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Sauli Eerola

University–Industry Co-operation Using a Practice-based Innovation Tool: Case Advisory Professorship Programme in Materials Technology

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Abstract

In the thesis the usability and effectiveness of a practice-based innovation tool for university–industry co-operation, the advisory professorship model, is evaluated. The research material was collected by applying the tool with a materials technological emphasis in the regional co-operation network in 2008–2012. The inputs, functions and internal dynamics of the innovation environment, as well as the results and effects of innovation activities in the materials technology advisory professorship programme (MTAP) network, are analysed qualitatively using a conceptual framework for the evaluation of regional innovative capability and the Network-Based Innovative Capability (NBIC) matrix.

In the network of the MTAP programme, new practice-based innovation processes, concentrated in practice-based problems and development targets in companies products, operational environment or markets were created. The role of the university was especially in producing of information in the front-end phases of innovation processes, related mostly to properties and processing knowledge of materials, the feasibility of development ideas and in searching of new R&D opportunities. The nature of university based research inputs was typically fast and short-termed. Some innovation processes ended up as new products or product improvements. New knowledge, information and knowledge networks were created. The advisory professorship model can be considered a useful practice-based innovation tool for regional university–industry co-operation with some limitations.

In the thesis the materials technology related regional resources, infrastructure and needs from both private and public sectors are also studied and levels of regional availability, access and delivery options for materials technological research are analysed in the Lahti region. Based on this information, it is suggested how the knowledge, network and innovation system related to materials technology should be developed further by public policies and strategies in the region.

Keywords: Materials research, practice-based innovation tools, regional development, materials technology, university–industry co-operation, innovation environment, innovation capability

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Lahti, May 2014

Sauli Eerola

Supervisor	Prof. Pentti Järvelä Tampere University of Technology Finland
Reviewers	Prof. Jarna Heinonen Turku School of Economics University of Turku Finland
	Prof. Mika Suvanto University of Eastern Finland Finland
	Dr. Kai Syrjälä FIMECC Oy Finland
Opponents	Prof. Jarna Heinonen Turku School of Economics University of Turku Finland
	Prof. Jaan Kers Tallinn University of Technology Estonia

Abbreviations

ABS	Acrylonitrile-butadiene-styrene
CVD	Chemical vapour deposition
DfE	Design for the environment
DMS	Department of Materials Science
EP	Epoxy
FGMs	Functionally gradient materials
HUT	Helsinki University of Technology
HVOF	High velocity oxyfuel
IC	Integrated circuit sector
IPNs	Interpenetrating polymer networks
IPR	Intellectual property rights
LCA	Life cycle analysis
LCPs	Liquid crystal polymers
LSBP	Lahti Science and Business Park
LUAS	Lahti University of Applied Sciences
LUT	Lappeenranta University of Technology
MTAP	Materials technology advisory professorship programme
NBIC	Network-based innovative matrix

NSI	National system of innovation
PA	Polyamide
PC	Polycarbonate
PE	Polyethylene
PEEK	Poly(ether-ether-ketone)
PES	Poly(ether-sulfone)
PET	Poly(ethylene-terephtalate)
PMMA	Poly(methyl-methacrylate)
POM	Polyoxymethylene
PP	Polypropylene
PPSU	Poly(phenyl-sulfone)
PS	Polystryrene
PSU	Polysulfone
PTFE	Polytetrafluoroethylene
PUR	Polyurethane
PVC	Polyvinylchloride
RDPM	Regional development platform method
RIS	Regional innovation system
SHOKs	Strategic Centres for Science, Technology and Innovation
SiO_2	Silicon oxide

SMA	Shape memory alloy
SMP	Shape memory polymer
Tekes	The Finnish Funding Agency for Technology and Innovation
TUT	Tampere University of Technology
UP	Unsaturated polyester

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1 Introduction

The development of materials technology is seen important for future scenarios. It is estimated that nowadays 70 % of all technical innovations depend directly or indirectly on the use and on the properties of materials, and the share is still increasing. Especially nano- and biotechnologies have been in the focus of strategies in the 21st century. The environmental impacts of the production and processing of materials are also becoming more critical. Forecasting the futures of markets and products cannot be accomplished without the knowledge of materials science and engineering. [1-4]

Materials science is a field of study focused on researching the properties, structures, compositions, processing and usability of different materials. The achievements of materials engineering are usually the result of integration with other sciences; it is an interdisciplinary science field by nature. New applications and innovations are developed, for example, in the interfaces with chemistry, physics, process engineering, mechanics, electronics and medicine [2].

There is a lot of mechanical engineering industry and other manufacturing industry in the Lahti region that use and process large amounts of different materials (metals, plastics, wood, etc.). Lahti has a long industrial tradition and the industrial sector employs 18.3 % of the labour (2009) with a turnover of 3.1 billion Euros (2010) [5].

The regional consciousness of the importance of materials and materials technology for the competitiveness of the region can be seen in the regional development work, strategies and research activities. For example, in 1998, the Development Centre of Plastics and Plastics Industry, Muovipoli Ltd, was established in the region with a national focus. In the regional development work, a cluster-based policy was adopted in 2005. Environment, grain, mechatronics, plastics and wood were the clusters identified in the region, later also living and health, and well-being clusters [6; 7]. In the competitiveness and economic development strategy for Lahti region for years 2009–2015, the vision of Lahti region is to be Finland's most business-friendly and environmentally efficient area in 2015, including material and energy efficiency [7]. In the regional plan of Lahti region until 2035, technological megatrends include material technological issues such as nanotechnology and intelligent surfaces and materials [8].

On a larger scale, the emphasis in the regional development and innovation work and strategies shifted towards regional innovation systems and practice-based innovation models in the Lahti region. Practice-based innovation processes underline knowledge transfer from theory to practice and also bringing knowledge from different disciplines into innovation processes [9]. The innovation strategy presented in 2005 diverged from the strategies of other main cities in Finland; in other strategies the development of innovation environment, strengthening of knowledge structure and trust in the power of research activities were the key elements. In the Lahti strategy, the main resources were directed to promoting the linking of the best available knowledge to concrete, firm-based innovation processes. [10] In innovation policies and systems, the role of universities is also changing. In the regional innovation policies universities have been seen as crucial factors and main drivers in building a competitive advantage for a region. In practice-based innovation models, the innovation processes are triggered by practical challenges and needs of the companies rather than by the universities themselves, undermining the role of universities as main drivers of the regional innovation systems. [11]

There are several tools for practice-based innovation processes, which are used in the Lahti region as part of the research work and regional development. One main and most applied tool is the model of advisory professorship. It is a tool to utilize knowledge and expertise of the universities in the regional development work. The aim is to transfer national, high-level research knowledge to regions whose own scientific resources are limited. The advisory professorships are based on the strategic co-operation relationships between regional players and the departments of Finnish or foreign universities, the so called advisory units. A professor of the advisory department is appointed as an advisory professor, whose main objective is to formulate relevant research activities and groups based on the local needs from public and private sectors. [10] Lahti does not have its own university but it has the Lahti University Consortium, which is a network of three Finnish universities.

