdly, the role of larger, more demanding and sophisticated customers (especially Nokia) was relatively more important in the Oulu region than in the Luleå region. Finally, the Oulu region was characterised by clusters of firms in expanding or emerging industries, while Luleå and the Luleå region were characterized by mature branches of industry, centred on the processing of natural resources.

Ohinmaa et al. (2001) analyze different high technology industries such as e-content industry, e-learning industry, wireless technology industry, and medical technology industry, in three Nordic regions: Oulu in Finland, Luleå in Sweden, and Trondheim in Norway. They report that Information Technology, Data and Telecom was the fastest growing industry sector in Luleå at that time, with Ericsson Erisoft, Telia Research, Frontec Norr, and Tulldata as the leading IT companies. Table 20 shows the comparison of Oulu and Luleå high technology made by Ohinmaa et al. (ibid). The comparison illustrates on one hand the dominant role of wireless technology and Nokia-related technologies in Oulu region and, on the other hand, the strong position of Luleå in developing Internet-based applications.

Table 20. Comparison of Strengths and Weaknesses between Oulu and Luleå regions (Ohinmaa et al. 2001).

<table>
<thead>
<tr>
<th>Technology</th>
<th>Oulu</th>
<th>Luleå</th>
</tr>
</thead>
<tbody>
<tr>
<td>e-Content</td>
<td>World class IT-firms/organisations aimed at software and platforms for content industry</td>
<td>strong in IT-consulting, web-design/database, Internet/Intranet, world class in IP R&amp;D</td>
</tr>
<tr>
<td>e-Learning</td>
<td>weak in e-learning, strong intensive to improve e-learning</td>
<td>strong at R&amp;D, new industry, few providers, university well established in distance learning</td>
</tr>
<tr>
<td>Wireless technology</td>
<td>World’s leading regions in R&amp;D and production, strong in wireless interface and production</td>
<td>World class in R&amp;D in software and applications, weak in production</td>
</tr>
<tr>
<td>Medical technology</td>
<td>strong in measurement and biomedicine, strong at IT and content, strong basic medical research</td>
<td>strong at production, strong at telemedicine</td>
</tr>
<tr>
<td>Total number of employees</td>
<td>13 000–15 000</td>
<td>3 000–4 000</td>
</tr>
</tbody>
</table>
Table 21 summarizes the key characteristics of the regional HT clusters in Oulu, Luleå, and Pisa regions based on various studies of the Oulu, Luleå, and Pisa HT clusters.


<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oulu</strong></td>
<td><strong>Insufficient amount of world-class</strong></td>
</tr>
<tr>
<td>Strong ICT sector with a locomotive</td>
<td>research</td>
</tr>
<tr>
<td>company (Nokia)</td>
<td>Lack of HT entrepreneurs and business-</td>
</tr>
<tr>
<td>New sectors e.g. environment,</td>
<td>minded thinking</td>
</tr>
<tr>
<td>wellness, broadening the HT base</td>
<td></td>
</tr>
<tr>
<td>Strong research and educational</td>
<td></td>
</tr>
<tr>
<td>community</td>
<td></td>
</tr>
<tr>
<td><strong>Luleå</strong></td>
<td><strong>Insufficient amount of HT firms</strong></td>
</tr>
<tr>
<td>Strong ICT sector focused on R&amp;D</td>
<td></td>
</tr>
<tr>
<td>and consulting</td>
<td>Lack of locomotive HT companies</td>
</tr>
<tr>
<td>Strong Triple Helix co-operation</td>
<td></td>
</tr>
<tr>
<td><strong>Pisa</strong></td>
<td><strong>Lack of HT identity</strong></td>
</tr>
<tr>
<td>Outstanding R&amp;D infrastructure</td>
<td></td>
</tr>
<tr>
<td>Good living infrastructure and</td>
<td>Lack of venture capital</td>
</tr>
<tr>
<td>accessibility</td>
<td>Lack of coordinated technology transfer</td>
</tr>
<tr>
<td>and networking</td>
<td>and networking</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oulu</strong></td>
<td><strong>Nokia reduces activities in Oulu</strong></td>
</tr>
<tr>
<td>ICT related know how combined with</td>
<td>Inability to attract foreign companies</td>
</tr>
<tr>
<td>new application areas</td>
<td>and experts</td>
</tr>
<tr>
<td>Safe living and work environment</td>
<td></td>
</tr>
<tr>
<td><strong>Luleå</strong></td>
<td><strong>Insufficient relative weight in national context</strong></td>
</tr>
<tr>
<td>Process IT combining the high technology know how and traditional industry</td>
<td></td>
</tr>
<tr>
<td><strong>Pisa</strong></td>
<td><strong>Fewer HT companies due to lack of entrepreneurial attitude</strong></td>
</tr>
<tr>
<td>The capacity of the research community to attract students</td>
<td></td>
</tr>
</tbody>
</table>

112
5 Research findings

In this chapter the research findings of this study are presented. The chapter is largely based on the data gathered in the interviews in Oulu, Luleå, and Pisa regions between 2007–2008. Comparisons are made between the theoretical aspects raised in Chapter 2 and the information gathered in the empirical part of this study. The details of the implementation of the interviews and the informants were already presented in 3.5.

The cluster definitions and contents of the case study clusters are discussed, after which the findings of the data about the structural characteristics and dynamic evolution of the clusters in Oulu, Luleå and Pisa are discussed. The perceptions of the decision-makers in the case study regions on the future cluster development are presented. Finally, a summary of the findings closes the chapter.

The chapter includes several quotes from the interviewees. The main purpose of the quotes is to communicate more of the atmosphere of the interviews implemented in different regions, countries, and cultures.

5.1 Definitions and contents of case study clusters

The informants in Oulu, Luleå, and Pisa were asked to comment on the definitions and contents of the clusters.

In Oulu, all the informants listed ICT, or ICT and telecommunication, as the key technology sector of the Oulu HT cluster. The wellness cluster was mentioned by several informants as another key technology in Oulu HT cluster. Software technology, environmental technologies, and content and media technologies were mentioned by some informants as important technology branches in Oulu although their importance to Oulu HT cluster was considered limited compared to the dominant ICT sector. It was suggested that the cluster analysis should not only focus on the dominant industry branches as of today, but the analysis should identify the industry branches of the future with the best match to the present technology know-how base in Oulu region. One interviewee suggested the geographical scope of the Oulu HT cluster be extended to include the Oulu region, the city of Oulu and neighbouring municipalities – a half-circle from the city of Oulu with a 24 km radius and approximately 200,000 inhabitants. The geographic restriction of the Porter (1998a) cluster definition was questioned by several informants. They stated that the global high technology business environment has changed remarkably in the last few years, one reason being the
introduction of efficient global internet connections. According to some informants, the Porter cluster definition can be fully met in Oulu within the ICT and telecom cluster only. The shortcomings of the Oulu HT cluster compared to Porter’s (1998a) cluster definition mentioned by the informants pointed to a lack of effective regional think tanks and standard-setting agencies. Moreover, more business training was requested by some informants to complement the technical training given by the educational institutions in the Oulu region.

“Yes, it is ICT, software, the know-how of electronics starting from semiconductor design, that is top class. Also, printable electronics, that is world class in Oulu.” (O8)

“Today, we have top expertise around Nokia in telecom, telecom systems know how, then we have the RF technology know how, ASIC design, and production technology packaging. Also, wellness technology around Polar company. Also it is interesting what EB company can accomplish with the automotive industry.” (O9)

“It is wireless technology that is known as the Oulu Phenomenon...we are, even by absolute measures, the largest concentration in the world in certain niches of wireless technology” (O11).

“The question should be: which industries should be included in Oulu HT cluster, not technologies. The relationships, they don’t come from technologies but from the combination of market development and the industrial enablers, technology being one of them. I criticize Oulu in that sense that everything is still prioritized from the viewpoint of technology. One should think in a more market and industry branch oriented way” (O1)

In Luleå, the majority of the informants referred to the Process-IT co-operation concept as the core element of the Luleå HT cluster. Some informants suggested the broadening of the Luleå HT cluster definition to include even the most advanced steel production. Most of the informants stated that the critical cluster elements listed in Porter’s (1998a) cluster definition exist in Luleå but some cluster elements lack strength and breadth. The shortcomings of the Luleå HT cluster mentioned most frequently by the informants were a lack of vocational training providers, standard setting agencies, and think tank activities.
“Well, the broader concept, our flagship, is Process-IT. It is where the research from the university and our traditional industry meet... when they meet things start happening” (L4).

In Pisa, the ICT and pharmaceutical sectors were listed by a majority of the informants as major HT sectors in Pisa region. Biomedical research and industry were also listed as promising HT areas in the Pisa region. Some informants had difficulties in defining the Pisa HT cluster – or even high technology. One informant said that, during the earlier stages of the Pisa HT cluster, most of the cluster activities took place within the 20 km or 50 km radius but nowadays even the high technology co-operation activities between Pisa and Siena at a distance of 120 km could be regarded as Pisa HT cluster activities. The informants argued that most of the regional cluster elements listed by Porter (1998a) can be found in Pisa. Several informants questioned the intentional efforts to develop the Pisa HT cluster. It was mentioned that the regional cluster development and dynamics occur in Pisa, unconsciously, without planned effort.

“We have HT companies because they are working in information and communication technology and something related to that but there is no particular field, there is poor organisation in that aspect, I don’t know if we are perfectly comparable to the other poles in your research...There is no awareness that there is a Pisa HT cluster” (P1)

“Let us also discuss what high tech is. In my opinion, PC or computer seller is not HT. Please be careful with these numbers of high tech.” (P8)

“In Pisa, there is a very high level of potential for a very strong cluster but the limitation comes from the lack of systematization. Yes, it’s a latent cluster!” (P9)

Based on the interviews, all three regions focus on ICT technology as the common feature of a HT cluster. In the Oulu region, the key industrial driving force has been and still is the Nokia Group. The Oulu region is attempting to diversify the HT cluster into other sectors such as wellness, biotechnology, media and content, and recently the environment. In Luleå, one of the key driving forces during the last few years has been the Process-IT concept. In Pisa, there is no clear driving force to be identified in ICT technology/industry development compared to Nokia in Oulu and the Process-IT co-operation concept in Luleå. The Pisa region has the pharmaceutical sector as the other major HT sector in addition
to the ICT sector – but only a few informants mentioned the pharmaceutical industry as the driving force of the Pisa HT cluster.

The informants in all three regions were flexible in using definitions such as high technology, HT cluster, ICT technologies. The informants recognized, however, the lack of clear definition of concepts such as HT and clusters, confirming the ambiguity of the cluster definitions also outside academia. Moreover, the challenge of counting the HT jobs for the regional statistics in a reliable, and comparable manner was raised by several informants. This is not a new phenomenon as Männistö (2002) points out: “The Oulu region has been described as an extreme centre of expertise where almost 10,000 top professionals work. However, more than 50% of this personnel work in ordinary professions as electronic technicians. In electronics subcontracting, the requirements for education are low; only six months training is sufficient for numerous jobs.”

5.2 Structural characteristics

5.2.1 Main categories of actors and cluster structure

The informants were asked to comment on the structure and the key actors of the regional high technology cluster in their region based on the illustration of cluster structure by Andersson et al. (2004), including the key categories of actors: companies, government, financial institutions, research community, and institutions for collaboration or IFCs. The informants were asked to evaluate the activity, role, and importance of each cluster category. The following analysis summarizes the findings of the interviews on the cluster structure and key actors. Each category of actors is analyzed, after which the overall cluster structure is evaluated.

Companies

In Oulu, the informants unanimously confirmed the dominant role of Nokia in the past and present development of the Oulu HT cluster. Several informants stated that a high level of know-how and expertise has accumulated over years in high technology companies in the Oulu region. At the same time, some informants were worried about the diminishing role of local decision-making inside big companies, especially in Nokia. Previously, the local managers in Oulu had more
independence in their decision-making. Some informants claimed that the success of Nokia has not necessarily helped the formation of high technology start-up companies in the Oulu region. It has been too easy for many companies and entrepreneurs to remain as subcontracting companies with Nokia acting as the largest, if not the only, customer. It was also noted by some informants that Nokia has been very efficient in attracting potential high technology entrepreneurs in Oulu region to work for Nokia, reducing the number of new high technology start-ups in the recent years in Oulu region. Also, several informants stated that the number of high technology start-up and growth companies is insufficient in Oulu compared to the potential of the region.

“Nokia is one of the largest telecommunication manufacturers in the world… there is still a relatively strong electronics industry here in Oulu that could be utilized more efficiently. The potential is still there, and that expertise is not to be found in many places in Europe.” (O2)

“When they say that we can produce 150 new high technology companies that is of no importance. But if we can create high technology start-ups with an annual growth of 100% for 3–4 years and 1000% a year thereafter, this should be the level of ambition the region should aim at.” (O8)

In Luleå, the lack of large locomotive companies and even medium-sized high technology companies was frequently stated as a shortcoming by the informants. Several informants made a comparison between Oulu and Luleå, Oulu having Nokia as the flagship high technology company. It was stated that there are too few entrepreneurs in Luleå with managerial skills and capacity to manage the company growth from 20–30 people to 200–300 people, with an estimated 10–15 companies in the Luleå ICT cluster today really active in export markets. Many informants confirmed that today, there are several new, rapidly developing ICT companies in the Luleå region. The recent success stories of the Luleå HT growth companies were regarded as positive signs to high technology development in Luleå. Many informants noted that the international downturn of internet-related businesses in the beginning of the 2000s adversely affected several high technology companies in the Luleå region, resulting in bankruptcies and job cuts. Several informants pinpointed the importance of the data department of Swedish customs, Tulldata, which acted as a buffer with a slightly different business cycle compared to many ICT companies in Luleå. Tulldata in Luleå employed some of the ICT experts that lost their jobs during the so-called dot.com crash. On the
other hand, according to some informants, the ICT downturn in the beginning of the 2000s had positive effects in the form of several new start-up companies. Some informants expressed their worries about the most promising ICT companies moving out of the area especially to Stockholm at a relatively early stage.

“The Luleå company Marratech Ab started 12 years ago as a spin-off from the Luleå University of Technology and created a very good programme for PC-based video conferences over the internet. This year Google bought Marratech for 100 M SEK” (L6).

“Several high technology companies start at a relatively early stage looking for the possibility to move the operations, at least the management, to Stockholm. People think that they must sit there...the big picture with the high tech companies in Luleå is that they prefer having R&D related operations in Luleå instead of running the whole company from here, and that is a drawback.” (L7).

In Pisa, the informants stated that there are some strong companies in the ICT and pharmaceutical sectors in the Pisa region. However, the vast majority of the companies are small, i.e. between 1–5 employees. Several informants mentioned the lack of medium-sized companies as a considerable shortcoming of the Pisa HT cluster. Some informants argued that there are high technology companies in the Pisa region with very low or no interaction at all with the Pisa HT cluster activities. It was also mentioned that there are small HT companies in the Pisa region with excellent ideas but the companies lack a marketing approach.

“The enterprises in our area are very, very small so we speak about micro-enterprises.” (P4)

“We have a number of companies, even HT companies that are not interacting with this cluster world, or they have very low interaction. Mostly, the small companies are integrated in this cluster world... but also there are companies that are, for instance, engineering companies, delivering high tech service all around the world that are in Pisa, and very poorly interact with the cluster” (P1)
In Oulu, the national innovation system in Finland was appreciated by several informants. There were also critics to be found about e.g. the insufficient utilization of national R&D resources in Oulu and the limited access from Oulu region to national R&D funds. The national decision-makers in the Helsinki region were considered to be too far away from Oulu. The national innovation system was also criticized for favouring big corporations such as Nokia and Kone. It was also claimed that the tension between the capital region in Finland and the Oulu region still exists; the Helsinki region would like to see Oulu more as a regional satellite and the international top class expertise to be concentrated in Helsinki region. The regional government received mixed evaluations from the informants. On the one hand, their role in building up the high technology infrastructure was appreciated by many informants. On the other hand, the regional funding organizations were criticized for not being able to prioritize the development projects and not providing enough support for ambitious internationally oriented projects. According to many informants, the role of the city of Oulu in the development of the Oulu HT cluster has diminished. The city was urged by the informants to take a stronger position in the Oulu HT development. It was also stated that the city of Oulu is in good economic shape and genuinely committed to finance high technology development in the region, as opposed to several other city-regions with a lot of talk and visions but without a true commitment.

“We do have clear strengths (with the national innovation system) here, a strong belief and spirit, we believe that we shall succeed with innovation even in the future.” (O10)

“In my opinion, the national sector, the municipalities, and the regional sector invest awfully lot to internal structures, their fixed costs are huge which leave few resources for operative measures... I don’t know if it works better in other countries” (O8).

“We do have that so-called soft money, we have even too much soft money for all kind of regional policy based project circus which causes too many talented people getting stuck in those public sector driven projects. The talented people should go to companies to learn from real enterprises. There are too many and too small projects, and we know that 40 % of funds go to administration and applications of follow-up projects. Is this reasonable?
Does it create growth? The engine is not working properly. I would bring aggressive money into the system and also people, not only from inside the region but also from outside, top professionals, the right people to the right stages.” (O8)

“One of the positive things in Oulu is the excellent economic condition of the city, with the possibility and resources to invest.” (O11)

In Luleå, several replies pointed to the fact that the national funds and national networks are not fully utilized in the Luleå HT cluster. The increased activity of the national innovation agency Vinnova in Luleå region, including the long-term co-funding of the Process-IT programme, was mentioned by many informants as a positive example of national intervention. The regional government was considered to be more important to the regional HT cluster in Luleå than the national government by most informants. Some informants argued that although the regional government emphasizes the high technology branches in their strategies, a large share of the funding has been allocated to traditional industries. The role of the city of Luleå was widely regarded as important. Many informants, however, referred to the limitations in allocating the city funds to high technology development in the Luleå region. The role and weight of high technology in the Luleå regional development was also discussed.

“Regional government has had and still has a big importance, also via access to specific financial resources, even EU funds latterly. The national government has less of a role.. During the last few years, Vinnova for sure has had an importance here, in the Process-IT” (L1)

“We have not prioritized high technology as number one in the region. We have used high technology to modernize our base industry” (L6).

In Pisa, some informants commented that there has been no national strategy for the development of the high tech sector generally. According to the informants, the regional government plays a more important role in Pisa HT development than the national government. Some informants argued that the regional government has to balance among the different interest groups in Tuscany which prevents them from prioritizing specific sectors and projects. The regional government would have resources but they have to balance between the cities and between the various old and new technologies. Some informants regarded the understanding of high technology business by the regional government as
insufficient. It was also claimed that the public sector investments in the development of electronics in the Pisa region have been considerable although the industrial output has not been very satisfactory. The province of Pisa and the municipality of Pisa have, according to the interviewees, more interest in developing HT sector in Pisa than the regional government – but the financial resources of the province and the Pisa municipality are rather limited. The regional government was criticized by some informants of not having the proper strategic vision of Tuscany as a high technology region.