In 2007, when the professorship of plastics technology of Tampere University of Technology (TUT) was to end, the question arose in the region about the best way to ensure the availability of the scientific knowledge of plastics and materials technology in the region. With the financing of Regional Centre Programme, a study was made of the needs for university based material technological know-how of industrial companies in the Lahti region by the author of this thesis [12]. On the basis of the study, the materials technology advisory professorship programme (MTAP programme) began in 2008 between Lahti region and the Department of Materials Science (DMS) at TUT. The MTAP programme included both local activities in Lahti and activities at the main campus in Tampere. The main regional activities were to coordinate and activate the research and development projects in materials technology and link the resources of the main campus to the region. The development of local activities of TUT in Lahti and co-operation with other universities and research and education organizations with activities in materials technology in the Lahti region were included to the regional tasks. Instead of a single advisory professor, all the professors at DMS in TUT were part of the MTAP model to help companies in materials technology related issues and to create new joint research activities. The programme was financed by the European Union, City of Lahti, Regional Council of Päijät-Häme and companies in years 2008-2013.

1.1 Research problems and objectives of the study

The main objectives of the research are to study and to get information on the materials-technical knowledge, network and innovation system in the Lahti region and the usability of the advisory professorship model as a practice-based innovation tool for regional university–industry co-operation. Furthermore, the research gives information of the applicability, benefits and limitations of practice-based innovation tools and the role of universities in practice-based innovation policies. The role of universities in university–industry co-operation can be approached from two perspectives: from the regional and industrial viewpoint, on the one hand, and from the university viewpoint, on the other. This thesis focuses mainly on the first perspective, looking at the effects of the model on the innovation environment and on concrete innovation processes of companies. However, in the conclusion part its relation to the more traditional activities and strategies of the universities will also be shortly discussed.

As presented in Chapter 3, the development of materials science, engineering and technologies is a key issue in the future development from global, regional and industrial points of view. New materials and technologies can offer remarkable competition advantage especially when adopted in the existing value chains. In low-tech companies, continuous process development can be the most beneficial strategy to give at least temporary advantage in the price competition. Important industries in the Lahti region using and processing different materials are the machinery, plastics, wood, furniture and electrical and electronics industries. Recycling, building and health technology are also present in the region.

The objectives of the research can be reached by setting up two main research questions. The research questions of the study are:

1. What were the main inputs, functions and internal dynamics of the innovation environment and possible results (outputs) and effects of the innovation activities in the network of the materials technology advisory professorship programme (*research question 1, RQ1*)?
2. What are the most important materials, technologies and fields of materials science for the materials processing industries in the Lahti region and how to develop and arrange the materials-technological expertise and innovation system in the Lahti region so that it would serve the region and its needs best (*research question 2, RQ2*)?

Figure 1 shows a schematic presentation of the research area and the scope of the dissertation study. The research field is between materials science and practice-based innovation theories, having its fundamentals in economics, social sciences and innovation system and network theories. The resources and knowledge utilized by the model are mainly derived from the field of materials research and science. This knowledge is made available to the region and its industries with a tool based on practice-based innovation theories.

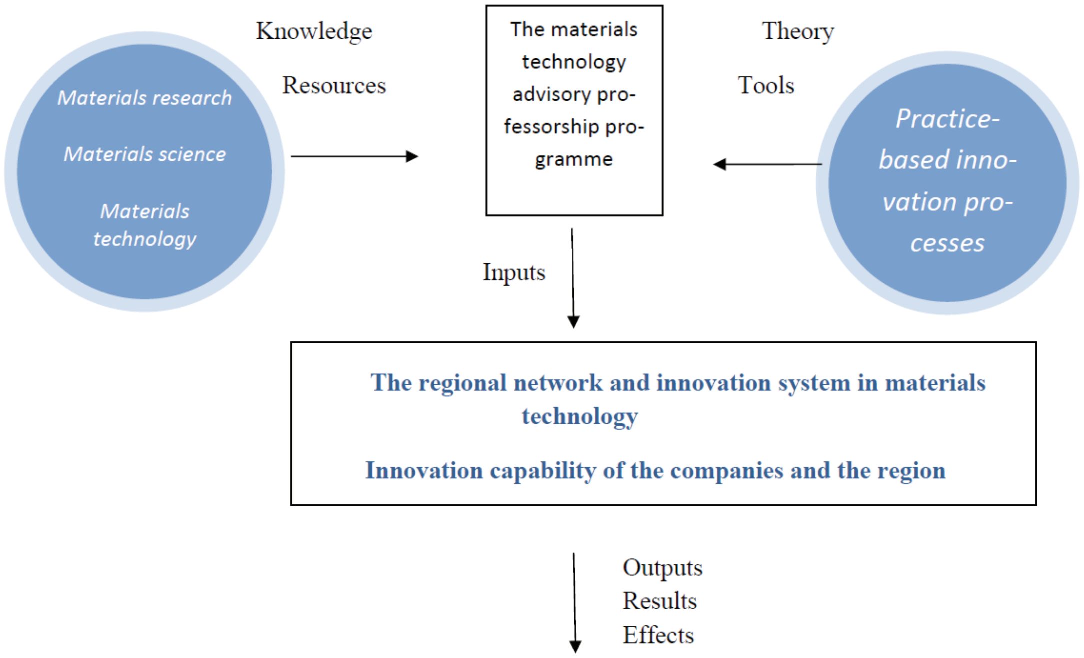


Figure 1. Scope of the thesis.

As an implication of the study, the aim is to find targets for public policies and strategies pertaining to the development work of the regional innovation system in materials technology. The targets will be based on the evaluation of the innovation environment, capability and processes related to the MTAP programme, and information on regional resources, infrastructure, knowledge and needs of both private and public sectors.

1.2 Structure of the thesis

The structure of the thesis is presented in Figure 2 on page 6. The research problems, objectives and the methods of the study are described first in Chapters 1 and 2. The state of the art part includes Chapters 3 and 4. Chapter 3 describes the main engineering materials and their application fields. Materials science and engineering, as well as new materials and technologies are shortly viewed to get an overall picture about the future research fields. The development and current situation of materials and materials technology in Finland are summarized both at industrial and university levels. The sustainable use of materials is also viewed. It is globally becoming a critical factor and also affects strongly the industrial use and processing of materials. In the development policies in the Lahti region, where the experimental part of this dissertation was conducted, the development of the cleantech sector, including material efficiency, has turned out one of the key aims of public development policies and strategies. As part of the continuous process development in industry using materials, resource efficiency has always been important in industrial operations. However, with limited resources and increasing raw material prices, material-efficient processing and use of recycled materials is becoming a more critical factor for the industries in the Lahti region, too.