“The national government initiative is limited and scant.” (P3)

“The region has more power but they don’t use this power. For example, in other Italian regions, like Piemonte, Veneto, they created clusters such as photonics, IT, media. Tuscany has not even decided what to do.” (P7)

“Because of the public debt, the authorities are not allowed to invest much in this Pisa cluster.” (P6)

“The local government is interested in traditional sectors because there are a lot of jobs there, a lot of votes there. I think they don’t believe to a very large extent in high tech so we missed that coordinating actor.” (P5)

“The newspaper Il Sole 24 Ore had an article two years ago stating that Pisa is like Finland because the money spent from governmental institutions in Pisa R&D was a lot more than in other parts of Italy. The money was not missing, the point was that in terms of return, how many companies have grown on the basis of these investments. In that sense, Pisa is the last place in Italy. The Government has been very good, also national funding, it’s good that they put money in, that they believe in the project. So: Input is of critical importance, output has no role.” (P8)

Financial Institutions

In Oulu, the majority of the informants regarded the role of financial institutions as rather weak in the Oulu region. The regional banks and the local venture capitalists were not mentioned as critical actors in the Oulu HT cluster. The amount of active business angels, re-investing money gained from previous high technology ventures, was considered to be limited, although growing, in the Oulu region. According to some informants, Oulu lacks local venture capital actors
with sufficient experience of international high technology funding. The amount of potential high technology growth companies is not sufficient to motivate the long-term presence of such actors in the Oulu region. One informant stated, however, that the possibilities of raising venture capital in companies in the Oulu region have improved remarkably lately. It was also claimed that the location of the financial institutions doesn’t play an important role anymore. It was mentioned that numerous high technology companies raise funding from sources outside venture capital firms.

“Why should we need that Oulu based funding? The interest of the international funding institutions is the key point.” (O10)

“It is a fact that the majority of the high technology companies even in Silicon Valley have FFF-based funding: friends, fools, and family, but they are not seen in the publicity.” (O9)

In Luleå, the majority of the informants stated that there is a lack of venture capital in the Luleå region. Moreover, many informants claimed that there are only few business angels in the Luleå region providing funds for new high technology companies. The absence of competent people within the high technology branches, that have sold their companies and remained in the region acting as business angels for new high technology start-up companies, was mentioned by several informants. Some informants claimed, however, that the availability of venture capital is not a major bottleneck in Luleå HT development.

“The weakest link here is the venture capitalists, bringing in not only funds but also competence. The other financial institutions provide funds but not competent capital. The real business angel activity doesn’t exist in Luleå.” (L1)

“We were not able to create that many ICT millionaires during the ICT hype period.” (L7)

“Seed capital is a failure, seed capital, entrepreneurship. Venture capital, it exists, but the problem here, it requires seed capital.” (L3)

“We have actors in Luleå specialized in providing financing to this type of companies...but they are below the critical size, measured by funds.” (L7)

In Pisa, most informants considered financial institutions one of the weakest links in the Pisa HT cluster. According to several informants, the traditional banks in
the region are not too familiar with the specific characteristics of the high technology entrepreneurship. The lack of venture capital was stated as a challenge by the majority of the informants. At the same time, however, it was also claimed that the availability of venture capital funds is not the biggest problem in the Pisa HT cluster. It was mentioned that, often in Italy, the start-up companies have a long “early growth” period, 5 years or more, which makes it problematic for the venture capital companies to invest in these start-ups.

“I cannot think of any financial institution which has played a relevant, visible role. Even the two banks that are most typical in Pisa...they are not interested, don’t seem to be interested and have no active role” (P5)

“They know the high tech companies. It is a matter of not having the proper risk-taking attitude, not having the expertise, not having the ability to understand the high-tech business plans” (P8)

“In Pisa, there are a lot of venture capital type funds available, but the entrepreneurs don’t ask for those” (P11)

The Research Community

In Oulu, the research sector – together with the companies – was considered the most critical element of the Oulu HT cluster by the majority of the informants. According to some informants, the Nokia activities in the Oulu region would never have taken place without the strong technical university and research community in the region. The role of the University of Oulu in building up the Oulu HT cluster was widely recognized. There were, however, some doubts about the present competitiveness of electrical engineering education at the University of Oulu. The role of the Technical Research Centre of Finland, VTT, in Oulu in identifying and promoting the latest technologies was largely appreciated. Oulu University of Applied Sciences was mentioned as one strong element of the Oulu innovation system, delivering a well-educated labour force to the innovation system – although some informants had their doubts about the real innovativeness of the projects run by the Oulu University of Applied Sciences. The future of the University of Oulu, including a possible stagnation, lack of ambition, problems in attracting students to fill all the study places, low number of foreign researchers, and the conservatism of the research community including an unwillingness to take risks raised worries among the informants.
“Our industry in Oulu would not have identified the possibilities of printable electronics without the contribution of VTT.” (O1)

“Are they squeezing the University into one mould?” (O8)

In Luleå, the competitiveness of the Luleå University of Technology (LTU) was considered to be one of critical success factors of Luleå HT cluster by most informants. LTU was regarded as the cornerstone of the Luleå HT cluster. There were, however, concerns among the informants about the ability of LTU to stay on top of world-class research and to produce top-class experts even in the future. Some informants expressed their worries about the university research in Luleå being too theoretical without proper connections to the needs of the region. The latest trend of LTU, not being able to fill all the study places, was seen a worrying sign of students not being attracted to studying high technology in Luleå. Additionally, the company and job losses in the Luleå region during the downturn of ICT in the early 2000s, resulting in a reduction of university-industry contacts in the region, were clearly expressed. The role of the Centre for Distance Spanning Technology CDT was appreciated in gathering the necessary consortia behind the development projects and in raising regional funding.

“Our high technology companies are strong. A great deal of expertise can be found in our companies rather than from the university. Our hope is that the university can provide the critical mass even in the future.” (L10)

“If we are expected to build e.g. magnificent bridges it is not enough to have students just sitting and studying. We need also the skilled labour, people able to build the nice bridges in practice.” (L6)

“Luleå University world-class? Sure, but relatively few persons make it, and the situation is not as good as it used to be. we have lost Telia Research, we don’t have Frontec Group any more, it has decreased the university-industry contacts.” (L7)

In Pisa, the research community was seen as the cornerstone and the strongest element of the Pisa HT cluster by the large majority of the informants. The breadth and depth of the research in Pisa was widely considered to be important in further developing the Pisa HT environment. According to the informants, the University of Pisa, the Scuola Normale, Scuola Superiore Sant’Anna and the Pisa units of the national research centre CNR form the strong core of the Pisa research. Pisa was still regarded as the leading research city in Tuscany region,
leaving Florence and Siena behind; however, the development of the HT industries has not been fully exploited in Pisa. Also, the relatively low amount of the Pisa research results utilized inside the Pisa region caused concerns among the informants. The lack of commercial thinking and entrepreneurial spirit among the Pisa professors were seen as additional hindrances to the Pisa HT cluster development. The big shortcoming of the research community was stated to be the inability to interact with the companies. Also, the general aging challenge of the university staff in Italy was discussed.

“In any case it is true that Pisa is the most important in terms of research. In terms of industry it is Florence.” (P10)

“Pisa is certainly the best university and research centre in Tuscany, the pulsating heart of education...so the potential is all there, the missing factor is coordination.” (P7)

“What is the competitive advantage of the Pisa cluster, I would say is the brains produced by the university system.” (P5)

“There is a great disproportion between the amount of the research produced here and the number of the research products that stays in the Pisa area.” (P3)

“In the academic world, the average age of the university professor in Italy is 65 years! It is necessary to give power to young generation. We need a change of generation. We need more testosterone” (P10)

Institutions for collaboration (IFCs)

In Oulu, several informants responded that the leading IFC role at the starting phase of the Oulu HT cluster development was taken by the Revontuli Group, a voluntary-based association of high technology entrepreneurs, after which the technology park, Technopolis, took the leading IFC role. One informant stated that even Nokia Networks acted as a leading IFC at one stage in Oulu region, catalyzing and orchestrating the subcontractor companies in the Oulu region and in other places in Northern Finland to serve the needs of rapidly growing Nokia activities. After Technopolis extended geographically its activities to other cities in Finland and became a public listed company in the late 1990s, nobody seems to have taken the clearly dominant IFC role in the Oulu HT cluster, according to
many informants. Almost all the informants in Oulu stated that the role of the Technopolis Company as the key IFC of Oulu HT cluster has changed remarkably during the years. The majority of the informants understood, however, the strategy choices of the privately-owned Technopolis Company. The present role of the Oulu Innovation Ltd, established in 2005, as the leading IFC in Oulu HT cluster raised discussion among some of the informants. Many informants expect a more business-oriented approach from the IFCs in Oulu region.

“The role of Technopolis has changed. The technology centre used to gather the firms together, it used to provide a place to exchange information, it used to have the synergy effect. Now... it has turned into real estate business” (O2)

“I am wondering about the role of Oulu Innovation. The city of Oulu has the economic development unit, it has economic development director; then we have Oulu Innovation that has outsourced the management of clusters, such as the environment cluster to Technopolis and micro and nanotechnology cluster to Micropolis technology centre.” (O3)

“The IFCs can be activators between companies and other actors but one should be careful with them; if the IFCs start inventing things themselves, if they start to become institutions the first reaction will be that companies go away – and we have sometimes these symptoms.” (O9)

In Luleå, almost all the informants stated that there are too many IFCs in the region, resulting in the fragmentation of the IFC activities. Some informants argued that the importance of the IFCs to the Luleå HT cluster development is marginal. An organisation such as Oulu Innovation in the Oulu region was proposed for Luleå, too. The Aurorum Science Park, as IFC, was not regarded as playing a critical role in Luleå HT development, although the incubator activities of Aurorum were appreciated by several informants. The present role of Aurorum in the Luleå regional HT development after the privately owned real estate company Diöös took over the ownership in 2007 seemed to be unclear to some informants. They questioned the willingness and ability of Aurorum to act as the leading high technology development actor in the Luleå region after the ownership change. According to several informants, the role of Internet Bay should be enforced. The special units of LTU e.g. CDT were regarded as efficient also in IFC type of activities.
“I would have liked to see Technopolis Oulu take over our science park. A professional, aggressive developer” (L8)

In Pisa, the co-ordination between the IFCs is not functioning, according to many informants. Also, the number of small IFCs with limited resources is high. Several informants referred to previous attempts to create an organization acting as a cluster promoter in the Pisa region, Consorzio Pisa Ricerche being the most frequently mentioned initiative. The establishment of a HT cluster firm or organization to Pisa was suggested. The role of technology centres in Pisa HT cluster development was not regarded as crucial. The Polo Navacchio Industrial Park was recognized as the best-performing and most promising technology centre in Pisa region by most of the informants. Besides the Polo Navacchio Industrial Park, only the SSSUP Pontedera Technology Park was considered to have relevance in the development of the Pisa HT cluster.

“There have been two, or three attempts, one is consortium, Pisa Ricerche, the other one has been Aurelia which was on regional level, that was essentially a failure, and the third one is the research campus in Navacchio, they are doing a good job I believe.” (P3)

“You put the transfer of technology in the middle of the cluster structure figure as if they act as a single entity, but this is very, very different in Pisa. We have here something like that, several institutes for collaboration, but very split, and that causes a lack of coordination.” (P1)

“In fact, Tuscany has the largest number of Technology Transfer Centres in Italy, literally in every city and town, even in small towns. Every town feels that there is a need. But when they discuss with their neighbour town, they find immediately diversities rather than common interests” (P7)

The overall structure of the cluster

In Oulu, several informants stated that the cluster structure figure describing the cluster structure and key categories of actors (Andersson et al. 2004) is incomplete without connections to actors outside the Oulu region. They wanted to add the external world and markets to the figure. Several informants would have liked to remove the IFCs from the centre of the cluster actor figure – to be replaced by companies. It was also mentioned that the structure of the high technology cluster concept is rather complex in Oulu.
“Connecting companies to this cluster world is challenging, and it has been activated. The world has changed in a way that running a local cluster is extremely challenging. Each of these local cluster categories is a cluster itself, each “sub-cluster” is also connected to global clusters. It is not any more possible, as a matter of fact, to draw a 2-dimensional picture of the world, not even 3-dimensional picture. Some years ago this regional cluster figure described the activity properly, but today only to a little or some extent. “ (O11)

"In a way, our cluster structure is complex, with different layers accumulated over years. It is difficult enough to explain in Finnish how the system works so you can imagine trying to explain to foreigners how the system works here in Oulu.” (O7)

In Luleå, the overall cluster structure of Andersson et al. (2004) figure was largely accepted by the informants. The financial institutions and IFCs were mentioned by many informants as the weak parts of the Luleå HT cluster. It was also suggested by some informants that the IFCs should not be at the centre of the regional cluster figure. The Triple Helix type of co-operation of e.g. Process-IT co-operation was appreciated by many interviewees.

“In Luleå, we have all these cluster categories presented. Some of them are strong, some of them weak. But it is this co-operation between actors, this interplay between every function, every category, which we won’t achieve if we don’t move in the same direction.” (L9)

In Pisa, the figure of the overall cluster structure described in interviews received little criticism. Some informants did not, however, seem to have the sense of Pisa HT cluster identity in spite of the cluster elements being present in the Pisa region. The positioning of the IFCs at the centre of the cluster structure raised questions and comments. Some informants would have liked to have either companies or the research community located at the centre. Also, company affiliations and trade unions were added as important actors in the Pisa HT cluster elements by some informants.

“We have all the subjects of the cluster but we lack the common theme of the cluster. (P1)
“Trade unions, of course, we have trade unions and also industrial unions. Particularly in the Pisa area, the trade unions, which means Camera di Commercio, are playing an important role.” (P1)

Table 22 summarizes the findings of the interviews concerning the cluster structure and the key actors.

Table 22. Cluster structure and key categories of actors in Oulu, Luleå and Pisa: summary of the findings of the study interviews.

<table>
<thead>
<tr>
<th></th>
<th>Oulu</th>
<th>Luleå</th>
<th>Pisa</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Companies</strong></td>
<td>Nokia still a clear leader.</td>
<td>Lack of HT locomotive</td>
<td>Lack of HT locomotive</td>
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<td></td>
<td>Insufficient amount of</td>
<td>company. Promising start-</td>
<td>company. Most ICT</td>
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<td></td>
<td>growth companies and high</td>
<td>ups and growth companies</td>
<td>companies have 1–5</td>
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<td></td>
<td>tech start-ups.</td>
<td>– bought up at early stages.</td>
<td>employees. SMEs lack</td>
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<td></td>
<td>SMEs lack marketing skills</td>
<td>SMEs lack marketing skills</td>
<td>marketing skills and</td>
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<tr>
<td></td>
<td>and resources.</td>
<td>and resources.</td>
<td>resources.</td>
</tr>
<tr>
<td></td>
<td>Some clustering activity</td>
<td>Some clustering activity</td>
<td>Little clustering activity</td>
</tr>
<tr>
<td><strong>National government</strong></td>
<td>Too far away.</td>
<td>Too far away.</td>
<td>Of little help.</td>
</tr>
<tr>
<td><strong>Regional Government</strong></td>
<td>Some high tech priority.</td>
<td>Little high tech priority.</td>
<td>Financial resources but no</td>
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<td></td>
<td></td>
<td></td>
<td>high tech priority.</td>
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<tr>
<td><strong>City/Province</strong></td>
<td>Diminished role but still</td>
<td>Active but not central role</td>
<td>Active in Pisa HT cluster</td>
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<td></td>
<td>important element of HT</td>
<td>in HT cluster.</td>
<td>initiatives but insufficient</td>
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<td></td>
<td>cluster.</td>
<td></td>
<td>resources.</td>
</tr>
<tr>
<td><strong>Financial institutions</strong></td>
<td>Weak cluster actors</td>
<td>Weak cluster actors</td>
<td>Weak cluster actors.</td>
</tr>
<tr>
<td><strong>Research Community</strong></td>
<td>University the critical</td>
<td>University as one of the</td>
<td>Strong combination of</td>
</tr>
<tr>
<td></td>
<td>actor – but losing strength.</td>
<td>critical cluster actors –</td>
<td>university, elite schools,</td>
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<td></td>
<td>VTT Research Centre</td>
<td>but losing strength.</td>
<td>and research centres.</td>
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<tr>
<td></td>
<td>important.</td>
<td></td>
<td>Insufficient university-</td>
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<td></td>
<td>University of Applied</td>
<td></td>
<td>industry co-operation.</td>
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<td></td>
<td>Sciences has a role.</td>
<td></td>
<td></td>
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<tr>
<td><strong>IFCs</strong></td>
<td>Too many, too weak.</td>
<td>Too many, too weak.</td>
<td>Too many, too weak.</td>
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<td></td>
<td>The role of technology park</td>
<td>The science park (Aurorum)</td>
<td>The role of science parks</td>
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<td></td>
<td>(Technopolis) as the</td>
<td>important but never taken</td>
<td>traditionally weak,</td>
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<td></td>
<td>dominant IFC diminished</td>
<td>the role of the leading IFC.</td>
<td>expectations of Polo</td>
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<td></td>
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<td></td>
<td>Navacchio.</td>
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<tr>
<td><strong>Overall structure of</strong></td>
<td>Companies need to be</td>
<td>Companies need to be</td>
<td>Companies need to be</td>
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<td><strong>the high tech</strong></td>
<td>given a more central role.</td>
<td>given a more central role.</td>
<td>given more of a role.</td>
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<tr>
<td><strong>cluster</strong></td>
<td></td>
<td></td>
<td>Trade Unions also having a</td>
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<td></td>
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<td>role.</td>
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</table>
Table 23 summarizes the theoretical aspects vs. empirical findings concerning the cluster structure and key actors.

**Table 23. Cluster structure and key actors; theoretical aspects vs. empirical findings.**

<table>
<thead>
<tr>
<th>Theoretical aspects suggested</th>
<th>Empirical findings indicated by this study</th>
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<tbody>
<tr>
<td>The composition of the cluster consisting of five key categories of actors: companies, government, financial institutions, research community, and IFCs (Sölvell et al. 2003, Andersson et al. 2004)</td>
<td>The five main categories exist but a breakdown of e.g. governmental actors is needed. Additional actors e.g. trade unions may have a role</td>
</tr>
<tr>
<td>Hybrid organisations, including Triple Helix, suggested to complement the cluster structure (Etzkowitz &amp; Leydesdorff 2000, Andersson et al. 2004)</td>
<td>The role of the companies is suggested to be central and prioritized. The IFCs currently play a relatively marginal role</td>
</tr>
<tr>
<td>Hybrid organisations e.g. incubators and Triple Helix applications exist or are in planning stage. Triple Helix approach in Oulu and Luleå is acknowledged with little criticism.</td>
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</table>

Based on the findings of the interviews, the Andersson et al. (2004) figure describing the key categories of cluster actors, although illustrative – could be refined. The balance of the Andersson et al. (2004) figure – with approximately equal sizes of the “balloons” describing each category of cluster actors – does not fully match with the reality of the regional science-based clusters of this study. Furthermore, many informants did not feel comfortable with the typical positioning of the cluster categories by Andersson et al. (see Fig. 21, “Andersson et al. (2004)” on the left), the biggest criticism was targeted at the presumed central role of the Institutions of Collaborations or IFCs.

Regarding the cluster structure and categories of actors, the following suggestions are suggested to refine the illustration by Andersson et al. (2004). Firstly, an additional category of cluster actors, New Interest Group (N), e.g. trade unions, could be added into the figure whenever relevant, instead of being included into e.g. IFCs (see Fig. 21, “Alternative 1”). Secondly, many informants in this study would suggest including a cluster structure with companies in the middle and the IFCs “serving” the cluster at the outer circle (see Fig. 21 “Alternative 2”). Thirdly, the Triple Helix nature of the cluster could be emphasized especially in the cases of science-based clusters with an important role given to the research community (see “Alternative 3”). In addition to the three alternatives, the possibility for adding cluster-type activities but on a smaller
scale inside a cluster, or mini-clusters, sometimes even without e.g. government intervention, should be provided.

Fig. 21. Cluster structure and main categories of actors: alternative representations.

The cluster actors could be illustrated by the stakeholder map of Freeman (1984) presented earlier in Chapter 2 which would include all the stakeholders. Based on the information gained in the case study interviews, the positioning of the IFCs in the middle of the Freeman stakeholder figure would overestimate the importance of the IFCs. The central part of the figure, the Firm, could be replaced by cluster companies, describing the cluster where companies clearly dominate the whole cluster (which has been the case in e.g. the Nokia-driven Oulu ICT cluster). The shortcoming of applying Freeman’s stakeholder map is that the versatile, inter-linked nature of clusters would not be illustrated properly.

Based on the findings of this study, some suggestions can be made about the individual categories of clusters actors of Andersson et al. (2004) figure. The Government category could be split into various subgroups such as the national government, regional government, and local government. Moreover, international organisations, such as the European Union, could be included when they adopt the same type of functions as the national organisations under the Government category from the viewpoint of the clusters. Another suggestion would be to draw a clearer line between categories of Government and Financial Institutions. There are numerous organisations under the category Government providing funds to cluster companies. In each case the organisations represented in each category should be defined clearly.

Regarding the Financial Institutions category, a large number of the companies receive funding not only from institutions such as banks or Venture Capital companies but also from private persons. The private persons investing money to high technology companies should be mentioned under the category
Financial Institutions. The category of Research Community could be re-named or, alternatively, split into two categories to emphasize the role of Educational and Training Institutes in the cluster. It may happen, especially in the cases of science-based clusters, that the focus stays on the university-level only, missing the role of other levels of training. As an example, the Oulu Polytechnics, the predecessor of the current Oulu University of Applied Sciences, played a significant role in Northern Finland as a source of qualified labour especially to Nokia in the 1990’s.

The empirical data of this study confirms the interest of both the Oulu and Luleå regions to utilize the Triple Helix structure in the near future, emphasizing the role of the university in the regional science-based cluster. The key initiatives utilizing the Triple Helix co-operation structure include the Triple Helix Alliance (City of Oulu 2007b) and the Process-IT concept of Luleå (Johansson et al. 2007). There are co-operation initiatives including Triple Helix type planning also in the Pisa region, e.g. Consorzio Pisa Ricerche, but the results have not been satisfactory yet, according to the informants of this study.

5.2.2 Main structural elements

The evaluation of the case study interviews focuses on the following main structural elements of the clusters introduced in Chapter 2: internal competition vs. co-operation, social capital and trust, leadership, and internal vs. external linkages.

Internal competition vs. co-operation

In Oulu, the inter-company co-operation between high technology SMEs has, according to some informants, diminished over the years. At the same time, as was mentioned in the interviews, some companies have created “mini-clusters” inside the Oulu region based on their specific needs – without public sector intervention. Many informants would like to see more inter-cluster activities between the various branch-specific clusters e.g. between ICT, wellness, and biotechnology clusters. The willingness to co-operation between the actors is still to be identified in Oulu region.

"The current key persons of the companies are not any more graduates from the same coffee table at the Oulu University, and too often the companies don’t even know what the other companies are doing." (O9)
"This kind of trust and ability to co-operate functions when we talk about fundamental matters such as research or technology development. But the closer you get in the value chain towards the business opportunity, the more difficult it gets. But even there, on the way, you might find groups discussing rather openly about business opportunities." (O7)

"The inter-company co-operation is functioning, especially if you have co-ownerships in your partnership companies. But everybody fights for their own business." (O3)

In Luleå, the majority of the informants stated that the co-operation between cluster companies has remained on a healthy basis in the Luleå region. Some informants stated that there is internal competition between the HT companies in Luleå in the local marketplace but the competition turns into well-functioning inter-company co-operation when the companies join forces aiming for markets outside the Luleå region and bigger orders. The inter-company co-operation is more intensive between the technical experts than between the marketing and management. It was also claimed that the inter-company co-operation between the ICT companies in Luleå was more intensive during the downturn of the ICT sector in the early 2000s than during the better times some years later.

"I think the competition still is rather limited, the companies rather gather a consortium to get bigger orders. I think the co-operation is stronger than the competition in Luleå. This is obviously due to the limited size of the local market." (L1)

"We have this mindset that the entrance of a sharp competitor (to Luleå, JT) strengthens our companies, engineers may even have lunch together and learn from each other. Then it happens that business people (from competing companies, JT) don’t sit together, but regarding technology development we have very close co-operation, even a considerable amount of transfer of technical competence between the companies" (L10)

"It is not black or white here. Some companies co-operate with other companies while some other companies prefer working alone." (L8)

"During the ICT downturn 2001–2004, the co-operation between our companies increased remarkably. During the better times, you don’t have to co-operate, you have so much to do. Which is sad in my opinion, one should
co-operate even more during the better times and aim for the big customers.”
(L8)

In Pisa, the overall level of co-operation between various actors of the Pisa HT cluster was not considered satisfactory although some informants argued that the co-operation between the cluster actors has gradually increased. The micro-clusters, consisting of only a few actors inside the clusters, were suggested as additional instruments of future inter-company co-operation inside the Pisa HT cluster.

“Companies compete to a certain extent but that competition is especially among small firms. OK, I can see a sort of transition from competition to co-operation in the world of small firms” (P5)

“There are many small companies around a big company like Piaggio so they are in fact a cluster but because they work for the same company, not really because they decided to be inside the same cluster.” (P2)

Social capital and trust

In Oulu, the informants emphasized the technologically oriented mindset and values attached to the Oulu HT cluster. The city image has been heavily connected to the technology brand. The informants revealed, however, that the “Oulu Spirit” co-operation has partly diluted, one of the reasons being the changed role of locomotive companies, especially Nokia, with the decision-making power of local managers transferred to the company headquarters and/or overseas locations. Also, as one informant put it, the pace of the international business today simply does not allow too much local co-operation compared to “the good old days”. The trust between the cluster actors and key decision-makers is, however, still to be identified in the Oulu region. According to many informants, the mutual trust is higher between the researchers and engineers, even in the private sector, whereas the commercial people are more reserved about co-operating with other companies in the Oulu region.

“If some company had created a brand such as Technology City Oulu, an internationally known brand, it would be a big decision to change it.” (O11)

“Then there is this issue of values, culture: one should not underestimate it because the creation of the culture of knowledge is a fertile soil, ready for the
next generation to build on. The specific culture of Finnish regions has an important impact on people. People start activities that have given positive experiences in the past” (O6)

“In the early stages, there was a kind of enthusiasm, the community was small enough to become a primary community, everybody knew each other and shared pain and luck together.” (O1)

“We are still too technology-oriented, that is the answer; we should think more business wise and that discipline you hardly can teach at the university. It is the ability to see business opportunities, that is not embedded into our culture. The generation after World War II has not gained that mentality, maybe previous generations had it.” (O4)

“We have a lot better local co-operation spirit here in Oulu compared to Otaniemi (the high technology concentration in Espoo, Helsinki region, JT), but it should focus more outwards.” (O10)

“Trust, it has changed. Until the early 1990s, there was no need for written agreements although agreements were made, but that was not essential. You could count on another’s word. Today, you have to make written agreements. Companies aim to build up networks with actors they trust. You cannot assume that all the companies in the Oulu region are reliable – as they used to be. At that time, there were only a few actors, you knew them, the ones acting in a reliable way were selected. Today, we have also unreliable actors here, trying to leave holes in agreements. In practice, the companies limit their activities to only reliable actors. The overall trust is lower than before. Then of course, because of the international clients, there is also the international contract practise to be considered.” (O2)

In Luleå, the co-operation between the local actors is, according to the informants, good and functioning – with one exception: the intermediaries or Institutions for Collaboration (IFCs) are not co-operating in an optimal way in Luleå. According to some informants, there seems to be some mistrust between the IFCs in Luleå. Also, according to some informants in Luleå, the “Jantelag” or “Jante Law”, a syndrome preserving social stability and uniformity, has not completely disappeared in the Luleå region. According to Jante Law, one should not think that one is any more special or better than others (Persson & Ceccato 2001). The city image in general was regarded as satisfactory; however, the
importance of using the city image as an instrument to attract high technology experts to Luleå was also brought up in the interviews. The mutual trust in the Luleå high technology environment was regarded as good—at least compared e.g. to Stockholm.

“We must have culture, that is what Oulu is doing, too. We shall have successful companies, successful university, broad culture with trade, sports, Luleå Hockey Team, everything, that is a quality of life, people in a good mood in Luleå, then you can achieve a lot” (L6).

“I would like to believe that the Jante law attitude is gone. Things have become better but the Jante law attitude still exists… We have not allowed people to become rich. The ones that have sold their companies, they have left the city” (L1).

“We trust each other, each others’ promises. This can be seen very clearly when we interact with national venture capital, how much more legal services and contracts are needed, we can still do business without that” (L7).

“If you participate in a long-term project the trust builds up during the project…people from Stockholm are intrigued when they come here and notice that we know each other. If you compare the Kista HT cluster from Stockholm and our cluster, our trust level is much higher. I conclude that our trust level is rather high.” (L1)

“There is competition especially between the IFCs but it depends on the persons. The picture looks better than 5–10 years ago.” (L2)

In Pisa, many informants took up the image of Pisa which is highly dominated by the leaning tower of Pisa and the strong university and research community. It was proposed that the Pisa region should be promoted not only from the point of view of lifestyle but also from the point of view of an excellent location for setting up a high technology company. The stronger role of companies and also universities in promoting the Pisa region was proposed by some informants. Trust between the actors of the Pisa HT cluster is still today a challenge, according to the informants. The cultural issues were given as an explanation of the poor trust and individualism in the Pisa region by several informants. The deep university culture was given as one reason for the lack of a common strategy and the relative low amount of HT growth companies in the Pisa region.
“Why is the high technology cluster important for Pisa? It would be much nicer to have a city within 10 years which relies more on high technology, this would have a social impact on the city, the quality of life of the city would be much improved because this type of knowledge-based activities requires the city to be different and contributes to the city being different. So, at the moment Pisa is an average mid-sized city. I think that if it really was a high-tech Pisa, it would be much more interesting to live there.” (P5)

“There is no promotion of the image of the Pisa HT cluster” (P1)

“The university gets the benefits of the Pisa high technology cluster. Because, for me, Pisa is like a big campus, so just walk in the street and find the best biologists, philosophers. The industry would get the same but they usually don’t get the same advantage because they tend to stay on their own sites.” (P7)

“Usually small firms trust and do not trust each other, as in any other parts in the world. What is more important is trust among these institutions such as the Chamber of Commerce, Federation of industries, universities. They don’t trust each other a lot, they very often want to have the first position in every theatre, and this makes co-operation more difficult.” (P5)

“I don’t rely on these who are inside, the IFCs” (P8)

“There is a risk, cultural risk… Japan is opposite, maybe they don’t have individuality but they have the culture, they obey, they accept. IFC balloon in Japan should be huge but in Italy it is very small. We have good individuality but less coordination” (P7)

“Co-ordination is difficult in general, and in hi-tech areas even a bit more difficult but in the case of Pisa the fact that there is a deep university culture makes it particularly difficult to agree on a common guide.” (P5)

**Leadership**

According to the interviews in Oulu, the leadership of the Oulu HT cluster was initially taken in the 1970s by the Reventuli Group, an informal club of high technology entrepreneurs. The cluster leadership was gradually transferred to the City of Oulu and the Technology Park, Technopolis. After Technopolis broadened its operations into other cities in Finland, the leadership function of Technopolis
in the Oulu HT cluster was gradually diminished. In today’s situation, every informant confirmed that there is no clear leadership of the Oulu HT cluster. The key actors co-operate but the coordinated cluster action is largely missing. The high technology cluster initiatives coordinated by Oulu Innovation Ltd. exist but “live their own life” as one informant put it. The isolation of the branch-specific clusters is claimed to be partly due to project-based nature of the activities; each project concentrates on one branch without proper connections to other branches. Several inter-company initiatives are also realized without additional IFC activity in the Oulu HT cluster. The informants could provide names of the earlier key individuals of Oulu HT cluster but were not able to nominate any single individual as the leader of the Oulu HT development in today’s situation. Several informants stated that Mr. Pertti Huuskonen, the President of the Technopolis, was the leading person of the Oulu HT cluster until the end of the 1990s. It was argued that the relative importance of leading persons in the development of the Oulu HT cluster was much higher in the emerging phase of the Oulu cluster than today.

“The situation is scattered in Oulu today. One gentleman visiting us commented that this is like a field of tribes with war lords around here.” (O1)

“Before, the Oulu HT cluster had an owner. Mr. Pertti Huuskonen, of Technopolis.” (O3)

“We have this Oulu Inspires initiative. But if some project has a steering group of 30 people, it seems that we are not intentional but sporadic. I don’t know if the initiative has a leader at all.” (O9)

“Time has changed. In the beginning, we had nothing here in Oulu, at that time just one person could be the leader. Today, this is a much bigger system, not any more to be directed by one individual.” (O10)

“The roles of the actors are related to a life cycle. In the beginning of the innovation cycle, research is vital, and if you look at financial institutions, the ability to tolerate risk and catalyze growth is important in the beginning. The government and IFCs, they are also important in the beginning. Then comes clustering and increased importance of companies; the role of the government diminishes. The local government has a rather significant role in the beginning. Without the favourable policy of the City of Oulu towards the
Technology Park, the growth would have been directed towards other fields. ”

(O1)

According to the informants in Luleå, the Luleå HT cluster does not have a clear leadership in today’s situation. There is no organization recognized as the leader of the cluster, or cluster locomotive. When asked about earlier key individuals of the Luleå HT cluster, the informants could name some persons, the most frequently mentioned previous key persons of the Luleå HT cluster including Östen Mäkitalo (Telia), Thomas Nilsson (LNAB, formerly high tech entrepreneur), Mikael Börjesson (CDT/Luleå University), Staffan Ruuth (Avantra). There is no formal organisation either to take the indisputable role of cluster leader. Organizations such as Internet Bay and the Luleå development company LNAB run activities typical to the cluster coordinators such as matchmaking events and joint projects. Some informants suggested that Internet Bay should take the leading role. The financial resources of Internet Bay were, however, estimated to be rather limited to run the Luleå HT cluster. Several informants compared the situation in Luleå with Oulu and expressed their hopes to imitate at least partly the experience of Oulu in Luleå regarding e.g. strong leadership of the HT cluster and the establishment of an organisation with similarities to Oulu Innovation to act as a “cluster motor” in Luleå.

“There is a lot of democracy in Luleå, I would say. It is obvious that we don’t have any Nokia here, it is not that easy here, we don’t have a locomotive gathering the cluster...Ericsson used to have the locomotive role.” (L10)

“The leading person, in order to have full credibility, needs to possess branch-specific knowledge of the cluster and be a senior expert from companies or from the university.” (L 7)

In Pisa, there is no organization or person at the moment taking the lead of the Pisa HT cluster, according to the interviews. The individualism of the Italian people was given as an explanation by several informants of the difficulties in organizing a cluster with strong leadership. However, several informants would like to see a strong leader of the Pisa HT cluster, including a strong individual or group of individuals in charge. The previous attempts, including Pisa Ricerche, to build up a cluster motor type organisation, were not considered successful by the informants. The individuals cited as key persons of the Pisa HT cluster e.g. the president of Scuola Superiore Sant’Anna, professor Varaldo, the directors of
Navacchio Science Park Giari and Epifori, and the CNR Director, professor Donato.

“We have no charismatic leader in Tuscany like we used to have in the past” (P10)

“There are several organisations which care about high technology cluster but nobody is taking the lead.” (P5)

“[160x662]Italians are individuals, by education. Ruling Italians is virtually impossible. So, making a strong plan in Italy is impossible. So I think that Tuscany is the core of this... We have also a main limitation, we fight each other!” (P7)

**Internal vs. external linkages**

In Oulu, the links between companies and the research community, especially between Nokia and the university, have been intense and strong throughout the development of the Oulu HT cluster, according to the majority of the informants. Some informants added that there are numerous ongoing non-public co-operation projects between the research community and the high technology companies in the Oulu region, further strengthening the ties. Several informants mentioned the link between the City of Oulu, the University of Oulu, and the technology companies in Oulu region – or the Triple Helix – as crucial for the Oulu HT cluster development. One informant claimed that the Oulu region is still trying to do even too many activities inside the Oulu region, following the tradition originating from the starting phases of the Oulu high technology development. It was suggested that the formation of local interaction and local buzz should be increased by cross-sector initiatives. The increased presence of foreign companies, especially the recent interest from countries like India, was mentioned as one sign of international interest in Oulu. Several informants stated that the global links of the Oulu high technology cluster, although existing, should be further strengthened. Increased contacts from Oulu to the leading international high technology centres e.g. Boston, Silicon Valley, and Cambridge where the markets, finance, and companies really meet, were suggested, too.