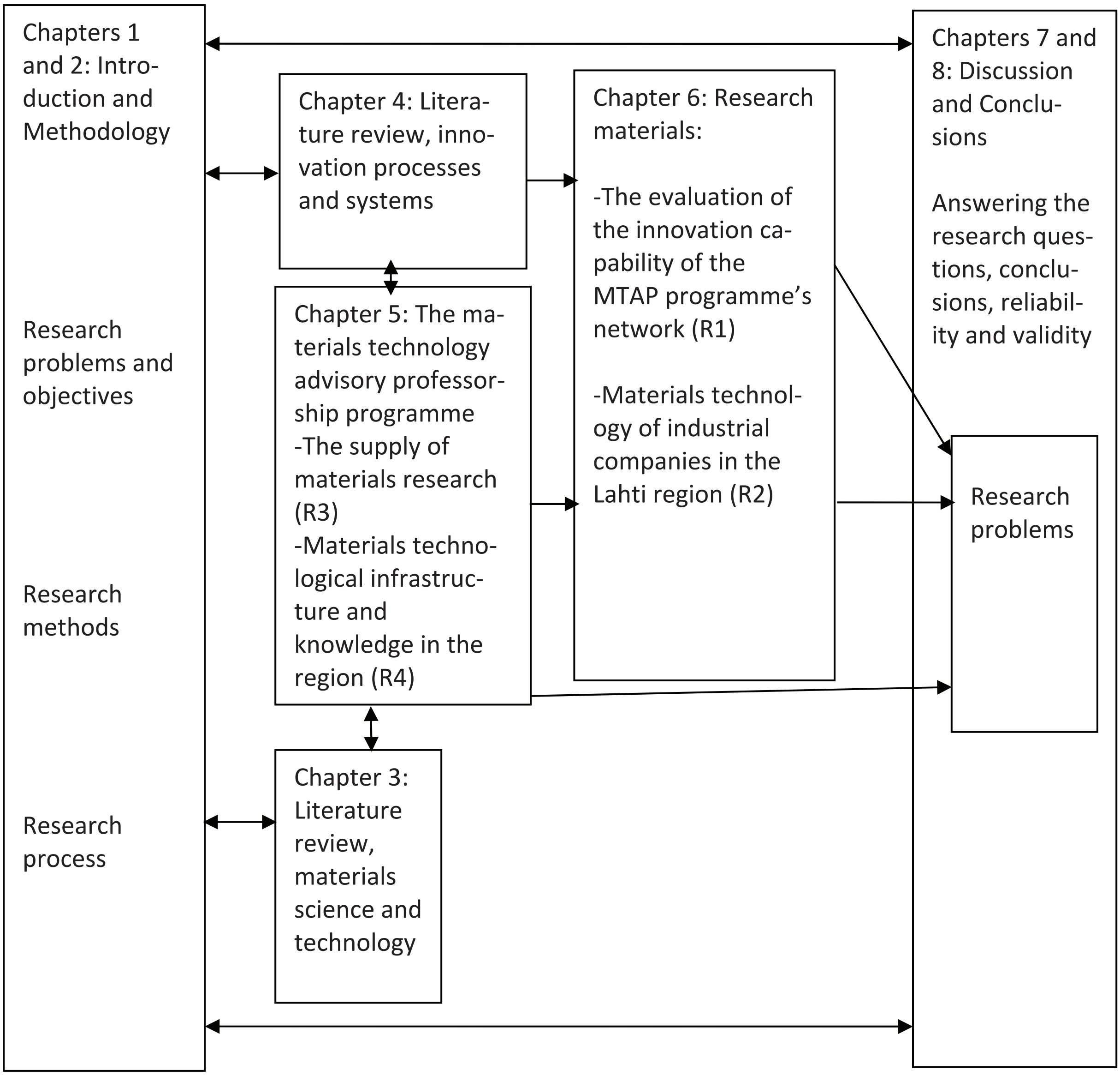


Figure 2. Structure of the thesis.

After the materials technological part, innovation processes and systems, especially practice-based innovation processes and their tools are described in Chapter 4. The background and principles of the advisory professorship tool are explained. The role of universities in the regional innovation policies and university–industry co-operation are viewed. The characteristics and differences of innovation processes in low-tech and high-tech industries are summarized. There is also a chapter about how innovativeness can be and is measured. Two frameworks used in the experimental part of this study for measuring and evaluating the innovation capability are also presented and explained in this chapter more precisely.

The advisory professorship programme in materials technology is presented in Chapter 5. It presents the planning and building up processes of the MTAP programme, followed by a detailed description of the main tasks and aims of the programme. The main activities in university–industry co-operation and regional development are viewed. In Chapter 6, research materials concerning innovation environment of the MTAP programme and the materials technologies for industrial companies of Lahti are presented.

Chapter 7 is the discussion part. First, the innovation capability and effectiveness of the MTAP programme is analysed, followed by an analysis related to the development of the regional innovation system in materials technology.

After the analysis, the reliability and validity of the research is discussed. The conclusions are given in Chapter 8. After the conclusions, recommendations for further research are given.

2 Methodology

The philosophical backgrounds of scientific research are typically divided into hermeneutics and positivism. Whereas positivism (objectivism) searches for objective findings and truth, in hermeneutics (relativism, subjectivism) the focus is on understanding the phenomena and reality through subjective ways [13]. The qualitative research methodology represents mainly the hermeneutical and the quantitative methodology the positivistic research approach [14]. In case studies, both quantitative and qualitative research methods can be used to give information of the phenomenon or behaviour of the research object. This thesis represents the qualitative research methodology, although it also includes some quantitative parts.

2.1 Research methods

The research methods of the thesis are presented in Table 1 on page 11. Most of the empirical data and materials will be based on two research interviews of the companies that participated in the materials technology advisory professorship programme during 2008–2012 or in the planning process of the programme. These two interview rounds provide empirical data for both research questions and constitute the primary research materials. All the research interviews were made by the author. Structured interviews are a widely used quantitative research method, but they can also be used in qualitative research. [15]

The first research interviews were made in 2007. These structured interviews were also the basis for launching the MTAP programme in 2008. In the study the main materials and fields of materials technology and demand for materials research in fifteen large international industrial companies in the Lahti region were examined (R2). The structured form used in the study is illustrated in Appendix 1. The first interviews gave information about the priorities and importance of materials to the companies and what materials technology related research services the companies had utilized and were going to use in the future, as well as the possibilities and challenges of materials technology related research in the future. The companies’ interests to invest in materials technology related research or development activities in the future were also examined. This research material is analysed with two methods. In thematic analysis, the challenges and opportunities for materials technology are analysed through the focus areas of regional development. The other analysis is based on theories of the regional effectiveness of universities. Interdependencies of companies and their environment can be categorized in terms of traded and untraded interdependencies in a local context [16]. This mechanism based approach can also be used in analysing the dynamics of the regional effectiveness of universities [17]. The delivery and accessibility of materials technological knowledge were used to represent the traded mechanisms of regional effectiveness of universities. Untraded mechanisms included all activities and resources already existing in the region. The feature evaluated was the level of functioning of the mechanisms.