“In my opinion, a combination of Nokia and the University of Oulu has been built and strengthened during the years, then additional companies have been created. That combination is extremely difficult to tear down.” (O7)
“We got it (the intense co-operation, JT) started during the former City Mayor’s time. Paananen, it worked well for a long time. Today, it has slightly deteriorated.” (O1)

“This is the trap. If you start thinking about the local cluster configuration, it is not so. You have to start thinking about external connections. This kind of local ecosystem does not exist any more. We should start thinking about the connections to the world outside these local ecosystems…It has to be understood that the researchers in the 1980s did not have …this digital space in which you are all the time connected, it does not matter if you are on the other side of the world or in the room next to you. Only the time difference slightly matters.”(O10)

“The element that doesn’t come out (of the cluster actor figure, JT) is the actor representing market, or pull effect. All these elements presented here are push actors. Equally strong or even stronger effect comes from the pull effect. Especially in cities like Oulu and Luleå, geographically remote places, the connections to markets, the interaction towards markets, the identification of demand factors are prerequisites for the development.” (O1)

In Luleå, the strongest ties between the cluster categories in Luleå are, according to the interviews, between the companies and research organizations. The Triple Helix nature of the Luleå HT cluster was mentioned by several informants, including the co-operation between companies, Luleå University of Technology LTU, and regional authorities, especially Norrbotten county administration. Some informants commented, however, that the co-operation between companies and research organisations should be even more intensive. According to some informants, the co-operation as such is not sufficient if the co-operation between the actors does not lead to practical measures. The external links of the companies in Luleå and other cluster actors were largely seen as insufficient. The SMEs inside the HT cluster are, according to the informants, still far too oriented to local markets, which prevents the growth opportunities.

“I would like to suggest this: companies should intensify the contacts with the research organisations. There is so much more to be utilized” (L8)

“In Oulu, I think they are considerably better in attracting export-oriented companies, and we can ask why. Luleå is largely oriented to local markets
and not really external markets. It would be an advantage to Luleå region if we could attract people experienced in international business.” (L8)

In Pisa, the strongest ties between the cluster categories are, according to most of the informants, between the regional government and the research community in Pisa. The small companies, especially, lack ties with the other cluster actors. The lack of coordination between the cluster actors and even inside the cluster categories of actors was frequently mentioned as a weak point of the Pisa HT cluster. Some informants pointed to possible cultural reasons as an explanatory factor behind the relatively weak ties between the actors. It was mentioned that the importance of external links in Pisa HT cluster are far better understood among the universities and the leading companies compared to a large majority of the SMEs.

“Well, it is, you know, the four strongholds of Pisa: University of Pisa, Scuola Normale, Scuola Superiore Sant’Anna, CNR: if they could really have a very synergistic approach, they could have the development in their hands, it is kind of talking integration, it is not a system, so influence from outside is more important.” (P 3)

“Governments and universities and more clever companies realize that they have to manage the change, they have to open to the markets, so once they realize this, they are preparing. About small companies, they will follow the trend, but the big companies open the way – I hope this will be the case.” (P2)

The empirical part of this study highlights the increased importance of the external linkages of the clusters, thus supporting the findings of e.g. Wolfe & Gertler (2004) and Bathelt et al. (2002). The findings of the interviews also suggest that the focus of the regional cluster actors, especially the internationally-oriented companies, is more and more on external linkages, or often on global pipelines, partly diminishing the relative importance of the local inter-cluster cooperation. The traditional illustration of “closed” regional cluster does not have the same explanatory power as it used to have, according to the interviews of this study.

Table 24 summarizes the key findings of the interviews concerning the structural elements of regional science-based clusters in Oulu, Luleå, and Pisa.
Table 24. Main structural elements of regional science-based clusters in Oulu, Luleå, and Pisa: major findings of the study interviews.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Oulu</th>
<th>Luleå</th>
<th>Pisa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal competition vs. co-operation</td>
<td>&quot;More co-operation than in Helsinki&quot;.</td>
<td>&quot;More co-operation than in Stockholm&quot;.</td>
<td>Individualism instead of co-operation.</td>
</tr>
<tr>
<td></td>
<td>&quot;Business as usual&quot;</td>
<td>&quot;Business as usual&quot;</td>
<td>&quot;Business as usual&quot;</td>
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<tr>
<td></td>
<td>between companies.</td>
<td>between companies.</td>
<td>between companies.</td>
</tr>
<tr>
<td>Social capital and trust</td>
<td>The &quot;Oulu Spirit&quot; diminished.</td>
<td>Competition and mistrust between IFCs.</td>
<td>Individualism, some mistrust.</td>
</tr>
<tr>
<td></td>
<td>Strong &quot;high tech city&quot; image.</td>
<td>Lack of strong &quot;high tech city&quot; image.</td>
<td>Lack of strong &quot;high-tech city&quot; image.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;Jante law&quot; mentioned.</td>
<td></td>
</tr>
<tr>
<td>Leadership</td>
<td>Previously strong leaders, current lack of leading organizations or individuals. Expectations of the role of Oulu Innovation.</td>
<td>&quot;Swedish democracy&quot; instead of strong leadership.</td>
<td>Previously strong individuals, current lack of leading individuals or organisations.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expectations of the role of Internet Bay.</td>
<td>Failed attempts to create &quot;cluster motor&quot;.</td>
</tr>
<tr>
<td>Internal vs. external linkages</td>
<td>Strong ties between companies and research community.</td>
<td>Strong ties between companies and research community.</td>
<td>Strong ties between regional government and research community.</td>
</tr>
<tr>
<td></td>
<td>Triple Helix linkages focusing on University, VTT, City, regional government, selected companies. The focus moving rapidly from local ecosystem to global linkages.</td>
<td>Triple Helix linkages focusing on University, City, regional government, selected companies. The focus moving gradually from local ecosystem to global linkages.</td>
<td>Elements of Triple Helix co-operation, lack of coordinated effort. The focus moving gradually from local ecosystem to global linkages.</td>
</tr>
</tbody>
</table>

Table 25 shows the theoretical and empirical findings related to the main structural elements of the clusters analyzed:
Table 25. Main structural elements: theoretical aspects vs. empirical findings.

<table>
<thead>
<tr>
<th>Theoretical aspects suggested</th>
<th>Empirical findings indicated by this study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competition vs. co-operation</td>
<td></td>
</tr>
<tr>
<td>Intensity and nature of competition and co-operation (Enright 2001).</td>
<td>“Business as usual”. Local co-operation and competition playing less dominant role than before.</td>
</tr>
</tbody>
</table>

Social capital and trust

Non-metropolitan regions and social capital (Doloreux et al. 2007).
Nature of trust, monitoring (Cooke & Morgan 1998).

Larger companies “too busy” to invest time in regional cluster activities.
Nordic regions still have “co-operation spirit” — although somewhat diluted.
Technical people having rich consultative structure enabling mutual monitoring.
Trust between the IFCs not optimal.

Leadership

Civic entrepreneur (Wolfe & Gertler 2004).
Shared leadership (Sotarauta 2007, Hallencreutz et al. 2002).

Current lack of leading cluster personalities and organizations.
Indicating the change from strong leading individuals at the start phase to shared leadership at the later cluster stages.

Internal vs. external linkages

Local buzz vs. global pipelines (Bathelt et al. 2002).

The focus is moving from local buzz to global pipelines.

Based on the findings of the interviews, the current co-operation inside the regional clusters plays a less dominant role than during the earlier stages of the clusters. The findings did not show any particular support for the argument (Enright 2001) of more intense competition or co-operation inside the clusters compared to competition and co-operation outside the clusters. The increased need to co-operate intensively with partners outside the regional cluster diminishes to some extent the local co-operation. The competition between the companies inside the regional clusters is argued to have remained at the “usual” level without any significant changes. In some cases, companies competing in the local business environment are willing to co-operate in external markets e.g. to participate in larger projects. The “social glue” inside the regional science-based clusters is still to be found in the Nordic HT clusters in Oulu and in Luleå although somewhat diluted, supporting the argument of Putnam (2000). The pace of the global business limits the possibilities of internationally oriented high
technology companies to participate in developing local business environment. The Pisa region seems to have problems in joining the forces to strengthen the HT cluster despite several initiatives. The level of trust between the cluster actors in the case study regions is regarded as being at an “acceptable” level especially compared to capital regions. The highest level of mistrust is found inside the IFC category and between IFCs and other actors. Based on the findings of this study, the level of trust is high among the technical experts, who have a local culture of discussing the technical development even with the competitors. The rich discussion and consultation culture between the technical experts enables the cluster participants to monitor their interactions, supporting the argument of Cooke & Morgan (1998) and Maskell (2001). All the case study regions currently lack a strong leadership in the HT cluster. According to the interviews, the strong individuals had a bigger leadership role in the beginning of the cluster development. Shared leadership is more likely when the cluster gains volume and strength.

The findings of the interviews indicate that the importance of external linkages has clearly increased in the regional science-based clusters, emphasizing the external or global pipelines of the regional science-based clusters. Fig. 22 presents a modified illustration of internal and external linkages of the regional science-based cluster, partly adopted from Bathelt et al. (2002). The figure includes the internal regional cluster environment with cluster actors and the local buzz consisting of local information flows, gossip, and news. The external information flows with partners from the outside are illustrated by global pipelines.
5.3 Dynamic evolution

The development path of the case study clusters over time

The informants were asked to comment on the development path of the regional science-based clusters of the case study.

In Oulu, the informants largely considered the rapid development of the Oulu region, from traditional industry to high technology region, a success story. The informants gave several explanations for the development of the Oulu HT cluster. The informal group of key persons, the Revontuli Group, was mentioned by several informants as an important catalyst in getting the development of high technology in the Oulu region started. The explanations for the rapid development of the science-based regional cluster in Oulu given by the informants included the importance of timing, the location decisions by Nokia, the intensive lobbying by the regional actors, the early exit from a large part of the traditional “smokestack”
industry allowing investments in high technology branches, the active role of the City of Oulu, the active role of a handful of key persons, the favourable regional policy of the Finnish government, risk taking, and pure luck. The proper timing in providing an industrial infrastructure at the time of the ICT upturn, including the explosive growth of mobile phone business, was mentioned as an additional element of success. Some informants in Oulu mentioned lost opportunities in the Oulu HT development including the lack of new high technology companies.

“We had persons, maybe 20–30 persons, from the University of Oulu Electrical Engineering department: a collection of companies were established by them, not necessarily from the same technology branch. It was not the companies but the persons who built up the high technology cluster. It was not an organization or a network that did it. The City of Oulu, they provided walls.” (O9)

“This chain of actors is the most essential: The University Of Oulu – VTT Technical Research Centre of Finland – the education, training, and industrial infrastructure that was built 10 years before it was actually needed” (O1)

“In Oulu, the public sector has done an enormous job in building up this infrastructure. The companies did not need to contribute, they just paid the rents and did their business.” (O5)

In Luleå, the establishment of the Luleå University was stated by almost all the informants as one of the most important factors paving the way to the development of the high technology concentration in the region. The role of special research units of the Luleå University such as CDT was emphasized by several informants. The industrial development of the Luleå HT cluster has been highly dependent on a handful of key events, according to the informants. First, the location decision of the teleoperator company Telia’s research unit in Luleå was mentioned by several informants as one of the critical steps towards ICT industry growth in the region. Moreover, the development of the Luleå University spin-off company Arctic Software, followed by additional spin-offs, was cited as a pioneering event especially for the SME development in the ICT sector in Luleå. The role of the telecommunication company Ericsson was also frequently mentioned by the informants as one key element of the Luleå HT cluster development.
Many informants in Luleå mentioned Ericsson as a lost opportunity for Luleå. Luleå was unable to attract more Ericsson jobs, or more Ericsson research units, to locate to the area. The ICT downturn in the years 2000–2001 was described by most informants as a temporary financial and mental shock to the Luleå ICT cluster development. The recovery has taken place in recent years, however. The latest upturn was partly explained by the recent favourable economic situation in the Luleå region. The replies of the informants about the reasons for the development of the Luleå HT cluster varied from the contribution of the right people at the right time to the rapid response to the needs of the traditional industries in the region to modernize and automate their production. The combination of the Luleå University of Technology and a very competitive traditional industry was given as the main explanation by several informants.

“We have Ericsson here, Erisoft. However, Ericsson has never had the same presence and weight in Luleå as Nokia has had in Oulu...In Northern Sweden, the location alternatives for the companies are not as obvious as in Northern Finland. Maybe Ericsson chose not to allocate too many resources to one place, Luleå” (L1)

“Luleå has a great focus on ICT today with international ambition from beginning. We have different types of companies bought up recently: Marratech, Effnet, NordNav. NordNav was sold to a company in England after 4 years from the idea stage at the Luleå University. They wanted the IPRs, and specialist competence. Marratech–Google deal was different, there Google decided to expand here in Luleå... they have development here and sales office in Stockholm” (L10)

“This e-health, or wellness, or fitness, that could have become a really powerful cluster here in Luleå. It is not about the resources, it is simply an inability to decide on common strategy” (L9).

“We are experiencing right now the best overall industrial upturn in Luleå in my lifetime... In the 1990s, it was telecom industries, Ericsson and Nokia as drivers of ICT, now it is actually other branches, even construction and base industries as drivers of ICT, and the European demand”(L9).

“Contrary to Luleå, the city of Umeå had no paper industry so actually we had a better starting point from the point of view of applying ICT to industry” (L3)
In Pisa, the informants largely agreed on the major stages of Pisa HT cluster development (DiMinin et al. 2003, 2006): birth and innovative growth 1955–1980, consolidation and stability 1980–1995, and clustering and restart 1995–2004. The Piaggio company was seen as the starting point of the rapid industrial development of the advanced technology sectors in the Pisa region after the 2nd World War. According to the interviews, Piaggio has not, however, taken the locomotive role in the HT development in the region. Furthermore, the relatively low amount of regional subcontracting of Piaggio worried some informants. One informant explained that in the past, there were practically no connections between the industrial sector and the research organisations in Pisa region. Only after the industrial sector started to decline, the regional government started to look for new solutions and increased co-operation between the traditional industry and the research organizations.

The informants gave several explanations for the development path of the Pisa HT cluster. The long tradition of research in the fields of high technology attracted the international HT companies and high-level research organisations, such as CNR, to locate in Pisa. The tradition of high level research in Pisa was mentioned by several informants as the fundamental reason for several international companies such as Olivetti, IBM, Marconi, to set up their operations in Pisa. The informants largely agreed on the crucial role of the research organizations (i.e. the University of Pisa, the special schools Scuola Normale and SSSUP, and the CNR units) in the development of HT activities in Pisa region, arguing that the development of the Pisa HT cluster would have been remarkably slower without strong research organisations. The development of Pisa airport into an international airport including e.g. direct flight connection to New York was mentioned as a valuable prerequisite and enabler of the future development of the Pisa HT sector. Several informants in Pisa contended that the city has lost several big opportunities to strengthen its high technology industry. The closing of the research centres of Olivetti and Marconi in Pisa have had a negative effect on the development of the Pisa HT cluster. The lack of coordination between the policy makers and the lack of understanding of the needs of the HT industries were seen as important reasons for the stagnation of the promising growth of the Pisa HT cluster. Also, the unsuccessful attempts of building up a joint effort to support and promote Pisa HT sector were mentioned by some informants.

“That was because of the very rich research environment was established in Pisa region, it is an enormous story that started from Enrico Fermi” (P1)
“In the late 1980s, there was an important conference in Pisa with all relevant organizations. In the first half of the 1990s, there was this project for a Science Park and a lot of tension and a lot of discussion took place... a bit less based on walls, bricks. The result was that the 1990s were a decade of heavy talking, heavy discussion, some money, a lot of problems, misunderstandings, a lot of jealousy and the whole science park, let's say, fashion declined, and the result was that, in my opinion, starting from the later 1990s and early 2000s those who were able to start initiatives, started initiatives without worrying too much of networking both at regional and at local level, for example Sant’Anna built its own science pole in Pontedera. Navacchio got the money, built the incubator” (P5)

“These big companies, as a matter of fact, in a few years retired from Pisa, they closed their laboratories and this was a big failure; not that these were production centres but research centres, so the impact on manpower employment was not so strong but the loss of intelligence meant we fell out of the research context” (P1).

Cluster life cycle model and case study regions

The informants were asked to evaluate the match of the DTI (2004) cluster life cycle model with the Oulu/Luleå/Pisa region HT sector development. The informants were also asked to position the HT clusters in the region along the DTI (2004) cluster life cycle trajectory.

In Oulu, the DTI cluster life cycle model was well accepted by the large majority of the informants – but not all of them. According to some informants, the DTI model should include the possibility of iterative rounds or even the possibility of taking an entirely new direction. Several informants also stated that there are numerous products at different stages of the life cycle inside the same cluster. One informant compared the development of the high technology concentration in Oulu and the S curve of companies. Most of the interviewees stated that ICT and telecommunication has reached the mature stage. Many informants added, however, that the accumulated volume and expertise in the Oulu ICT cluster makes it a strong actor even at a mature or declining stage. Electronics production was seen to have reached the declining stage. All the remaining sectors were estimated to be either in emerging or establishing stage,
software and wellness sectors most frequently evaluated to have entered the establishing stage.

“Any industrial sector follows the S curve trajectory. Technology concentrations behave in this manner, too, not because they themselves have this feature but because the companies located in the technology concentration have that feature, so the S curve type of development of the technology concentration is a kind of consequence of the development of the industrial basis there.” (O1)

“The disadvantage of the life cycle model comes from the fact that it directs people to think easily that we just jump from one phase to another... even though some other step would be much more promising to be taken. This life cycle model sort of reduces the options...in practice, there are always development paths available to overcome the difficulties.” (O6)

“Telecommunication, not growing as an aggregate but constantly being renewed, with new generations. Software, difficult to estimate. Maybe establishing, but will it ever really fly? Biotechnology, maybe emerging. Environment, already existing. Wellness, already established. Content and media, emerging.” (O2)

“ICT, somewhere between mature and decline. Content and media emerging, wellness has developed a bit further; established. Biocluster emerging, they have longer cycle, too. Environment, emerging, too...ICT is able to renew, we have top experts at the university if only we can use them.” (O8)

“Electronics industry, we should get more out of it. We don’t have own products, it’s a pity because so much more could be done from the know how in the region. We lack entrepreneurship, funding, risk taking, also creativity, and marketing. Anyway, we have electronics expertise in the region. A lost opportunity.” (O2)

In Luleå, several informants stated that the Luleå HT cluster has experienced a re-start, second phase, after the ICT crash in the early 2000s. Some informants estimated that the new growth stage took off in the years 2004–2005. The key persons of the new growth stage include ICT experts and entrepreneurs both from the previous periods of growth in the late 1980s and 1990s and newcomers. Many informants stated that the Luleå HT community is much better prepared to possible downturns than before the ICT downturn in the early 2000s.
“We have gone the entire cycle, second round is on its way for many. They were 25 years old during the first round, now they are 45 years old…” (L2)

“This becomes easily like product life cycle curve…these clusters can bounce back… actually the cluster life cycle resembles Boston Consulting Matrix.” (L1).

“We are maybe experiencing the second round, between established and mature... Today, it is like (ICT) in Sweden on a miniature scale, the second round with a healthier development... Definitely... exactly... moving in a spiral course!” (L3)

“That time, under ICT hype, the investments here in Luleå were not that well thought out, money was invested in unclear plans, we had no competence with ICT investments and we were beaten there. This time, we are much better prepared... it is a healthier development, and also with a more realistic view of our position on the world map.” (L7)

“The region has more than 100 years experience of base industries but only 20 years of this high technology. Actually, we have already reached a declining stage inside our embryonic stage of the HT cluster.” (L7)

In Pisa, several informants stated that one should not look at the Pisa HT cluster as an aggregate when analyzing the life cycle. One should instead look at the components: industrial sectors or even sub-sectors. Based on the interviews, there are three major categories of companies with different life cycles in the Pisa HT cluster: Piaggio (now in the re-start phase), big high technology companies (now in the mature stage), and small companies (now in the embryonic phase). The pharmaceutical sector was stated to be at the mature stage whereas at least parts of the ICT companies were analyzed to be at the embryonic/established stage. The possibility of starting another round of life cycle was supported by several informants. It was also argued that the Pisa HT cluster is currently experiencing a more profound change than only cyclical development.

“I think the ICT sector, in some sense some of the companies in Pisa have done all the life cycle but now they are starting with different concepts, not only hardware or software but with something more... second round, exactly!” (P2)

“It is not a change of cycle, it is a change of paradigm!” (P10). 

152
Critical mass

In Oulu, it was claimed that the Nokia-driven ICT cluster has reached the critical mass. Several informants in Oulu mentioned that Nokia has attracted a large proportion of the talent available in high technology job markets both to Oulu region, and to stay in the region, making the possibilities of attracting talent to other Oulu HT clusters more challenging. The attempts to reach the critical mass in other clusters than the ICT cluster in Oulu region may face this bottleneck of talented people willing to work in Oulu. The optimal size of Oulu – not too small to reach the critical size of certain key activities, not too big to ensure the intense co-operation between decision-makers and the experts – was mentioned as one advantage of the Oulu high tech community.

“Well, it is still the co-operation between the decision-makers and experts and the relatively small size of Oulu. It is kind of controllable, they know each other. The optimal size, it remains under half a million people. Maybe it is closer to 200.000 people and then it is like Oulu region. It is a kind of optimal size to run less than three major clusters.” (O3)

“People talk often about the economies of scale which obviously exist, but size alone does not solve these problems. For example, in Italy, a cluster in a community of 7.000 people had gained a globally significant market share. The lower limit is difficult to say but the direct correlation to size is not necessarily to be found. It depends more on the activity.” (O6)

In Luleå, the lack of critical mass was mentioned by many informants as a fact hindering the full utilization of the clustering effect. For example, a lot of expert services are not to be found in the Luleå region. The concept of optimal size was raised by Luleå informants, stating that some business activities can be handled in a smoother way in non-metropolitan cities like Luleå compared to e.g. Stockholm region. In Luleå, it was stated that Luleå region is simply not big enough to be able to produce all the specialized services for the high technology cluster; quite often the services have to be bought from e.g. Stockholm region. One informant argued that Luleå is able to produce cluster-type activities only in the ICT sector.

“We don’t have a quantitative critical mass in the Luleå HT cluster” (L4)

“We have a small university. An extremely smart professor, he has decided to leave the university and work for Google. If you have the critical mass it does not hurt that much.” (L9)
“I must admit, comparing to others, we have problem with the critical mass. Not only the population but also breadth and when compared to Oulu Innovation, you have gathered the actors together and invest heavily, that kind of focused investing we don’t have here.” (L9)

“Being small is good in some ways but in some ways also a disadvantage. I guess that we sometimes are too few, we don’t have the critical mass, to have the best possible development. What we need to do is to grow but also to have even more collaboration with experts in other places in the world.” (L 6)

In Pisa, the full utilization of the clustering effect is, according to the informants, more of an issue of lack of synergy and cooperation than lack of the sheer size of the Pisa business and research community.

“What has happened with the vast mass of research, university, CNR? It is the industrial base that is not corresponding, with some exceptions e.g. software for navigation, you have special shipbuilding. Pisa failed to make mass together. You have Pisa Ricerche, Pont-Tech, Navacchio, competition instead of co-operation.” (P10)

Path dependency and lock-in

In Oulu, the informants largely agreed on the list of path-dependent events and characters of the Oulu HT development by Männistö (2002), including e.g. the foundation of the University of Oulu with electronics as one of the focus areas, the diversification of the traditional industry in the region to the electronics industry, the foundation of VTT Electronics research centre in Oulu, the foundation of the Technology Park, the Technology City Oulu project, the heavy investments of Nokia, and the expansion of the markets of the telecommunication companies in Oulu. It was also mentioned that Oulu was able to exit the mature industries before other regions, resulting in an early entrance to high technology branches. Several informants mentioned the present technology-oriented mindset as a hindrance to further development of the Oulu HT cluster. It was claimed that the Oulu region has focused on the telecommunication path so intensively that there is almost a forced desire and need to maintain the telecommunication path even in the future.

“Oulu had the courage to give up the smokestack industry before Pori, Kotka, others, there was also some luck involved because we got Otala and some
others with new visions to the university. Yes, we were lucky...we should behave like the Japanese: if they invest 2 billion and fail they just forget. We would not have the courage to do the same.” (O3)

“Yes, this path dependency can be identified. It shows up as thinking about the economic risk but above all in that this entire group of decision-makers, we are now here at maturity stage, they have lived this curve, they cannot give up the curve but try to find ways of continuing the development along the old curve, but we cannot do anything. The decision-makers don’t have tools, they are defenceless about the changes in markets and globalisation. In order to start a new development curve, one should change the entire team of decision-makers.” (O1)

In Luleå, several informants emphasized the critical role of keeping up with the latest technology development in the strong high technology fields within ICT. Also, the clear focus of the university-level activities in Luleå on technical disciplines was mentioned as a reason for the relatively high proportion of HT industries in the region. Some informants, however, criticized the heavy commitment to a technology-driven strategy, emphasizing the need to invest in a marketing-oriented approach in the Luleå HT cluster development in the future. The lack of critical mass and high dependency on only few world-class experts was seen as a risk to the future development.

“I argue that the HT development here is more driven by technology than by the global markets. It is based on the competence we chose, one day, to build up our competence at the university. Then, we shall see the current weakness of the university, what it means. But I believe that the embryo lies there, on the focus on telecom, and then, one should not forget the historic-cultural first GSM call from the hill of Luleå, Ericsson Research Centre, and plenty of those, so that builds up the tradition of a forefront position in small niches, we are still world-class in many aspects” (L10)

In Pisa, some informants mentioned that the tendency of the public sector decision-makers to support the old, declining industrial sectors diminishes the possibilities of the Pisa HT cluster development. Also, the long tradition of supporting long-term oriented science is problematic from the viewpoint of entrepreneurial activities, according to some informants.

“Most of the research is invested in declining sectors.” (P 9)
“I don’t think we can go to a mature phase, this doesn’t sound correct to me. We can either become a growing cluster in good high tech or a stable cluster in good high tech. I think that given our scientific roots, we can not become mature in the sense of declining technologies...the matter is to try to understand whether we will become a heavy impact cluster from an economic point of view or just a nice cluster in the third Italy.” (P5)

“Art for art. This is science for science. You have to cut this vicious cycle. The problem is how to cut. Research has its own horizon, its own awards.” (P10)

Table 26 summarizes the findings of the interviews concerning the dynamic evolution of the clusters.
Table 26. Dynamic evolution of regional science-based clusters in Oulu, Luleå, Pisa: Major findings of the study interviews.

<table>
<thead>
<tr>
<th>Issue</th>
<th>Oulu</th>
<th>Luleå</th>
<th>Pisa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Why did the region experience the HT evolvement path?</td>
<td>University, VTT, and City in important roles, Nokia factor, early transition from traditional industry to HT.</td>
<td>University in crucial role, Integration of the ICT and the needs of traditional industry.</td>
<td>Research community in crucial role. The lack of coordination preventing even greater HT success.</td>
</tr>
<tr>
<td>Cluster life cycle model vs. the realized evolution</td>
<td>Individual cluster companies and projects in very different stages.</td>
<td>Individual cluster companies and projects in very different stages. Second life cycle round for some companies.</td>
<td>Individual cluster companies and projects in very different stages. Second life cycle round for some companies.</td>
</tr>
<tr>
<td>Critical mass</td>
<td>The Nokia driven ICT cluster has reached critical mass</td>
<td>The size of Luleå considered as a hindrance.</td>
<td>Coordination and synergy more relevant than the sheer size.</td>
</tr>
</tbody>
</table>

Table 27 presents the theoretical aspects suggested vs. empirical findings indicated by the study regarding the dynamic evolution of the cluster.
Table 27. Dynamic evolution of the regional science-based cluster: theoretical aspects vs. empirical findings.

<table>
<thead>
<tr>
<th>Theoretical aspects suggested</th>
<th>Empirical findings indicated by this study</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cluster life cycle</strong></td>
<td></td>
</tr>
<tr>
<td>General life cycle model (DTI 2004)</td>
<td>Cluster life cycle follows to a large extent the DTI model as an aggregate but the components of the</td>
</tr>
<tr>
<td>Predetermination (Pouder &amp; St. John 1996) vs. transformation (e.g. Wolters 2003)</td>
<td>cluster may have deviating evolution paths. Supporting the possibility of transformation.</td>
</tr>
<tr>
<td><strong>Technology/industry life cycle and clusters</strong></td>
<td></td>
</tr>
<tr>
<td>Hype cycle (Linden 2002)</td>
<td>Similarities between the shapes of the regional ICT clusters and the Gartner Hype Cycle during the dot-</td>
</tr>
<tr>
<td></td>
<td>com upturn, downturn, and recovery.</td>
</tr>
<tr>
<td><strong>Critical mass</strong></td>
<td></td>
</tr>
<tr>
<td>Sufficient size (Swann 1998)</td>
<td>Supporting the minimum size to be reached.</td>
</tr>
<tr>
<td>Organizational thinness (Tödtling &amp; Trippl 2005, Doloreux et al. 2007)</td>
<td>Emphasizing the importance of critical mass – with the suggestion of “optimal size”.</td>
</tr>
<tr>
<td><strong>Path dependency and lock-in</strong></td>
<td></td>
</tr>
<tr>
<td>Clusters and path dependency (Britton 2007)</td>
<td>Region-specific, path dependent trajectories identified.</td>
</tr>
<tr>
<td>Functional, cognitive, and political lock-in (Grabher 1993), lock-in and deficiencies (Tödtling &amp; Trippl 2005)</td>
<td>Variations: risk of high tech lock-in, non-metropolitan fragmentation.</td>
</tr>
</tbody>
</table>

Based on the empirical findings of this study, the general cluster life cycle models can partly explain the behaviour of the regional clusters over time – but not completely. The aggregate evolvement of the case study clusters of this study over time follows to a large extent the cluster life cycle model of DTI (2004). The DTI (2004) model is, however, too general to describe the versatility of the activities of various cluster components and sub-components over time. The findings of the case study of these regions support the Wolter (2003) conclusion of the cyclical development of regional clusters with possibilities of transformation or renewal – not supporting a deterministic behaviour of regional cluster as argued by Pouder & St. John (1996). The trajectories of the case study HT clusters over time vary according to the technology sector. The time period needed to complete the life cycle is different between e.g. biotechnology and ICT sectors.

The empirical findings of this study give some indications on the possible spiral movement of at least certain cluster components. According to the interviews, additional cycles are possible for at least some companies after the...
completion of the first life cycle. In Luleå, it was argued that especially in the case of entrepreneurs from the first round participating also in the second life cycle, the management of the companies is more experienced and better prepared to face the new situation in the marketplace than in the beginning of the first life cycle, forming a self-enforcing spiral path (see Fig. 23).

Fig. 23. Cluster life cycle: spiral path.

The Gartner Hype Cycle model would match relatively accurately the interview replies of this study, especially the experts in Luleå concerning the downturn of ICT in the beginning of the 2000s, the so-called dot.com crash, followed by the gradual recovery. The shape of the Gartner Hype Cycle, including the peak of inflated expectations, disillusionment, and slope of enlightenment, resembles the shape of the Luleå HT cluster in the end of 1990s and in the beginning of 2000s.

The findings of the study support the theoretical aspect of the importance of the critical mass in the dynamic evolution of the clusters. For Luleå region, with smaller population and level of HT cluster employment, the issue of critical mass and organizational thinness (Tödtling & Trippl 2007) seems to be more serious issue than for the other case study regions in Oulu and Pisa. The findings of this study suggest also the concept of optimal size of the HT cluster and region, reaching the minimum critical size of the HT cluster but avoiding the problems
related to metropolitan HT clusters, including e.g. traffic problems, housing costs, and the fragmentation of the cluster actors (Florida 2005b) and possible difficulties of larger urban centres in achieving effective degrees of mobilization (Gertler & Wolfe 2006). Based on the findings of this study, the following citation from a research manager in the small university town of Lund in Sweden would not be a surprise in Oulu and Luleå, perhaps also in Pisa: “To live here is perfect when you have this type of qualified job and also want your kids to go to decent schools and childcare without hours of commuting. I know, because I talk to colleagues from all over the world and they just sigh when they hear about my situation. It takes me less than five minutes to pick up my daughter from school, and my wife works just across the street. Everything is close, and still there are a lot of qualified jobs here”. (Asheim et al. 2007)

The case study descriptions confirm that regional science-based clusters are time-specific and place-specific units, affected by path-dependent series of events and decisions. The HT clusters also face the potential deficiencies of regional innovation systems. Tödtling & Tripl (2005) propose the main innovation barriers related to regions as: organisational thinness, lock-in, and fragmentation, presented in 2.4.4. The findings of the study reveal that the three case studies face a mix of these innovation barriers. In Oulu, the findings suggest a potential risk of “high tech lock-in”: the highly successful development of especially ICT sector combined with the “techno-mentality” increases a risk to stick to the old “techno-mentality” and strategy – that used to give excellent results. Luleå is facing the organisational thinness related to a critical mass. In Pisa, the mentality of the region includes elements of lock-in related to supporting the old, declining industrial regions. The Pisa HT cluster has also elements of fragmentation, more typical of metropolitan regions, with numerous small actors and problems in joining forces.

5.4 Perceptions of future development and judgmental biases

As presented earlier in this study, the cluster decision-makers base their decisions on the perceptions of future cluster development. This study focuses on past and current status of the clusters but the analysis of the strategic management issues of perceptions and potential judgmental biases concerning the future cluster development is included into the study because perceptions and biases directly relate to the current status and decision-making process of the regional science-based clusters. The following analysis contains the key findings of the case study
interviews on three major issues of the future cluster development. Firstly, the perceptions of the informants on the major effects of the globalisation trend on the regional science-based clusters in their regions are analyzed. Secondly, the opinions of the informants concerning the preparation of the cluster decision-makers for the future challenges of the clusters are evaluated. Thirdly, the perceptions of the informants concerning the possibilities to prolong the positive cluster development cycle are analyzed.

The analysis includes an evaluation of the potential judgmental biases in strategic decision making (Mintzberg et al. 1998) applied to the cases of Oulu, Luleå, and Pisa science-based clusters.

Regional science-based clusters facing the challenges of globalization

In Oulu, the globalisation trend was accepted by all the informants as an essential element of the present and future development of the Oulu HT cluster. Several informants stated that especially the ICT and telecom sector will be driven by global trends, whereas the environmental and wellness sectors will be largely driven by national trends. Some informants noted that the Oulu region has been driven by globalization trends already long before the high technology era. Oulu had the industrial concentration related to tar until the tar market collapsed when new technologies and materials replaced tar as the material of shipbuilding. According to the informants in Oulu, it is possible to adapt and react to the changes caused by global and international trends. The Oulu region has become an established high technology concentration which makes it easier to prepare for the future. The recommendations of the informants on how to react to the globalisation effects on the Oulu HT development included e.g. the attraction of an international labour force, moving higher up in the value chain of the production, and doing everything to keep Nokia in the region. According to some informants, the cluster decisions regarding the globalization should be made so that the real wellbeing in the region increases.

“"Yes, we have in Oulu far better possibilities to succeed than 20–30 years ago. At that time, Oulu had nothing. Today, we have a tremendous experience on high technology development. It is crazy that we have these discussions here every now and then that we should leave ICT and look for services and everything else. The difference between static friction and rolling friction is
huge, and we have reached the condition of the rolling friction here in Oulu with our high technology. “(O9)

“If we start competing for jobs with China, we finally end up lowering our wellbeing to the level of China. We have to search for core competence and services in our clusters that provide more added value than China or other regions.” (O6).

In Luleå, the majority of the informants stated that the Luleå HT cluster is heavily dependent on the globalisation trends and international competition. The development of the SMEs is facing a dramatic change because of globalisation. The proper monitoring of the international and global trends related to the companies and research activities in Luleå were considered essential measures to adapt to globalisation.

“If you look at the ICT cluster in Luleå, it is very linked to global development... the SMEs that are growing here – we have several companies here in the R&D phase – after one year they might be taken over by the telecom giants, or be practically laid down, or be closed down fully or partially (the Luleå unit, JT), or find their decision-making in the hands of international venture capital. The young companies don’t follow any more the traditional local-regional-national-international development but go directly to global markets, thus, in practice, eliminating the local/regional development phase.” (L7)

In Pisa, the informants largely accepted the fact that globalisation is having more and more influence on the industrial and research activities in Pisa region. At the same time, the informants emphasized that the future is still largely in their own hands in Pisa. According to many informants, the best ways to prepare and react to the globalisation include e.g. increased co-operation and synergy between the four strongholds of the Pisa research (University of Pisa, CNR, special schools Scuola Normale, Scuola Sant’Anna) and a new vision for the development of the technology parks. It was also stated that the Pisa HT development is not as dependent on one key actor as e.g. Oulu having the great dominance of one company, Nokia, and its activities in the Oulu region. According to the majority of the informants in Pisa, the issue of internationalization of the SMEs is crucial for the development of the Pisa HT cluster. Today, too many SMEs focus only on local or national markets. The issue of generation change related to globalisation was claimed to have a profound effect on the development of the Pisa HT
environment. Young talented people in Pisa – and in Italy in general – do not want any more to run one-man companies. The talented ones are increasingly looking for international education e.g. at Harvard University followed by a career in large companies. The old generation cannot handle the globalisation and is forced in many cases to sell their business activities. Some informants pointed out that the amount of foreigners should be much higher in Pisa HT activities in order to improve the access to the global market.