In addition to the demand for materials research, the other part of the preparation of the programme was to chart and analyse the regional supply of academic and applied materials technology related research and to make suggestions on how to organize it best for the regional needs. In the Lahti region, there were two universities and one polytechnic with research in the materials technology. The universities were TUT and Helsinki University of Technology (HUT), today known as Aalto University. The polytechnic was the Lahti University of Applied Sciences (LUAS). The competences of these organizations were divided into materials based and research field based knowledge areas. The competences were analysed by cross-tabulation with the industrial needs (R3). Information from this analysis was also used as secondary research material in the analysis of availability, access and delivery of materials technological research. The MTAP programme was built in 2008 on the basis of the information produced by both of these study parts (R2 and R3). The novelty and the main difference of the MTAP programme compared with previous advisory professorships in a region was that the whole department with its professors and researchers were participating in the model, instead of one single professor. The budget and length of the MTAP programme were also larger than in the previous applications of the tool. The portion financed by the companies was also remarkably bigger than in other applications. The level of co-operation with industries was built-in in the project plan in great detail. The actual effects and networks of the tool had not been evaluated previously, though University of Helsinki, Aalto University and Lappeenranta University of Technology (LUT) had held advisory professorships in the region. The main aims, tasks and operational model of the MTAP programme were planned and agreed with TUT, Lahti Science and Business Park (LSBP), Muovipoli Ltd and industrial companies to enable the utilization of materials technology related knowhow of the DMS of TUT. It was based on two main operational areas: regional activities and the activities of DMS at TUT.

The second interview round was performed in autumn 2012 (R1). The main aim of the study was to give information of the innovation environment and capability of the MTAP programme network and the results of the model. The innovation environment was analysed by measuring the innovation resources, institutional setup and internal dynamics of the innovation network related to the MTAP programme. In addition to these innovation capability measures, the intermediate and proper results (outputs) were measured. The outputs of innovation activities are e.g. new intellectual property rights (IPR), new products or services, process improvements and effects on turnover or profits. The questions of part two were formed through two theoretical frameworks; a *conceptual framework for the evaluation of regional innovative capability* (Figure 6, p. 81) and the framework of *the Network-Based Innovative Capability (NBIC) evaluation matrix* (Table 11, p. 82), developed by Tura *et al.* [18]. The questions concerned, for example, the social and cultural characteristics of the co-operation network, the nature of produced information, actual tools and activities of co-operation, and the new innovation process created. Information of the other activities and processes created through the MTAP programme, like the number and budgets of the R&D projects planned and started, the number and issues of technological pre-studies, the number of other research processes started, the arranged seminars, etc. are also summarized in Chapter 5. The answers were analysed using theory-based content analysis with the NBIC matrix. Three sub-dimensions of innovation capability: openness or creativity, knowledge or expertise, and operationalization capability were evaluated. Background information and the materials technological profiles of the interviewed companies were also examined with questions concerning the use of materials, importance of materials technology and demand for materials research in companies. The summary of the research materials and methods are presented in Table 1.

Table 1. Summary of research materials and methods.

Research material	Code	Date	Method	Analysis method
Evaluation of the innovation environment (Primary)	R1	9-10.2012	Structured Interviews	Theory-based content analysis
Materials technology in industries in the Lahti region (Primary)	R2	3-4.2007	Structured interviews	Quantification Thematic analysis Theory-based analysis
Supply of materials research (Secondary)	R3	3-4.2007	Literature study	Cross-tabulation
Materials technological infrastructure and knowledge in the region (Secondary)	R4	6-9.2009	Literature study Survey	

The TUT DMS also participated in the regional development work of materials technology in the Lahti region, as defined and agreed in the project plan of the MTAP programme. Activities of two such development processes and the main results of the research reports are utilized in Chapters 3 and 5. The first process, described in Chapter 5.1, was concerning the infrastructure and expertise in materials technology and efficiency in the Lahti region [19]. The main findings of the study (R4) are utilized in this thesis to give secondary information to the research problem 2 and in the analysis of the delivery, access and resources of materials research in the region. There were three main objectives and stages of the study. The first stage was to chart expertise related to materials technology and material efficiency nationally and establish the position of Lahti in the national framework by means of a literature study. The second stage was to chart the infrastructure in the Lahti region related to materials technology and efficiency by means of a survey. The third stage was to define an operational model for its efficient use. The main results of another process in the regional development work are included in Chapter 3.7 [20]. It was connected to implementing the competitiveness and economic development strategy for the Lahti region for years 2009–2015 and to the planning process of the eco-efficiency development programme. In the planning process an overview of plastic streams in the Lahti region was created and main targets of development related to material efficiency of plastics evaluated. The literature views included in the state of the art part (Chapters 3 and 4) supported all the research questions.

2.2 Research process and collaboration

The first interviews of the dissertation study were made in 2007 by the author. A study concerning the infrastructure and expertise in materials technology and efficiency in the Lahti region was made in 2009. The second interviews were made in autumn 2012 by the author. The final writing and editing of the thesis took place in 2012–2014.

Most of the research work of the thesis was naturally individual work. Collaboration took place with the supervisor of this thesis, professor Pentti Järvelä and his research group of plastics and elastomers at the TUT DMS. The basic idea of the thesis was presented and discussed with professor Vesa Harmaakorpi from Lappeenranta University of Technology (LUT). Prof. Harmaakorpi and his research group have been developers of regional innovation theories, especially practice-based ones. The original model of practice-based advisory professorship tool is also based on his work and his research group's work. Prof. Harmaakorpi encouraged me to carry on with the idea.

The study part and results related to the part dealing with research question 1 offers novel information of the usability, mechanisms and effectiveness of the advisory professorship tool in university–industry co-operation, and information on the characteristics of the network formed while applying the tool. There has been no previous studies or researches concerning this research topic. There are publications and other literature related to practice-based innovation theories, and some practice-based innovation tools have been applied and studied in more detail, such as innobrokerage [21] and innovation session methods [22]. The main research contribution of the thesis is related to this research question.

First, in more detail, the study gives new information of the programme's resources, institutional setup, internal dynamics, results and effects in years 2008-2012. Novel information was produced concerning the innovation environment and capability including social level information of the co-operation network and its functions, characteristics of information and inputs to companies during the programme, information of the identification process of the research needs and the main tools and methods of co-operation. New information concerning the internal dynamics and absorptive capacity of the companies and the nature of the programmes information inputs compared with other external and internal sources of knowledge was also generated.

Secondly, new information was produced concerning the results and effects of the model, including new IPR or effects on IPR, new products, services or product improvements, process development, new knowledge, new data, new information or more efficient management of information, or expansion or increase of information channels and networks, caused by the programme. Likewise, information of the effects on turnover or profits or other possible influences than the intermediate and proper results, for example effects on company image or long-term competitiveness or on research culture, was generated.