“We have a real problem with internationalization. We should have many, many foreign students, foreign researchers; of course we have some but not enough. And our companies in the HT cluster mostly are looking for local and national markets, maybe some of them to the European market, but not to the global market. “(P1)

Cluster decision-makers preparing for the future challenges

In Oulu, the HT cluster development programme Oulu Growth Agreement (2002) and the innovation strategy Oulu Inspires (2006) were questioned by several informants. According to some informants, there is no high technology hype among the local decision-makers in Oulu region today; even some pessimism can be identified. Many informants emphasized the need to increase the quality of the information on the high technology issues provided to local decision-makers.

“First, we had the Oulu Growth Agreement filled with goals. The exercise turned out to be a disappointment. Why? That could be analyzed. Then we moved into another extreme, The Oulu Inspires strategy, without any concrete goals.” (O1)

“Today, the local decision-making on high technology issues is largely based on feelings and the media.” (O11)

In Luleå, several informants stated that the decision-makers in Luleå lack the vision and the overall strategy in developing the Luleå HT cluster. Some informants took up the need to focus on the promotion of entrepreneurship in the future development of the Luleå HT cluster. Several informants suggested benchmarking with other regions and ideas from outside to assist the local cluster decision-makers in preparing for the future challenges.
“We should travel more outside our region; benchmark what the others have done. Companies, they travel a lot, but our public sector and IFC representatives have a too limited view of what is happening outside our region.” (L2)

“Too little vision, nobody has the courage to say, a typical Swedish cultural issue.” (L2)

“The decision-makers need to be given more insights of the importance of this HT sector, how it looks, what are the impacts of it, that means studies like you are doing, also the Ylinenpää study on comparing Luleå and Oulu which turned out the be an eye-opener to many. Your research could be one way to start a process to provide a more in-depth view of HT clusters to the decision makers” (L7)

In Pisa, many informants mentioned that the decision makers still often prioritize the traditional sectors. The other problem is that the regional plans, despite the prioritizing efforts, turn out to be too fragmented and divided into too many sub-programmes. The ongoing discussion among the decision-makers about the future of the Pisa HT sector was seen as a positive sign by some informants.

“If you look at the recent regional plan of Tuscany, a totally new approach, identifies only 10 priorities. But: if you look at the implementation of the regional plan you find that each priority has been broken into 30, 40, even 50 items. Again – we call it interventional pioggia, or raindrops of intervention.” (P10)

“There is good debate, the debate in Pisa is probably the most lively in Tuscany. In Siena they are talking about the Palio horse race... Florentines, they fight as usual. Our debate is most advanced.” (P7)

How to prolong the positive development of the regional science-based cluster:

In Oulu, some informants argued that the regional strategic planning in Oulu region attempts to prolong the “Oulu Phenomenon” with the same ingredients and methods as have been used for decades. The need to train and attract a considerable amount of high technology sales persons to increase the international sales of the high tech companies in the Oulu region was widely recognized. The
importance, especially for peripheral places such as Oulu, of getting rid of the traditional technology-based thinking and base the future planning and strategy thinking on more market-based thinking was emphasized by many informants. It was stated, however, that it is essential to retain the core enabling technology know-how of electronics and software industries in the Oulu region even in the future. One informant stated that the size of the cluster is always dependent on the size of the market it is able to reach. The cluster, no matter how advanced, will collapse if the markets disappear. It is, therefore, necessary to identify the business cycles to prolong the positive development of the cluster. Another informant saw the future potential in applying the core technologies of the Oulu HT cluster, such as wireless technology, to neighbouring clusters such as wellness and biotechnology clusters. He advised Oulu to concentrate on disruptive technology solutions – which nobody else is able to produce.

In Luleå, several informants pointed out the importance of applying the high technology know how to the demands of the regional traditional industry even in the future. More weight should be given to business development and management skills instead of concentrating too much on research and technology issues, with less weight on planning only. Long-term thinking and joint commitment to common long-term goals were emphasized by some informants.

“I believe that we should go on focusing on our strong sectors where we can build upon the combination of world class industry and the university. That is, for example, steel products and engineering but also ICT. These are sectors that we are strong in today and sectors that will be important also in the future.” (L6)

“If we could here in Luleå, we should join our forces once or twice a year to discuss the strategy to get everybody to work towards the same direction.” (L2)

In Pisa, the challenges of generation change, increased coordination, and synergy creation between the key actors of the HT cluster were seen as key issues in ensuring a positive development cycle for the Pisa HT sector. According to the majority of the informants, the strong research base of the Pisa region and the accumulated know-how in the region enable positive development of the HT cluster in the future. Several informants emphasized the role of success stories and new, innovative openings paving the way to future HT entrepreneurs in Pisa

165
The future growth areas suitable to Pisa HT environment suggested by the informants included e.g. energy, wellness, and environmental sectors.

“*I am rather pessimistic in short term but critically optimistic in longer term. We have to learn by some failure.*” (P10)

The findings of the study on the perceptions of the future cluster development are summarized in Table 28.

**Table 28. Perceptions of the future development of the HT clusters in Oulu, Luleå, and Pisa: findings of the study interviews.**

<table>
<thead>
<tr>
<th>Issue</th>
<th>Perceptions in Oulu</th>
<th>Perceptions in Luleå</th>
<th>Perceptions in Pisa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Globalisation challenges</td>
<td>Oulu HT cluster heavily dependent on global trends. Oulu is well-prepared with its cumulated HT expertise. Not enough foreign labour force in Oulu</td>
<td>Luleå HT cluster heavily dependent on global trends. The SMEs are facing a dramatic change due to globalisation.</td>
<td>Pisa HT cluster heavily dependent on global trends. Internationalization of the SMEs crucial to Pisa HT cluster. Generation challenge. Not enough foreign labour force in Pisa.</td>
</tr>
<tr>
<td>Key decision-makers preparing for the future</td>
<td>Currently, no HT hype among the local decision-makers. Strategy programmes in the 2000s criticized. Request to support decision-making on HT issues with reliable data</td>
<td>Lack of vision and overall strategy in developing HT cluster a threat for future development. Request to more insights of the importance of HT sector</td>
<td>Traditional sectors still prioritized. Regional plans too fragmented. Debate on HT issues welcomed.</td>
</tr>
<tr>
<td>How to prolong the positive development of the cluster</td>
<td>Market-based thinking, focus not only on wireless technology.</td>
<td>Focus on business and marketing skills, joint actions.</td>
<td>Focus on coordination, synergy, and new growth areas.</td>
</tr>
</tbody>
</table>

**Judgmental biases and regional science-based clusters**

The replies of the informants in this study are based on perceptions of the past, current, and future status of the regional clusters. The informants have expressed their opinions on the issues related to regional science-based clusters. It should be borne in mind that when individuals process information to make decisions, they
exhibit biases and distortions (Mintzberg et al. 1998), as expressed previously in Chapter 2.

Based on the information gathered from the interviews, the analysis of the other sources of evidence regarding the case study clusters in Oulu, Luleå, and Pisa, and a comparison of Pisa and Tampere innovation environments (Teräs and Lehtimäki 2007), the aim in this study was to highlight the potential judgmental biases of the regional science-based clusters using the typology of Mintzberg et al. (1998). In the study the following examples of the types of judgmental biases were identified in the Oulu, Luleå, and Pisa HT clusters (see Table 29). The purpose of the analysis is not to present an exhaustive list of potential biases of the decision-makers of science-based case study clusters but to test the theory of judgmental biases by using examples from the case study clusters of this study.

Table 29. Judgmental biases of decision-making related to regional science-based clusters, examples based on empirical evidence (Adapted from Mintzberg et al. 1998).

<table>
<thead>
<tr>
<th>Type of bias</th>
<th>Findings of this study, examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Search for supportive evidence</td>
<td>In Oulu: reporting concentrates on success stories e.g. Nokia, the ‘Oulu Phenomenon’</td>
</tr>
<tr>
<td></td>
<td>In Luleå: reporting concentrates on success stories e.g. Process-IT</td>
</tr>
<tr>
<td></td>
<td>In Pisa: reporting concentrates on success stories e.g. a strong research community</td>
</tr>
<tr>
<td>Conservatism</td>
<td>In Oulu: a continuous belief in the recipe for success of the ‘Oulu Phenomenon’, reliance on the old generation in leading positions</td>
</tr>
<tr>
<td></td>
<td>In Pisa: a reliance on the old generation in leading positions</td>
</tr>
<tr>
<td>Illusory correlations</td>
<td>In Luleå: a belief in the partial imitation of the Oulu HT recipe for success</td>
</tr>
<tr>
<td>Attribution of success and failure</td>
<td>In Pisa: the main critics of the insufficient success of the HT cluster is sometimes directed to factors outside Pisa e.g. the national government</td>
</tr>
<tr>
<td>Optimism, wishful thinking</td>
<td>The Oulu Growth Agreement 2002 growth visions</td>
</tr>
<tr>
<td>Underestimating uncertainty</td>
<td>The Oulu Growth Agreement 2002 growth visions</td>
</tr>
</tbody>
</table>

The bias of searching for supporting evidence is illustrated by the examples of the excessive reporting of the rapid development of Oulu HT environment, the innovative Process-IT concept in Luleå, and the strong research base of Pisa, hiding the unwillingness to frequent reporting on e.g. the slow pace of new company formation in Oulu or the challenges in attracting new students to Luleå.
University of Technology. The bias of conservatism is illustrated by the example of the perception in the Oulu region of the future success elements of the Oulu HT cluster based on the same type of elements as in the 1980s and 1990s. According to some informants, the extrapolation of the future development from the historical development should be stopped to allow new, fresh thinking in the Oulu HT cluster. Moreover, the low representation of management by the younger generation in both the Pisa HT cluster and the Oulu HT cluster, were mentioned as signs of conservatism in the case study interviews.

The bias of illusory correlations is demonstrated by the example of the Luleå decision-makers willing to imitate the perceived success of the Oulu HT cluster, based on the belief that the ‘recipe’ for success of Oulu is largely applicable to Luleå. Furthermore, the thoughts expressed in Luleå of e.g. transferring the technology park concept from Oulu to Luleå are, according to the case study interviews, at least partly based on the old Technopolis concept having a significant role as the HT cluster facilitator and a regional actor. The bias of attribution of success and failure is demonstrated by the example of Pisa informants frequently attributing the shortcomings of the Pisa HT cluster at least partly to the national government or other factors outside Pisa. The biases of optimism and wishful thinking, and tendency to underestimate uncertainty, are demonstrated by the example of the Oulu Growth Agreement Programme, overestimating the Oulu HT cluster growth for the period 2002–2006.

The analysis of the judgmental biases and regional science-based clusters, although based on some examples only, gives a clear indication on the usefulness and applicability of the Mintzberg et al. (1998) theory of judgmental biases of strategic decision-making. At the same time, it should be recognized that the interpretations of the biases of cluster decision-making in the Oulu, Luleå, and Pisa HT clusters presented in this study can themselves be deemed to be biased.

Table 30 shows the theoretical aspects vs. empirical findings of the strategic management issues analyzed in this study.

<table>
<thead>
<tr>
<th>Theoretical aspects suggested</th>
<th>Empirical findings indicated by this study</th>
</tr>
</thead>
<tbody>
<tr>
<td>The biases of decision-making affecting cluster decision-making e.g. wishful thinking, attribution of success and failure (Mintzberg et al. 1998)</td>
<td>Examples of judgmental biases identified, supporting the Mintzberg et al. (1998) theory</td>
</tr>
<tr>
<td>Perceptions (Lehtimäki 2005)</td>
<td>Decision-makers of the clusters requesting reliable data to support the decision-making</td>
</tr>
</tbody>
</table>
The examples selected from the empirical part of this study illustrated in Table 29 support the applicability of the theory of judgmental biases (Mintzberg et al. 1998) to regional clusters. Furthermore, the need of the decision-makers in the case study regions to base their decisions more on reliable data on clusters, instead of beliefs and feelings, was expressed in the interviews.

Clusters or not?

The presentation of the units of analysis in Chapter 3 included a discussion on the nature of units of analysis: to what extent do the units of analysis in Oulu, Luleå, and Pisa regions meet the criteria set by the literature on clusters? According to Martin & Sunley (2003), it is not possible to support or reject clusters definitively with empirical evidence, as there are so many ambiguities, identification problems, exceptions and extraneous factors. Rosenfeld (2005), in one of the most detailed geographical cluster definitions, defines the geographical boundaries of clusters as distances firms and other institutions are willing travel for informal face to face meetings and by how far employees are willing to travel to work. Based on the findings of this study, all three units of analysis meet the Rosenfeld criterion. The outer circle of the Luleå region, the county of Norrbotten with its long distances, is geographically the most demanding case study region from the viewpoint of effective clustering. Based on the information gained in this study, all three case study regions provide evidence of at least some level of interconnectedness between the cluster actors (Porter 1998a) to be called regional clusters – especially with regard to the vague definitions of interconnectedness. This does not, however, mean that the state of interconnectedness is satisfactory in the three case study regions. Based on the information gained during the study, the Pisa HT cluster region especially has challenges regarding interconnectedness.

5.5 Summary of the findings of this study

The following analysis summarizes the key findings of the study. First, the present status of the case study HT clusters in Oulu, Luleå, and Pisa is evaluated based on the sources of evidence of this study. Second, the similarities and differences between the case study clusters are discussed. Finally, the key empirical findings related to cluster theory are examined against the cluster theory. The findings are based on all sources of evidence used in this study, enabling an additional triangulation of the evaluation.
Findings related to the case study HT clusters

Table 31 summarizes the present status of the Oulu, Luleå, and Pisa HT clusters as interpreted from the various sources of evidence of this study.

Table 31. Present status of the regional science-based clusters in Oulu, Luleå, and Pisa.

<table>
<thead>
<tr>
<th>Key features</th>
<th>Oulu</th>
<th>Luleå</th>
<th>Pisa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus industries</td>
<td>ICT/Telecom dominates</td>
<td>Focus on ICT, and the combination of ICT and process industries</td>
<td>Numerous micro-size ICT companies, larger companies only in pharmaceutical sector</td>
</tr>
<tr>
<td>Dominant companies</td>
<td>Nokia the flagship company, with diminishing relative importance</td>
<td>No HT flagship company, promising spin-offs bought out early by foreign owners</td>
<td>No HT flagship company</td>
</tr>
<tr>
<td>Mental high technology barometer</td>
<td>“Oulu Phenomenon” changed into uncertainty, search for new success stories</td>
<td>Optimism due to overall economic upturn in Luleå and recovery from ICT downturn. A wish to imitate Oulu HT success in Luleå</td>
<td>Insufficient high tech image and identity despite a strong accumulation of R&amp;D activity</td>
</tr>
<tr>
<td>The status of research community</td>
<td>Research community still strong, worries about keeping up the level of expertise</td>
<td>Research community (LTU) strong, worries about keeping up the level of expertise</td>
<td>Strong research community but insufficient industrial co-operation</td>
</tr>
<tr>
<td>HT cluster bottlenecks and challenges</td>
<td>Internationalization and growth of the SMEs, cluster leadership</td>
<td>Internationalization and growth of the SMEs, critical mass, cluster leadership</td>
<td>Internationalization and growth of the SMEs, HT cluster thinking, cluster leadership</td>
</tr>
</tbody>
</table>

The empirical part of this study analyzed in detail the three case study clusters in Oulu, Luleå, and Pisa. The case-specific findings based on all the sources of evidence used in this study are presented as follows.
In Oulu, the regional HT cluster is facing a new situation after a long period of exceptional growth. The ‘Oulu Phenomenon’ – a rapid development of a non-metropolitan region in the Far North largely based on accumulated know-how and successful public-private-partnership efforts – has been an internationally recognized success story until the beginning of the 2000s when the growth stagnated. The Oulu HT cluster has been propelled by the Nokia-driven ICT sector and ‘Oulu Spirit’ – i.e. a solidarity and co-operative willingness across the cluster actors, including e.g. strong leadership and a recognized cluster motor provided by the Technopolis Technology Park. The Oulu region still includes a strong concentration of accumulated expertise especially in the ICT sector, although its present status differs considerably from the status of the 1990s. The previous cornerstones of the Oulu HT cluster – the research community and the Nokia-driven ICT industry – are still in place but the insufficient amount of high technology entrepreneurship and internationalization of the SMEs raise questions about the future of the Oulu HT cluster. The Oulu region does not enjoy any specific privileges from Nokia compared to other sites, the pace of the global high technology business does not allow too much intraregional co-operation between the key individuals, the HT cluster lacks leadership, and the role of some formerly regional actors such as Technopolis has changed remarkably. Oulu HT cluster has diversified its activities into several fields outside the dominant ICT sector although the critical mass of the other sectors has not been fully reached yet.

The mindset of the key actors of Oulu HT cluster and decision-makers in the Oulu region has changed from high tech optimism into high tech uncertainty concerning the future development. The ‘Oulu Spirit’ of co-operation in the fields of advanced technologies still exists, but is somewhat diluted. The Oulu HT cluster is facing an aging problem: the old generation who created the ‘Oulu Phenomenon’ is gradually retiring – and the new generation with new ideas and fresh thinking has not taken up the baton of creating the ‘second wave of the Oulu Phenomenon’. The Oulu HT cluster is today, however, stronger than ever in many aspects given e.g. its accumulated know how of the global high technology business. It would be easy to assume that numerous regions all over the world would like to have the volume and dynamics of the Oulu HT cluster – even with all the challenges attached to it.

In Luleå, the regional HT cluster has experienced growth and success stories – but is still facing the challenge of critical mass. Luleå did not experience a rapid growth of high technology industries until the 1990s when the ICT driven research and expertise, originated largely at the Luleå University of Technology,
took off and resulted in a growth period in the late 1990s. The downturn of the Luleå ICT sector and the dot-com crash, although damaging the Luleå HT cluster, has been converted into a new growth period in recent years. Today, Luleå has largely recovered from the company and job losses and the mental shock of the ICT downturn in the early 2000s. Luleå has no strong locomotive high technology company. However, the overall HT development of the city of Luleå has been positive in the 2000s and includes several world-class HT start-up companies in ICT niche technologies. The Luleå University of Technology remains a cornerstone of the Luleå HT environment. The Process IT concept is a promising initiative joining the regional forces by combining the expertise of the traditional industry and the ICT know how in the region. Together with the overall improvement of the businesses in Norrbotten, the Luleå HT cluster is performing better than ever before, at the time of writing in 2008.

There are, however, challenges ahead in developing the HT cluster in Luleå. The bottlenecks of Luleå HT cluster include a relatively low level of internationalization of the SMEs and a lack of internationalization experts. One of the major issues related to the development of the Luleå HT cluster is its critical mass – or lack of it. The city of Luleå has only 73,000 inhabitants and the national relative importance of the Luleå region compared to e.g. Oulu in Finland is rather low (Teräs & Ylinenpää 208). The issue of critical mass extends to various elements of cluster development: e.g. the ability of the region to provide an infrastructure and support services to companies, the ability of the university to attract and keep its best talent and to build up credible research units, the motivation of the financial institutions to set up an office in Luleå. There are no rapid solutions to the problem of an inadequate critical mass to be suggested. The importance of joint actions, co-operation initiatives, and proper focusing of key activities provide some general guidelines for the further development of the Luleå HT cluster. Based on the findings of this study, at least a part of the Luleå HT community would like to imitate the elements of the perceived Oulu HT success story, including e.g. the technology park concept and the regional innovation promotion company concept. The findings of this study indicate that the perceptions in Luleå are partly based on the image of Oulu HT cluster as it was during the rapid growth phase.

In Pisa, the HT cluster has the potential to become an internationally recognized hot spot of high technology – but needs a clear vision, systematic and long-term efforts, and a genuine co-operation mentality. Pisa is a non-metropolitan city with a medium-sized university, where the public sector has
heavily invested in scientific research. This study confirms that the search for a HT identity is still ongoing in the Pisa region. The Pisa HT cluster is not well-known at least outside Italy. This study has revealed that the core elements of the Pisa HT cluster include the research community with considerable depth and breadth. Pisa has also a high technology industry ranging from big pharmaceutical companies to smaller ICT-related companies and spin-off companies, many of which originate from the local universities and research centres. The Pisa HT cluster lacks some elements considered important in the literature on clusters, such as intensive co-operation between the cluster actors, and activities to develop synergy between the cluster actors. The HT industrial base in Pisa lacks the locomotive companies to accelerate the growth of the SMEs in the region, and large scale venture capital funding. The Pisa HT cluster has elements of a latent cluster (Enright 2001) with a sufficient critical mass of firms in related industries sufficient to reap the benefits of clustering, but without the level of interaction and information flows necessary to truly benefit from the co-location. As an example, the pharmaceutical and ICT sectors could provide a platform to combine their research and business ideas in a similar way as, for example the Process-IT concept in Luleå which combines traditional industries and ICT sector.

Much depends on the willingness and ability of the Pisa region to implement a change from a latent HT cluster to a working HT cluster – fully utilizing the potential of the Pisa research and technology potential. There have been several efforts in the Pisa region to join local forces in the field of HT development but the results have been unsatisfactory so far. The specific challenge of the Pisa HT cluster is the need to significantly increase the level of internationalization of the HT businesses in the region. Finally, the city of Pisa has another challenge related to the city image and population growth: despite the huge amount of tourists visiting Pisa and students attracted by studies in Pisa, the number of residents in the city of Pisa has decreased steadily since 1981 (Varaldo & Lazzeroni 2005). This might have an effect on e.g. the relative attractiveness of the Pisa city when compared to other location alternatives within the Pisa province.

Similarities and differences between the case study clusters

In the following analysis the similarities and differences of the Oulu, Luleå, and Pisa HT clusters are presented, based on the data from all sources of evidence collected in this study.
The HT clusters in Oulu, Luleå, and Pisa have similarities both regarding the structure of the clusters and the evolution of the clusters over time. All the clusters have experienced a rapid growth in private sector jobs especially in the late 1990s. All the clusters have a strong research community able to produce research results and ideas to be commercialized. The amount of growth-oriented high technology entrepreneurship is, however, unsatisfactory in all three regions. The relative high proportion of ICT companies is a common feature to all the case study regions. The venture capital community is perceived as insufficient in the case study regions to support the development and growth of high technology companies. The non-metropolitan status of the regions causes challenges in e.g. channelling national research funds into the HT clusters. All regions have a relatively low level of internationalization in the SMEs, which is a major bottleneck for future development. In all clusters at least some unhappiness is expressed about the role and the efficiency of the IFCs. The findings of the study indicate that the current leadership in the case study clusters is not strong nor does it have dominant leading persons.

There are differences between the clusters. The cluster structure and the roles of key actors vary across the case study clusters. Oulu has Nokia as the locomotive of the ICT cluster, whereas Luleå and Pisa do not have such a locomotive HT company. The role of the city has been important throughout the development of the Oulu HT cluster, whereas Luleå and Pisa have not had such a strong involvement of the city in the HT development. The city HT image is also different in the three regions, Oulu has developed a high tech city image, Luleå has a more balanced image of know how without a specific high technology emphasis, and Pisa – dominated by its image of a tourism city – is still in search of a high technology identity. The national innovation system in Italy receives more criticism from the Pisa informants than the national innovation system in Finland and Sweden from the Oulu and Luleå informants. Also, the official statistics such as the European Innovation Scoreboard indicate that the level of innovation efficiency in the recent years has been lower in Italy than in Finland and Sweden. Oulu in Northern Finland and Luleå in Northern Sweden have the leading regional role in business and innovation activities, whereas Pisa has to compete with other cities in Tuscany, especially Florence and Siena. Oulu has been able to use the Technology Park concept as an efficient instrument in accelerating HT growth especially in the 1980s and 1990s. In Luleå, the Technology Park has hosted a significant amount of leading HT companies but the role in catalyzing growth has not been as significant as in Oulu. In Pisa
region, the Technology Park concept has been largely limited to incubator-type activities.

Differences were identified between the development paths of the HT clusters. The Oulu HT cluster experienced a long rapid growth period until 2002, when the growth stagnated. The Luleå HT cluster experienced a rapid growth period in the late 1990s, followed by a downturn in early 2000s and a gradual recovery in recent years. In Pisa, the HT cluster experienced a period of growth in 1996–2002, after which the number of HT jobs have remained practically stable despite the slowdown in the ICT sector caused by the dot-com crash. Teräs & Ylinenpää (2008) examine the development of the Oulu and Luleå HT clusters in the period 1998–2007, based on the previous study of Ylinenpää & Lundgren (1998). The examination indicates that the population growth in Oulu has been much greater than in Luleå, and that the relative national importance of Oulu in Finland is still higher than the relative importance of Luleå in Sweden. Moreover, the success of Nokia, although recently with relatively less importance to the Oulu region, has catalyzed a ‘snowball effect’ with e.g. world-class research related to wireless technology, and internationalized experts of Nokia adding value to high technology initiatives even outside Nokia.

There are differences in the accessibility of the case study clusters. The international accessibility of the Pisa region, and the Pisa HT cluster, has improved in the recent years, for example, there is a direct flight connection to New York. Both Oulu and Luleå meet the challenge of international accessibility due to their remote location and inadequate international flight connections.

Based on the findings of this study, Oulu has been able to utilize the ICT upturn, to realize a rapid high technology growth, and reach a critical mass in the ICT sector. Luleå HT cluster has also developed positively in recent years but the ability to fully utilize the high technology potential of the region and to ensure sustainability of the Luleå HT cluster in the case of new downturn periods is an ongoing challenge. In Pisa, the HT cluster includes several elements of critical mass especially in the field of research but the Pisa HT cluster has not fully utilized the strengths of the HT cluster partly due to the inability to coordinate the resources and implement joint actions to nudge the Pisa HT cluster on to a higher level.
The key findings of the study compared against the cluster theory are presented as follows.

**Regional science-based clusters are not isolated entities but are increasingly connected to the external environment.** The importance of external, or global, pipelines has increased in recent years especially in the high technology sectors, forcing the regional science-based clusters to perform not as “local ecosystems” of isolated entities but as co-operation units closely connected to external sources of new information and markets. The internal structure of the regional science-based cluster needs to be increasingly integrated into the external linkages of the cluster. The findings of this study are supported by the regional cluster literature, e.g. Bathelt et al. (2002), Wolfe & Gertler (2004), and Laestadius (2007). This study reveals the increased pace of the development of external linkages in regional science-based clusters in the last few years.

The illustration of the structure of regional science-based cluster as presented in the literature on clusters needs to be refined. Based on the empirical findings of this study, the presentation of the structure of the regional science-based cluster needs more options or alternative ways of presenting the cluster structure, such as additional categories of actors, and the breakdown of categories into subcategories. Furthermore, more emphasis should be put on identifying even hybrid categories of clusters. Instead of illustrating the IFCs as a central and dominant category of actors, companies should be the core element of a regional science-based cluster. The criticism by the informants in this study of the (often public-sector driven) IFCs indicate that the IFC type of support, although necessary, is not often organized effectively in regional science-based clusters.

The analysis of the dynamic evolution of regional science-based clusters supports the cluster life cycle concept – but each cluster has a story of its own. The empirical evidence of this study supports the life cycle model describing the dynamic evolution of the regional clusters, including various life cycle stages (e.g. DTI 2004). The study also supports the theory of the possible transformation of the cluster (e.g. Wolters 2003) instead of being predestined to decline and finally disappear after the maturation of the cluster (Pouder & St. John 1996). However, the detailed paths of evolution of the regional science-based clusters vary significantly as indicated by this study. Each cluster has its own historical setting and specific circumstances. The finding is supported by Tödtling & Trippel (2005) who claim that it is misleading to conclude that innovative activities
required to secure competitiveness are the same in all kinds of areas. The current literature on cluster life cycles concentrates largely on describing the evolution of the cluster over time as an aggregate. This study suggests that more emphasis should be given to the analysis of the components of the clusters instead of the analysis of the overall cluster life cycle. The analysis of the aggregate overlooks a lot of information regarding e.g. promising individual technologies and innovations which can experience a positive, upward trend sometimes during an overall downturn of the cluster. Moreover, the present cluster life cycle research, especially the research on high technology clusters, should pay more attention to the information provided by organizations working intensively with the market information, e.g. the Gartner Hype Cycle presented earlier in this thesis.

**Critical mass plays an important role especially in the development of regional science-based clusters in non-metropolitan regions.** Firstly, the population size sets the limits. It is sometimes difficult or impossible to find the human resources needed to implement the rapid growth in the non-metropolitan regions despite the proper choices of technologies and businesses. Secondly, the insufficient amount of core resources in regional science-based clusters increases the risks of missing the positive development. For example, a university with only few top researchers may be hit hard in the case of top experts leaving the region. The cluster may also face the risk of losing promising growth companies at a very early stage to other, bigger regions, if the company senses that the non-metropolitan cluster and region cannot provide the resources and support functions needed. This study suggests also the concept of optimal size of the HT cluster and region, i.e. reaching the critical size of the HT cluster but avoiding the problems related to metropolitan HT clusters.

**The development of regional science-based clusters not only relates to scientific and technological capabilities but also to aspects related to interpersonal and inter-organizational relationships, leadership, and strategic management.** The scientific and technological capabilities are the natural cornerstones of regional science-based clusters. Based on the analysis of this study, the development of the regional science-based clusters is, however, closely related to several other aspects such as interpersonal and inter-organizational relationships and strategic management. The social capital, the local buzz, and the ability to coordinate the resources of the regional science-based clusters have played – and still play – an important and complementary role together with the external linkages of a regional cluster. The findings of this study indicate that the leadership of the regional science-based clusters is related to the stage of the
cluster, a finding supported by e.g. Westerberg et al. (2007). Strong individuals are most needed in the emerging phase whereas shared leadership is more likely in the later stages of the cluster. This study reveals a current lack of strong cluster leadership in all the case study clusters, probably indicating even more profound changes in the leadership practices of regional science-based clusters. Based on the findings of this study, the regional science-based clusters in non-metropolitan regions may face not only deficiencies in the form of organizational thinness, typical of peripheral regions, but also group thinking resulting in lock-in situations (typical of old industrial regions), and deficiencies related to fragmentation (typical of metropolitan regions). The findings support but also complement the theory of potential deficiencies in regional innovation systems (Tödtling & Trippl 2005), introducing also variations such as the potential “high tech lock-in” situation. Finally, this study identified potential judgmental biases related to the perceptions of the cluster decision-makers on the future cluster development. The case study findings support the applicability of the Mintzberg et al. (1998) theory of judgmental biases to regional clusters.
6 Conclusions

In this chapter, the research process and the findings of this study are evaluated from the viewpoint of the research questions of the study. The theoretical and managerial contributions of the study are discussed, along with the validity and reliability of the study. The chapter also includes a discussion on the future of the regional science-based clusters. Finally, suggestions for future research avenues are made.

6.1 Answering the research questions

The main objective of this study was to provide an improved understanding of the structure and evolution of the regional science-based clusters. The existing knowledge and the empirical data on the research topic were presented and evaluated. The major research task of this study was to test the relevance and applicability of specific parts of the regional cluster theory to three non-metropolitan industrial and scientific concentrations in Finland, Sweden, and Italy. The following analysis summarizes the research work from the viewpoint of the research questions RQ1 and RQ2 in this study.

RQ1: How can the structural characteristics of regional science-based clusters be understood?

In this study the literature on the structural characteristics of clusters was reviewed especially from the point of view of the regional science-based clusters, and was followed by a presentation of the empirical data. The analysis of the cluster structure in this study focused on the following sub-questions:

- How are the regional clusters structured?
- What kind of main elements of regional clusters can be identified?
- What are the specific features related to regional science-based clusters?

The literature analysis identified the term “regional science-based cluster” which described also the target group of the empirical part. The descriptions of Sölvell et al. (2003) and Andersson et al. (2004) of cluster structure were used as the point of departure for the empirical part. In this study, internal co-operation and competition, social capital and trust, leadership, and internal vs. external linkages were chosen as the key structural cluster elements. The empirical analysis of the
structural characteristics of regional science-based clusters to a large part supported the cluster theory presented in Chapter 2. There were, however, some interesting elements disclosed in the findings of the study such as e.g. the role and the importance of the IFCs, the somewhat diluted internal co-operation atmosphere, the nature of the cluster leadership, and the increasing relative importance of the external linkages of regional science-based clusters.

Examples of specific structural features were identified relating to non-metropolitan science-based clusters especially in the Nordic regions e.g. the strong co-operation links between research communities and the companies, even the Triple Helix co-operation initiatives, and the relatively high level of co-operation and trust between cluster actors, especially among the technical experts.

The issue of the comparability of the structural characteristics of regional case study clusters was also raised by the research question RQ1. There were several similarities between all the case study clusters, such as e.g. the challenges in transforming the research know-how more efficiently into commercial products, the weak role of the IFCs, and the current lack of cluster leadership. The major differences included the different identities of the regional science-based clusters, the differences in the scope or variety of the clusters, and the differing abilities of the HT clusters to engage in co-operative actions.

In conclusion, the study was able to provide answers to the first research question, RQ1, in this study.

**RQ2: How can the dynamic evolution of regional science-based clusters be understood?**

The evolution of the regional science-based clusters over time was the main focus of the second research question, RQ2. In the study the literature on the dynamic evolution of clusters was reviewed especially from the point of view of the regional science-based clusters, followed by an empirical data. The analysis of the evolution of a dynamic cluster focused on the following sub-questions:

- What kind of models and concepts of the dynamic evolution of clusters can be identified?
- What kind of special characteristics of the dynamic evolution of regional science-based clusters can be identified?

The study also identified and analyzed the features of the dynamic evolution of non-metropolitan clusters.
The cluster life cycle theories were studied, such as e.g. the cluster life cycle model, the issues of different stages and the question of the possible transformation vs. pre-determination of the cluster evolution. The empirical part of the study focused on the analysis of the dynamic evolution of three regional science-based clusters in Oulu, Luleå, and Pisa.

The cluster life cycle study did not prove to be a straightforward analysis of an aggregate cluster, only. The findings of the study suggest that the case study clusters include companies and other cluster activities with different life cycles. A macro-level analysis of the aggregate of the regional cluster only would not have provided the variety of activities and their life cycles. While the findings largely supported the life cycle evolution of clusters by the cluster theory, the empirical data presented additional findings related to the development trajectory of regional science-based clusters, such as e.g. the possibility of an additional life cycle round.

The study identified special characteristics of the dynamic evolution of regional science-based clusters. Critical mass proved to be one of the key issues in analyzing the dynamic evolution. Moreover, interesting variations complementing the current literature on clusters were identified regarding the concepts of organizational thinness, lock-in, and even fragmentation in non-metropolitan science-based clusters.

The issue of comparability of the dynamic evolution of regional clusters of the three case study regions was the final focus of the research question RQ2. There were similarities between all the case study clusters such as e.g. a rapid growth of high technology related jobs especially in the 1990s. Differences were also identified, such as the role of the locomotive company in the developing stages of the cluster, and the different abilities of the case study clusters to replace job losses caused by e.g. the downturn of ICT jobs in the early 2000s, and differences related to the concept of the critical mass.

To conclude, the study of the dynamic evolution of regional clusters in the three case study regions provided answers to the second research question, RQ2, in this study.

Finding answers to the research questions RQ1 and RQ2 enabled the researcher to reach the target of gaining a deeper understanding of regional clusters, especially regional science-based clusters.
6.2 Contribution of the research

Theoretical contribution

The major research task of this study was to test relevance and applicability of specific parts of the regional cluster theory. The evidence of the study largely supported the theory on regional clusters introduced in the theoretical part of the study. The study was, however, able to suggest new ideas and modifications to the current knowledge on regional science-based clusters.

It has been shown in this study that, in order to gain a deeper understanding of regional science-based clusters, an efficient research approach should combine data from various sources and not rely too much on the general, aggregate cluster data only. With the choice of implementing a multiple-case study, instead of single-case study, the characteristics and challenges of the regional science-based clusters can be illustrated in a way not possible with single-case study.

The multiple-case study approach of this study provided added value to the literature on clusters, enabling a comparison of the structure and dynamic evolution of three regional science-based clusters in different innovation environments, different countries, and different cultures. The research settings and the selection of the case study clusters of this study are unique; according to the knowledge available to the researcher, the previous literature on regional clusters does not include a comparative multiple-case study of the nature of this study. The multiple-case study also assists in filling the research gap between extensive cluster studies deploying official statistics and the single-case studies (Cumbers & MacKinnon 2004). Moreover, the longitudinal approach, taking into account a longer time period and study of the cluster life cycle at different stages, provides value added elements to the literature on regional clusters dominated by ‘snapshot’ studies of clusters. This study did not concentrate on success stories only, thus avoiding the potential trap described by e.g. Cooke & Piccaluga (2004).