This study part is based on the interview study performed in 2012. The main results are also presented in the manuscript “Advisory Professorship Model as a Tool for Practice-based Regional University–Industry Co-operation”, Eerola, S. (corresponding author), Tura, T. (co-author 1), Harmaakorpi, V. (co-author 2) & Järvelä, P. (co-author 3) [23]. The manuscript was submitted to the European Planning Studies in February 2013 and was accepted to be published on 11th of November 2013. It was published online on 15th of January 2014. The author defined the interview questions of the study with co-author 1. The author selected the companies for the research, made the research interviews, analysed the answers, summarized and analysed the results, and gave conclusions. Co-author 2 participated in identifying two conditions necessary for the successful application process of the tool: adequate absorbing and transforming capacity of the companies, and sufficient technological and social knowledge in brokerage actions and expertise of practice based innovation processes. In the manuscript, the author’s role was to be the main writer contributing most of the text. Co-authors 1 and 2 were the main writers of the introduction, and the chapters concerning theories of the changing relation of universities and regions and practice-based innovation policy. Co-author 3 contributed to the chapter dealing with the background of the programme.

All the research work related to the research part concerning the industrial use of engineering materials and the main research and development fields in materials technology for industries in the Lahti region was completely planned and performed individually by the writer of this thesis. The work included the planning of the interview questions and the question form, selection of the companies, performing the research interviews, analysing the data and presenting and handling the results and giving conclusions. This study part gives new information of the main materials, materials research fields and technologies for companies and their levels and willingness for co-operation with universities and other organizations. It also provides novel information on priorities of materials to industries, the use of materials technology related research services, the importance of research fields in materials technology for the companies, the companies' opinions of the most important possibilities and challenges of materials technology related research in the future, and the companies' interests to invest in materials technology related research or development activities in the future.

The thesis also offers new information of the materials technology related development path, infrastructure and regional innovation system in the Lahti region, which helps in further regional development work and in generation of new processes and models. Some of this information is presented in Chapters 3 and 5 based on two research reports. The first study concerned the infrastructure and expertise in materials technology and efficiency in the Lahti region (Eerola, S., Laaksonen, H., Tiainen, T. & Tura, T. Materiaalitehokkuuteen ja materiaalitekniikkaan liittyvän osaamiskeskittymän rakentaminen Lahteen, 2009) [19]. The author was the corresponding author of the research report. The author's contribution to the study was to study the material efficiency on national and regional levels, to participate in positioning the Lahti region in materials technology and efficiency, and to make a suggestion of an operation model for the competence centre of materials efficiency and technology. The other study is the report concerning plastic streams in the Lahti region (Eerola, S. & Neva, T. Päijät-Hämeen muovivirrat, 2009) [20]. The study was performed together with T. Neva, and both participated in the writing process of the report. The report gave new information of plastics flows in the Lahti region.

2.3 Evaluation of the innovation environment

An interview study for companies was performed in autumn 2012 to provide information of the resources, institutional setup and internal dynamics of the MTAP programme years 2008–2012. In addition to these innovation capability measures (input resources), the intermediate and proper results (outputs) were measured. Interview questions were formed through a *conceptual framework for the evaluation of regional innovative capability* (Figure 6) and the framework of *the Network-based Innovative Capability (NBIC) evaluation matrix* (Table 11).

2.3.1 The interviewed companies

A total of eight companies participated in the programme; six of them were part of the programme from its very beginning in 2008 until end of the year 2013. All of these six companies were interviewed. The companies represented five different industrial sectors. They employ approximately 2,100 people in the Lahti region. The interviewed persons of the companies, the informants, were the people in charge of technological development and material issues: R&D directors, managing directors, etc. They were also in charge of the MTAP programme in their companies, acting as the main contact persons.

The materials technological profile and characteristics of the companies were established with the background questions (Questions 1.1-1.6 in Appendix 2). Table 2 on page 16 presents the priorities and usages of materials by the interviewed companies. Plastics were used in every company. Wood was used in five companies and metals in four companies. In priority order the most important material was metals, followed by plastics, wood, textiles and fibres and ceramics.

Table 2. Priorities and usage of materials by the interviewed companies.

	Usage [N]	Priority number (mean)
METALS	**4**	1
Steel	3	
Aluminium	4	
Alloys	2	
Copper	1	
Other	1	
PLASTICS	**6**	1.7
Thermoplastics	6	
Thermosets	2	
Engineering plastics	2	
Reinforced plastics	1	
Rubbers and thermoelastomers	3	
WOOD	**5**	2.6
Timber	2	
Plywood	1	
Paper/cardboard	4	
Fibreboard	0	
Impregnated or heat treated wood	0	
Other: Fuel wood	1	
TEXTILES AND FIBRES	**1**	3.0
Natural fibres	1	
Synthetic fibres	0	
Fibreglass, carbon fibres	0	
Ceramic fibres	0	
CERAMICS	**2**	3.5
Engineering ceramics	1	
Ceramic coatings	0	
Other: Construction waste	1	

Table 3 on page 17 presents the materials technology related research services utilized by the companies during 2010–2012. Material testing and analysis services were utilized by all six companies. Thesis works and product testing were also generally used.

Table 3. Materials research services utilized by companies during 2010–2012.

	Total [N]	Universities [N]	Polytechnics [N]	Commercial research services [N]
Theses	5	5	2	0
Other research work	4	4	1	0
Material testing and analysis services	6	6	2	4
Processing and manufacturing services	2	1	0	1
Product testing	4	2	0	4
Other: Product approval	1	0	0	1

The main research areas of materials technology for companies divided by different material groups were related to plastics (Table 4). Research connected to fibre materials and metals was also seen valuable. Among the research areas important were materials characterization and testing, fundamental research and material development, and recycling and recovering of materials.

Table 4. Answers concerning the most important materials research fields of the companies.

	Metals [N]	Plastics [N]	Wood [N]	Fibres [N]	Ceramics and glass [N]	Total [N]
Fundamental research and material development	2	4	1	2	1	10
Process development	2	4	0	2	0	8
Recycling and recovering of materials	1	3	1	3	1	9
Control of material streams	1	2	1	2	1	7
Material efficiency	2	3	0	1	0	6
Life cycle management and LCA	0	2	0	1	0	3
Characterization and testing	1	5	1	3	1	11
Material chain management	1	4	0	2	0	7
Environmental related material research	1	2	1	2	1	7
Joining methods	2	4	0	1	0	7
Composite materials	0	3	0	1	0	4
Material chemistry	1	1	0	1	0	3
Coatings	2	2	0	0	0	4
Surface treatment	2	1	0	0	0	3
TOTAL [N]	18	40	5	21	5	89

The interviewees were also asked to name the most important possibilities and challenges of materials research in the near future. Answers related to materials and production technology included material efficiency of production, multi-layer and hybrid structures, modularity, surface properties and intelligent packages. Recycling and environmental issues were for example life cycle management, analytics and characterization and recycling of the production waste. Composite and hybrid materials, biomaterials and nanotechnology were the answers related to new materials. Also product safety including consumer health, technological leadership and regulation and legislation connected to recycling were mentioned.