The Sölvell et al. (2003) notion of a regional cluster used in this study, being more comprehensive than e.g. Porter (1998a) cluster or the cluster concept as a subsystem of RIS concept presented by Cooke et al. (2007), provides a slightly different approach to regional clusters, thus enriching the research literature on clusters. This study suggests modifications to the presentation of the regional science-based cluster structure, including e.g. the possible addition of more categories of actors, and the breakdown of categories into sub-categories. The case analysis of main structural elements provided valuable insights especially
regarding the internal and external linkages of the regional science-based clusters, emphasizing the role of external linkages, or global pipelines, and supporting the Bathelt et al. (2002) theory.

The analysis of the dynamic evolution of clusters revealed the importance of studying clusters not as an aggregate, but at the cluster component level. The issue of critical mass was highlighted, and the concept of the optimal size of the cluster was suggested. The study provided more in-depth analysis of the dynamic evolution and potential innovation deficiencies related to non-metropolitan science-based clusters, also suggesting variations to traditional lock-in typology.

**Managerial contribution**

The multiple case study approach of this study was welcomed in all three case study regions. The importance of international benchmarking was emphasized especially in the Pisa region. The scope of this study – covering science-based regional clusters in non-metropolitan regions with a population of less than 500,000 people – was also appreciated as well as the rare combination of regional science-based clusters in Finland, Sweden, and Italy as case study objects. The comparison of science-based regional clusters in different innovation environments, even in different cultures, is also one way of demonstrating the dual nature of the regional science-based clusters regardless of location. In practice nowadays, the regional and local work environment is continuously connected to an international, even global innovation system, affecting every component and every decision-maker in the regional science-based clusters.

The informants of the study, most of them cluster decision-makers and/or representatives of the cluster interest groups, welcomed the possibility of discussing the clusters with the researcher. The in-depth interviews provided the decision-makers with a forum to think aloud, to focus on the strategic issues of the cluster development, and to find a forum to compare their cluster experiences with other regional clusters. Furthermore, the perceptions of these cluster decision-makers e.g. regarding the future of the clusters are likely to be of interest to many cluster practitioners.

One of the key managerial contributions of this study is the usefulness of the data to running, monitoring, and analyzing regional clusters. The managerial contributions of this study include updated data on regional science-based clusters in three regions. There are several earlier studies available on these clusters, e.g. Oulu high technology development has previously been studied by several
researchers but the pace of development in international business and technology development is so intense that updated information is always welcome. Furthermore, the importance of international contacts and networks is constantly increasing which increases the need to know more about business environments in other places, and beyond the borders of one’s own country. Clusters have been one of the major policy instruments in recent years, and the decision-makers appreciate reliable information and analysis on their own clusters.

The purpose of the study is neither to serve as a guidebook of managing regional science-based clusters nor to provide a ‘recipe for success’ to cluster practitioners or policy makers. The study illustrates the nature and characteristics of three European regional science-based clusters by using a multiple-case study approach, so that the cluster practitioners, as well as the researchers, are able to reflect their own experience of regional clusters to further develop their skills and experience of regional science-based clusters.

6.3 Validity and reliability

Yin (1994) presents four tests to ensure the quality of case study research:

- Construct validity (establishing correct operational measures for the concepts being studied)
- Internal validity (establishing a causal relationship, whereby certain conditions are shown to lead other conditions)
- External validity (establishing the domain to which a study’s findings can be generalized)
- Reliability (demonstrating that the operations of a study can be repeated, with the same results).

Construct validity can be met by the use of multiple sources of evidence. This study has used documents, archival records, interviews, direct observation, and participant-observation as sources of evidence. Feedback was given by several informants on the relevant summaries of the collected data. The validating procedures also include presentations at international conferences providing comments and suggestions by the conference participants regarding the research issues (Teräs 2007, Teräs & Kess 2007, Teräs & Lehtimäki 2007).

Yin (1994) states that that the internal validity can be extended to the broader problem of making inferences. The inferences have to be correct and all the rival explanations and possibilities should be considered. This study involved a number
of decision-makers, researchers, and other experts in all three countries and the supervisor of the study with whom the research findings, rival explanations, and possibilities were discussed.

The test of external validity deals with the problem of knowing whether a study’s findings are generalizable beyond the immediate case study. Cortright (2006) states that the generalizability of the findings from qualitative, bottom-up cluster case studies are “narrowly limited.” Bresnanan & Gambardella (2004) state that the “recipe approach” of high technology clusters, lumping science and technology research, education, skilled labour, and universities together in a single idea, overlooks alternative mechanisms for achieving a skilled labour pool, and stress that e.g. a university per se is not essential to the emergence of a successful cluster. Yin (1994) notes that it is difficult to generalize from one case to another. According to Yin, analysts fall into the trap of trying to select a “representative” case or set of cases. Yin advises researchers not to generalize to other case studies but to generalize findings to a theory.

In this study, the three cases have several things in common but also a lot of differences in the cluster structure, dynamics and the evolution of the cluster over time. The universal “recipe” approach to design and implement regional science-based clusters is not supported by this study. Every regional cluster is unique but there are certain common features for comparison against the regional cluster theory.

The final test of the quality of the research is reliability: if a later researcher followed the same procedure as described by the earlier researcher and conducted the study all over again, would the researcher arrive at the same findings and conclusions? In this study, the reliability is ensured by accurate documentation of research including recorded interviews, questionnaires, and proper compilation of the research data. The selection of the informants is a potential source of variation regarding the information collected. Each interview is unique making it impossible to obtain the exact same data with different informants. The interviews did, however, provide information about the units of analysis that the researcher could interpret in a coherent way. The snowball method applied to limited groups of decision-makers and experts – as in the case of regional science-based clusters – is likely to result in the selection to a large extent of same people independent of the selection of the first experts to be interviewed. The information gathered from the interviews reached saturation in all three case study regions; i.e. additional interviews would not have provided any significant new information from the viewpoint of the research objectives. The mix of languages used in the interviews
carries a potential source of misunderstandings. However, the interviews were carried out face-to-face, and the same information was requested in different forms when possible, thus ensuring that the interpretations of the researcher really represent the opinion of the informant.

The job assignments of the researcher in the Oulu and Luleå regions in the 1990s and 2000s may raise the question of the researcher’s objectivity with respect to the Oulu and Luleå cases. However, the role of the researcher – arising from job assignments in both regions – has been the role of expert, with the conscious aim of collecting objective results. The results of this study are based on the interviews of local decision-makers and the additional material provided by other sources of information, thus enabling a triangulation of the information. The case setting and selection is described in detail, as well as the data collection and analysis. A relatively high number of quotations from the informants in the study increase the reader’s possibility of sharing in the atmosphere of the interviews. All of these actions were carried out with the utmost care.

6.4 The future of the regional science-based clusters

This study aimed to provide an improved understanding of the structure and evolution of regional science-based clusters. After analyzing the findings of the case study clusters, it would be worthwhile to examine the more general issue of the role and importance of the regional science-based clusters as instruments of economic and industrial development.

Regional clusters aim to provide a platform, the way to compete globally with specific regional resources as a stock of ‘sticky’ knowledge, in order to overcome the risk of being out-competed (Isaksen 2005). Regional science-based clusters rely heavily on strong R&D activities and technology generators. The nature of the knowledge-intensive industries and services in the world of today is, however, deeply affected by globalization. Even the ‘stickiest’ stock of knowledge is likely to become rapidly outdated without an intensive global search of the latest know-how and expertise. In this sense, it is pertinent to ask: what is the future of regional science-based clusters?

Based on the findings of this study, the competitive advantage can be maintained and developed further also in non-metropolitan regions. This requires, however, the acceptance of global thinking and global work methods. The regional science-based cluster, in order to stay competitive, needs constant renewal extending to all the major categories of actors. The most advanced
companies and research organizations have already accepted the global way of thinking and acting. The public sector, especially the municipalities and regions, and the SMEs sometimes lag behind in introducing work methods and processes needed in global competition.

The regional decision-makers, especially in non-metropolitan regions, might argue that globalization leaves no space for smaller regions without all the resources available to, for example, the capital regions. However, even the world-class high technology companies are ready and willing to invest in regions far away from major international marketplaces if the conditions are right. As Mr. Olli-Pekka Kallasvuo, the CEO of Nokia, put it (Kaleva 2007d): “I don’t accept at all the argument that Oulu and Finland have no chances in the global economy. On the contrary, Finland has good chances if we concentrate in our strengths and do right things even better than today.”

What are, then, the ‘right things’? As discussed earlier, the term “innovation” means doing something new. According to Hospers (2005), the regional high-tech cluster policy has become trendy due to the EU-driven propagation of ‘best practices’, such as Silicon Valley in the US and the Oulu phenomenon in Finland. Hospers claims that in the European-wide innovation race most regions target similar activities, with the support of public authorities, the consequence being that nearly all of them back the development of information, bio and nanotechnology clusters. The European-wide high tech policy is, thus, fostering excessive investment or duplication in the same technologies. Hospers states that regions, investing in similar technologies and copying ‘best practices’, undermine their potential competitive advantage. Bellini & Landabaso (2005) state that regional innovation policies have suffered from the ‘best practice’ syndrome. Porter (2008) adds that the prosperity of regions comes from being different from the other regions, searching for distinctive capabilities rather than homogenizing or harmonizing the regions.

The findings of this study support the argument of regions having a tendency to imitate the ‘best practices’ of other regions with science-based clusters. The findings of this study suggest that cluster decision-makers should not imitate other regions, but should combine the information from other regional science-based clusters with the existing, cumulated cluster know-how in the region – to create new possibilities for advanced cluster concepts.

An issue related to innovation policy in Europe, having an effect on regional science-based clusters, is the weakness of “knowledge entrepreneurship” (Cooke 2007). Europe, more familiar with the IRIS, or Institutional Regional Innovation
System, has not been able to produce the desired output in the form of growth-oriented high technology companies and entrepreneurship in spite of significant investments into a research infrastructure. The findings of this study indicate that the European science-based clusters and regional innovation systems have the tendency to prioritize research and education at the expense of marketing and sales resources and skills. Therefore, the logical remedy would be to increase the market-focused elements of the ERIS, or Entrepreneurial Regional Innovation System, in Europe.

6.5 Suggestions for further research

Some of the theoretical issues related to regional science-based clusters highlighted in this study deserve further research. The definitions related to regional clusters and regional science-based clusters should be further clarified; the cluster terminology should provide a more solid base for the analysis of clusters. The relation between clusters and innovation systems deserves further research, especially the increasing external links “threatening” the traditional view of regional clusters and regional innovation systems. Regarding the structural characteristics of the cluster, the cluster leadership – or lack of leadership – is one of the research areas deserving more attention. Also, the cluster life cycle theory would deserve refining when it comes to splitting the evolution of aggregate clusters over time into the evolution paths of the cluster components. The concept of “optimal size” relating to the non-metropolitan regions, introduced in this study, deserves further attention and research. The issues of judgmental biases in the strategic management of clusters would be an interesting area of further research, too.

The qualitative multiple-case analysis of this study could be complemented by a quantitative case study with the same units of analysis. Also, a qualitative multiple-case study of regional science-based clusters could be implemented in different case study regions. An additional case study concentrating on only one or some of the key categories of cluster actors, e.g. companies only, would provide yet another viewpoint to further sharpen the picture on regional science-based clusters.

The findings in this study also suggest organizing a systematic, high quality data collection and analysis procedure to provide coherent and reliable information on the development of regional science-based clusters. This study highlights the rapid change in the globalisation of the high technology markets.
and its effect on regional clusters, putting the pressure on the research on regional cluster data to be as up-to-date as possible. The data collection procedure developed by Scuola Sant’Anna Observatory in Pisa (Osservatorio 2007) would be an excellent point of departure for a joint effort e.g. between Oulu, Luleå, and Pisa regions, to set up a pilot system.
References


Bellini N & Landabaso M (2005) Learning about innovation in Europe’s regional policy. IN-SAT working paper 03/2005 Pisa

Bergman E (2005) Sustainability of Clusters and Regions at Austria’s Accession Edge. Department of City and Regional Development, Vienna University of Economics and Business Administration. SRE-Discussion 05/06.


Appendix 1 List of informants

The following tables present the list of interviews in Oulu, Luleå, and Pisa in alphabetical order. The citation numbers in the text (e.g. O8, L4, P6) refer to the informants in chronological order, e.g. O8 refers to informant in Oulu who was interviewed as no 8 by chronological order.

Table 32. Informants in Oulu.

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elsilä Martti</td>
<td>Director, Technopolis Ventures Ltd</td>
<td>IFC</td>
</tr>
<tr>
<td>Frederiksen Ilkka</td>
<td>Director, Oulu Innovation Ltd/ Multipolis (retired in 2007)</td>
<td>IFC</td>
</tr>
<tr>
<td>Jakkula Olavi</td>
<td>Planning Manager, University of Oulu</td>
<td>Research</td>
</tr>
<tr>
<td>Karpinnen Martti</td>
<td>Partner, MConPartners Oy</td>
<td>IFC</td>
</tr>
<tr>
<td>Kivelä Jorma</td>
<td>Director, Jutron Oy</td>
<td>Companies</td>
</tr>
<tr>
<td>Lammasniemi Jorma</td>
<td>Director, VTT</td>
<td>Research</td>
</tr>
<tr>
<td>Lukkari Olli</td>
<td>Program Director, Oulu Innovation Ltd</td>
<td>IFC</td>
</tr>
<tr>
<td>Pudas Heikki</td>
<td>Director, City of Oulu</td>
<td>Government</td>
</tr>
<tr>
<td>Viim Toivo</td>
<td>Managing Director, OBN Oy</td>
<td>Financial Institutions</td>
</tr>
<tr>
<td>Virtanen Esko</td>
<td>Programme Manager, TEKES</td>
<td>Government</td>
</tr>
<tr>
<td>Yliniemi Ilkka</td>
<td>Director, Council of Oulu region</td>
<td>Government</td>
</tr>
</tbody>
</table>

Table 33. Informants in Luleå.

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hedlin Johan</td>
<td>Director, Internet Bay</td>
<td>IFC</td>
</tr>
<tr>
<td>Jangdal Susanne</td>
<td>Luftfartsverket (Aurorum Science Park until 2007)</td>
<td>Government/IFC</td>
</tr>
<tr>
<td>Larsson Åke</td>
<td>Linteum AB (Previously Aurorum Science Park)</td>
<td>Companies</td>
</tr>
<tr>
<td>Nilsson Thomas</td>
<td>Managing Director, LNAB</td>
<td>IFC</td>
</tr>
<tr>
<td>Petersen Karl</td>
<td>Mayor, City of Luleå</td>
<td>Government</td>
</tr>
<tr>
<td>Ruuth Staffan</td>
<td>Managing Director, Avantra AB</td>
<td>Companies</td>
</tr>
<tr>
<td>Rörling Ola</td>
<td>Director, Norrbotten County Council</td>
<td>Government</td>
</tr>
<tr>
<td>Sundvall Hans</td>
<td>Managing Director, Pemenco AB</td>
<td>IFC</td>
</tr>
<tr>
<td>Söderström Lars-Olov</td>
<td>Director, Norrlandsfonden</td>
<td>Financial Institution</td>
</tr>
<tr>
<td>Ylinenpää Håkan</td>
<td>Professor, LTU</td>
<td>Research</td>
</tr>
</tbody>
</table>
### Table 34. Informants in Pisa.

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bianchi, Giuliano</td>
<td>Professor, University of Siena</td>
<td>Research</td>
</tr>
<tr>
<td>Ciangherotti, Michela</td>
<td>Cabinet member, City of Pisa</td>
<td>Government</td>
</tr>
<tr>
<td>Dario, Paolo</td>
<td>Professor, Scuola Superiore Sant’Anna/Polo Valdera</td>
<td>Research</td>
</tr>
<tr>
<td>Donato, Luigi</td>
<td>Professor, CNR Pisa</td>
<td>Research</td>
</tr>
<tr>
<td>Gentile, Monia</td>
<td>Scuola Superiore Sant’Anna /Technology transfer</td>
<td>IFC</td>
</tr>
<tr>
<td>Giari, Alessandro</td>
<td>President, Polo Navacchio</td>
<td>IFC</td>
</tr>
<tr>
<td>(Assisted by Epifori,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elisabetta)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guardati, Maria</td>
<td>Senior officer, Assefi</td>
<td>Financial Institutions</td>
</tr>
<tr>
<td>Motto, Silvano</td>
<td>President, Yogitech SPA</td>
<td>Companies</td>
</tr>
<tr>
<td>(Assisted by Orlandi,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gabriele)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piccaluga, Andrea</td>
<td>Professor, Scuola Superiore Sant’Anna</td>
<td>Research</td>
</tr>
<tr>
<td>Turini, Graziano</td>
<td>Director of Economic Development, Province of Pisa</td>
<td>Government</td>
</tr>
<tr>
<td>Vitale, Emilio</td>
<td>Professor, University of Pisa</td>
<td>Research</td>
</tr>
</tbody>
</table>
Appendix 2 The interview questions, summary

The relation of the interviewee to the case study region
- in function of time
- current position

The structure and the key actors of the regional technology cluster
- comparison to Andersson et al. (2004) figure
- the roles
- regional/local vs. national authorities
- strongest ties (name)
- the major stakeholders (name)
- clustering initiatives in the region
- key individuals of the HT cluster (name)
- own organisation contributions/gains (name)
- co-operation, competition, trust (describe)
- role of technology centres (describe)
- what is NOT functioning?
- regional HT cluster and the Porter (1998a) cluster definition

Life cycle
- at which stage is the regional HT cluster (embryonic, established, mature, decline)
- how well does the life cycle model of DTI (2004) fit into the HT cluster development in the region?
- factors affecting life cycle (international, national, regional, local, other)

Perceptions of the future cluster development
- future in your own hands or predestined by global development? (comment)
- actions needed? (comment)
- how are the region and key decision-makers preparing for the future?
- how to prolong positive development stage of cluster cycle?

Other possible issues
Appendix 3 The map

286. Taparuggsangorn, Ataphongse (2007) Evaluation of MIMO radio channel characteristics from TDM-switched MIMO channel sounding

287. Elsilä, Ulla (2007) Knowledge discovery method for deriving conditional probabilities from large datasets


291. Lyöri, Veijo (2007) Structural monitoring with fibre-optic sensors using the pulsed time-of-flight method and other measurement techniques


294. Gore, Amol (2008) Exploring the competitive advantage through ERP systems. From implementation to applications in agile networks


298. Rabbachin, Alberto (2008) Low complexity UWB receivers with ranging capabilities


Jukka Teräs

REGIONAL SCIENCE-BASED CLUSTERS

A CASE STUDY OF THREE EUROPEAN CONCENTRATIONS