Table 5. Investments in materials technology related R&D in the near future.

Type of resource input	No invests [N]	Some invests [N]	Remarkable invests [N]
Internal R&D	0	1	5
External R&D services	1	4	1
Research services from universities	0	4	2

Five of the companies were going to invest significantly in internal materials technology related research or development in the next years. All of the companies were going to invest in university level research: both fundamental research and applied research, two companies with significant and four companies with some investments (Table 5).

2.3.2 Questions and interviews

To get empirical information on the evaluation of the innovation environment and capability of the MTAP programme, the interview questions were formed on the basis of two theoretical matrixes, as presented in Table 6 on page 20. The entire questionnaire form is presented in Appendix 2. Here the purposes of the questions and their placements in both frameworks are presented and explained.

The aim of Question 1 was to get a picture of the co-operation network and its functions. Interesting from the viewpoint of innovation capability was the social level information: how the network had been constructed and especially developed during the programme between individuals at universities and companies. It was known and obvious that most of the companies had been contacted mostly by a regional contact person, and the main contact persons of companies were the persons participating in the steering group work. However, it was expected that also other direct contacts would have been created, e.g. between university researchers or professors and the members of the R&D groups of the companies. The contacts and wideness of the network was not well known before the interviews, except from the starting point of the programme.

The aim of Question 2 was to get a picture of what kind of information and inputs were created and offered to companies during the programme. The question was related to the innovation environment and yielded information on the social level. The question did not only give information of the nature of inputs the university could offer, but it also gave answers to what the actual research needs and lacks of the knowledge in the companies were. It was already known that most of the research inputs were different kind of pre-studies of materials, their properties and technologies. In what kind of innovation processes the information was used and in what way, was generally not known. As part of Question 2 the interviewees were asked what kind of innovation or R&D model was used in the company. The origin of the question was that some interestingly different kind of systematic innovation models were observed in the companies. For example, one company clearly used the experiment-driven innovation model, where it was important to create new knowledge through fast experiments with a high risk of failure. In other companies the innovation models were more traditional stage-gate models with a lower risk and more systematic, process-oriented R&D operations.

The purpose of Question 3 was to get information on the identification process of the research needs. It was interesting to note which party was the main identifier of the research needs and the ultimate activator of the research processes, or if the identification was done more in co-operation.

Table 6. Questions of the interviews and their placements in a conceptual framework for the evaluation of regional innovative capability and in the NBIC matrix.

	Questions of innovation capability	**Information in conceptual framework for evaluation of regional innovative capability**	**Information in the NBIC matrix**
1	Description of co-operation network	Innovation environment	Social level
2	Description of information and inputs to companies. Systematic or experimental innovation model	Innovation environment	Social level
3	Analysis of research needs (company-based, university-based, together)	Innovation environment	Social level
4	Tools and methods of co-operation	Innovation environment	Structural level
5	Internal dynamics and absorptive capacity of companies	Innovation environment	Cultural level
6	Heterogeneity of information. Role of MTAP-model information	Innovation environment	Structural level
7	New processes or existing innovation processes	Innovation environment	Social level
	Question of results and effects		
8	New IPR, products/services/product improvements, process improvements, knowledge, information, information gateways	Intermediate and proper results	-
9	Would these results exist without MTAP-model and in what time	Intermediate and proper results	-
10	Effects on turnover or profits	Intermediate and proper results	-
11	Other influences (image, competitiveness)	Grade effects	-
12	New national or international networks, new innovation processes between organizations	Grade effects	Social level
13	Impacts on research culture or absorptive capacity of information	Grade effects	Cultural level
14	Impacts on technological specialization	Grade effects	Intellectual level

Concerning the structural level information in the NBIC matrix, Question 4 asked about the main tools and methods of co-operation. In addition to steering group work and normal communication tools, an intranet website was set up for the programme. It consisted of a public internet and a password-protected intranet part. Companies had individual passwords, securing the access to the sub-files of their own organization.

Question 5 tried to get information of the internal dynamics and absorptive capacity of the companies. Absorptive capacity means the organization's ability to value, assimilate and apply new knowledge [24]. It was the only question related to the cultural dimension of the innovation capability. The interviewees were first asked about how the co-operation and programme activities were organized inside the companies in general. Interesting was how well the organization was informed about the existence of the programme and availability of the research resources. The mobility and utilization of the research results inside the organization was also inquired. If the produced information cannot be spread and absorbed by the organization, there might be need for improvement e.g. in leadership, communication tools and skills, the nature and usability of the research results, and knowledge-based skills.

Question 6 asked about the role and position of the advisory professorship programme in materials technology compared to other external and internal sources of knowledge. It was also asked if the programme had increased the heterogeneity of the available information.

The last question concerning innovation capability was whether the R&D projects activated by the programme had been part of other, maybe larger R&D processes of the companies. Had new innovation processes been started with the help of the information created in the programme, or had the research activities of the programme been part of innovation processes started earlier?

There were also seven questions concerning the results and effects of the model. Question 8 asked if there had been new IPR or effects on IPR, new products, services or product improvements, process development, new knowledge, new data, new information or more efficient management of information, or expansion or increase of information channels and networks caused by the programme. Question 9 asked if these results and effects would also exist without the model and in what time line. Both Questions 8 and 9 were related to the intermediate and proper results of the model in the conceptual framework for the evaluation of regional innovation capability.

Question 10 asked about possible effects on turnover or profits. There was clear awareness that it would be very difficult to estimate the possible effects or separate the effects of the model from the other influencing factors, such as the market situation or new investments and resources.

The last four questions gave information of the grade effects in the conceptual framework for the evaluation of innovative capability. It was asked in Question 11 if the companies had noticed any other influences than the possible intermediate and proper results, for example effects on company image or long-term competitiveness.

Question 12 was about whether the programme had created new national or international networks for companies or created new cross-organizational innovation processes. One important aim of the programme was to create knowledge flows between different industrial sectors and clusters and technology transfers between the industries and organizations. Despite the expectations, not so many new joint projects between industries or other co-operation activities between industries were noticed during the programme. However, if there were co-operation between companies, it might not be visible to other organizations or the university.

Question 13 was related to the cultural level of the innovation network. It was asked if the model had had effects on the research culture of the companies or the nature of R&D activities. It was also asked if the model had improved the company's absorptive capacity of information.

The only question giving information on the intellectual level in the NBIC matrix was Question 14. It was asked if the model had had effects on technological specialization. It would have been possible in such cases where the company had given up a technology or technologies because of the information produced in the programme. Or, for instance, if the company had adopted a new technology with the assistance of the model, and it would have become the dominant technology.

The interviews were face-to-face structured interviews. The questionnaire form was send to interviewed persons before the interview. There were two copies of the form, one for the interviewee and one for the interviewer. The interviewer presented the questions and wrote down the answers of the interviewee in the form. The interviewer repeated the written answer so that the interviewed was able to check it. The duration of the interviews was approximately 1 to 1.5 hours. The interviews were not recorded.

2.4 Materials technology in industrial companies of the Lahti region

The empirical study part related to the role of materials technology and research in the Lahti region’s industries are described in this chapter. The main aim of the study part was to make a practical contribution to the question of how to develop regional materials technology related knowhow in the region. The perspective of the study was on the actual needs of companies, based on their history, strategies, markets, organizations and expectations of the future. The results presented in this chapter are used in Chapter 7.2 in analysing the levels of availability, delivery and resources of regional materials technology research and how the companies’ needs are related in the focus areas of regional development.

These development questions arose already in 2007 as part of a larger evaluation work connected to the updating process of regional public policies in Lahti region. The cluster-based policy was adopted in the regional development work in 2005. The identified clusters were environment, grain, mechatronics, plastics and wood [6]. In the new innovation strategy presented in 2005, the main resources were directed to promoting the linking of the best available knowledge to build concrete, firm-based innovation processes [9-11]. The new competitiveness and economic development strategy for Lahti region for years 2009–2015 was also under preparation, underlining the development of the Cleantech sector and environmentally efficient actions, including material and energy efficiency [7]. The strategies of the universities were also changing. The actions and even existence of the regional units of universities were under evaluation at many universities.

2.4.1 The sample

The companies' demand for materials technology research was examined by structured interviews. The companies were selected to the research by judgement sampling [25]. The key selection criteria of the companies were a) The companies represent all the main regional industrial sectors utilizing materials with a wide range, including metals, plastics, wood, textiles and ceramic materials and b) Their employment effect in the region is high especially in the industrial sectors they represent. Statistical generalization was not the purpose, because this was a qualitative research.

In 2007 the manufacturing industries in the Päijät-Häme region employed 19,289 persons with a gross value of production of 4.2 billion € [26]. In the Finnish standard industrial classification (SCI), the manufacturing industries are classified in 24 categories. The study included the industries whose key businesses are based on use and processing of industrial materials. Table 7 on page 25 presents the industries by SCI 2008 and the industries selected for the research. The study included the following industries: manufacture of textiles (no. 13 in SCI); manufacture of wearing apparel (SCI14); manufacture of wood and of products of wood and cork, except furniture (SCI16); manufacture of paper and paper products (SCI17); manufacture of rubber and plastic products (SCI22); manufacture of other non-metallic mineral products (SCI23); manufacture of basic metals (SCI24); manufacture of fabricated metal products, except machinery and equipment (SCI25); manufacture of electrical equipment (SCI27); manufacture of machinery and equipment (SCI28); manufacture of motor vehicles, trailers and semi-trailers (SCI29); manufacture of other transport equipment (SCI30), and manufacture of furniture (SCI31). In addition to the manufacturing industries, the industry of waste collection, treatment and disposal activities, or materials recovery was chosen (SCI38). Industrial activities in water supply: sewerage, waste management and remediation activities employed 202 persons in 2007, of which 159 in SCI38. The number of employees in these industries in the region of Päijät-Häme was 16,061 in 2007. The gross value of the selected industries was EUR 3.5 billion. [26]

Table 7. Industries according to SCI2008 and the industries selected to the study.

	Gross value (GV), personnel	2007	Industries of the study
C Manufacturing	*GV of production (1000 €)*	*4,169,630*	
	Personnel	*19,289*	
10 Manufacture of food products	*GV of production (1000 €)*	154,271	
	Personnel	912	
11 Manufacture of beverages	*GV of production (1000 €)*	275,885	
	Personnel	646	
13 Manufacture of textiles	*GV of production (1000 €)*	13,108	X
	Personnel	87	
14 Manufacture of wearing apparel	*GV of production (1000 €)*	81,815	X
	Personnel	726	
15 Manufacture of leather and related products	*GV of production (1000 €)*	703	
	Personnel	16	
16 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	*GV of production (1000 €)* Personnel	727,207 2,918	X
17 Manufacture of paper and paper products	*GV of production (1000 €)*	278,684	X
	Personnel	1,024	
18 Printing and reproduction of recorded media	*GV of production (1000 €)*	42,841	
	Personnel	281	
19 Manufacture of coke and refined petroleum products	*GV of production (1000 €)*	.	
	Personnel	.	
20 Manufacture of chemicals and chemical products	*GV of production (1000 €)*	60,826	
	Personnel	240	
21 Manufacture of basic pharmaceutical products and pharmaceutical preparations	*GV of production (1000 €)* Personnel	. .	
22 Manufacture of rubber and plastic products	*GV of production (1000 €)*	306,882	X
	Personnel	1,382	
23 Manufacture of other non-metallic mineral products	*GV of production (1000 €)*	146,478	X
	Personnel	696	
24 Manufacture of basic metals	*GV of production (1000 €)*	130,707	X
	Personnel	138	
25 Manufacture of fabricated metal products, except machinery and equipment	*GV of production (1000 €)* Personnel	381,946 2,089	X
26 Manufacture of computer, electronic and optical Products	*GV of production (1000 €)* Personnel	12,519 102	
27 Manufacture of electrical equipment	*GV of production (1000 €)*	208,379	X
	Personnel	1,137	
28 Manufacture of machinery and equipment n.e.c.	*GV of production (1000 €)*	814,610	X
	Personnel	2,957	

29 Manufacture of motor vehicles, trailers and semi-trailers	*GV of production (1000 €)*	63,465	X
	Personnel	524	
30 Manufacture of other transport equipment	*GV of production (1000 €)*	1,326	X
	Personnel	14	
31 Manufacture of furniture	*GV of production (1000 €)*	323,230	X
	Personnel	2,220	
32 Other manufacturing	*GV of production (1000 €)*	91,152	
	Personnel	534	
33 Repair and installation of machinery and equipment	*GV of production (1000 €)*	53,597	
	Personnel	645	
E Water supply; sewerage, waste management and remediation activities	*GV of production (1000 €)*	*56,940*	
	Personnel	*202*	
38 Waste collection, treatment and disposal activities; materials recovery	*GV of production (1000 €)*	29,851	X
	Personnel	159	

On the basis of the criteria, 31 companies were selected at the first stage. All the companies were contacted by e-mail or by phone and asked to participate to the research. Research interviews could be arranged with fifteen of the companies.

Table 8. Personnel of the companies and industries of the study.

Industry	Personnel	Company	Personnel	Share [%]
Textiles and wearing (SCI13, SCI14)	813	L-Fashion Group	420	52
Wood and paper industries (SCI16, SCI17)	3,942	UPM	350	9
		Karelia Upofloor	190	5
Plastics and rubber industries (SCI22)	1,382	Uponor	375	27
		Wipak	450	33
Other non-metallic mineral products (SCI23)	696	Pilkington Glass	115	17
Manufacture of basic metals (SCI24)	138	Stalatube	110	80
Manufacture of fabricated metal products (SCI25)	2,089	Peikko	280	13
Electrical equipment (SCI27)	1,137	Kemppi	415	36
Machinery and equipment (SCI28)	2,957	Raute	400	14
		Galvatek	35	1
		Oilon	275	9
		Merivaara	120	4
Motor vehicles and other transport equipment (SCI29, SCI30)	538	---	0	0
Furniture (SCI30)	2,220	Isku	700	32
Waste collection, recycling (SCI38)	159	Kuusakoski	150	94
TOTAL	16,071		4,385	27

The companies which participated to the interviews represented the industries selected to the study quite comprehensively. Only representatives of SCI29 (manufacture of motor vehicles, trailers and semi-trailers) and SCI30 (manufacture of other transport equipment) could not be reached for participation. However, these industries employ only 538 persons in the region of Päijät-Häme, which is 3.35 % of the total head count of the industries selected to the study. Table 8 on p. 26 presents the total personnel of the interviewed companies and the industries they represent in Päijät-Häme in 2007. The interviewed companies employed 4,385 persons in 2007, which was 27 % of the personnel of the industries studied. The turn-overs of the companies varied between 15 to 1,000 million Euros, and the number of employees between 35 to 8,500 persons. Best coverages were attained in the manufacture of basic metals (80 %), plastics and rubber industries (60 %), textile and wearing (52 %) and recycling (94 %). The lowest coverages were in wood and paper industries (14 %), manufacture of fabricated metal products (13 %) and motor vehicles and other transport equipment (0 %).

2.4.2 Questions and interviews

The formulation of the interview questions was based on defining the empirical counterparts to the key factor of this study part: the importance of materials technological research to the companies. They were defined as follows: the utilization of materials technological research in the past by the company represented by the informant, an estimate of the use of materials technological research in the future, opinion of the most important fields of materials technology for the company, opinion of the most important challenges and opportunities of materials technology in the future, and future investments in materials technological R&D. As background information, the interviewees were asked about the use of different industrial materials in the companies.

The interviewed persons of the companies, the informants, were the people in charge of technological development and material issues: R&D directors, managing directors, etc. A structured questionnaire form (Appendix 1.) was used in the research. Most of the questions were quantitative (Q1-Q4, Q6, Q7), expect one open question (Q5). The questionnaire form was send to interviewed persons before the interview. There were two copies of the form, one for the interviewee and one for the interviewer. The interviewer presented the questions and marked the answers of the interviewee in the form. The duration of the interviews was approximately 1-1.5 hours. The interviews were not recorded.

First the interviewees were asked about the usages and priorities of different materials and material groups in the companies (Appendix 1). The companies were asked to classify the main material groups in priority order with numbers 1-5. The materials were divided into metals, plastics, wood, textiles and fibres, and ceramics. Exact amounts were not asked, because companies do not usually have such information, and if they have, they do not want to disclose it to outsiders.

In the question form, metals were divided into steel, aluminium and alloys. Plastics were divided into thermoplastics, thermosets, engineering plastics, reinforced plastics, and rubbers and thermoelastomers. Wood was divided into timber, plywood, paper/cardboard, fibreboard, and impregnated or heat treated wood. Natural fibres, synthetic fibres, fibreglass, carbon fibres and ceramic fibres were part of the section concerning textiles and fibres. Ceramics were divided into engineering ceramics and ceramic coatings.

Question two asked what materials technology related research services companies had utilized in the past two years (2005-2007). In the questionnaire form, research services were divided into material testing and analysis services, processing and manufacturing services, product testing, thesis work, other research work and other consulting services. The research organizations were divided into universities, polytechnics and commercial research services.

Question four asked what materials technology related research services the companies were going to subcontract in the next two years. The research services were divided into fourteen research areas:

1. Fundamental research and development of materials
2. Process development
3. Recycling and recovery of materials
4. Materials efficiency
5. Life cycle management and LCA

6. Testing services
7. Prototypes and trial manufacturing
8. Material chain management
9. Environmental related materials research
10. Joining methods
11. Composite materials
12. Materials chemistry
13. Coatings
14. Surface treatment

The aim of question three was to identify the most important research areas of materials technology for companies. In the question form there were 14 areas of materials technology related research fields listed in vertical direction. In the horizontal direction were the main materials: metals, plastics, wood, fibres and ceramics. Fourteen preselected research fields were given so that the respondent could mark the main research area and also the material related to the research topic. The research areas were:

1. Fundamental research and development of materials
2. Process development
3. Recycling and recovery of materials
4. Control of materials streams
5. Material efficiency
6. Life cycle management and LCA
7. Characterization and testing
8. Material chain management
9. Environmental related materials research
10. Joining methods
11. Composite materials
12. Materials chemistry
13. Coatings
14. Surface treatment

Question five asked about the most important possibilities and challenges of materials technology related research areas in the near future. Question six asked about the companies' interests to invest in materials technology related research or development in the near future and Question seven an estimate of possible financing for university-level research in materials technology.

3 Materials science and technology

Knowledge and mastering of materials have been key elements in the development of human societies. It is estimated that nowadays 70 % of all technical innovations depend directly or indirectly on the use and properties of materials, and the percentage is still increasing [4]. The importance of mastering different materials for mankind can also be seen in the names of eras from Stone Age to Bronze and Iron Age. We can also use the concept of Space Age, which brought along new structural materials, like composites, and Electronic Age with semiconductors. The current era could also be defined as "Silicon Age", which started from the invention of the transistor. [3; 27]

The main classes of modern materials are metals (including alloys), polymers, ceramics, semiconductors, and composite materials. In the periodic table, most of the elements are metals, characterized by metallic bonding. Iron based alloys are most typical, and they are most used in different structural applications, based on their good fabrication properties and mechanical performance. Copper-based alloys, like bronze and brass, are used for example in electrical and thermal conductors and piping. Aluminium based-alloys are used, for example, in lightweight structures and engines. [27; 28]

The relative importance of engineering materials to society has changed in the course of history. In early societies, polymers and elastomers; wood, skins and fibres were important, as well as ceramics and glasses; stone, pottery, glass and later cement. The importance of metals increased gradually from the beginning of Bronze Age, and especially from the beginning of the Iron Age. Since the beginning of the 17th century, the importance of metals and especially steels increased strongly to the late 1950s. From the 1960s, the importance of polymers, composites and ceramics has increased again with tough engineering ceramics, high-modulus and high-temperature polymers, light composite structures, etc. [29]

The use of polymers has increased strongly since the 1960's. Polymers can be divided into three main groups based on their macromolecular structure; thermoplastics, thermosets and elastomers. The molecular chains of thermoplastics are not crosslinked, they flow at elevated temperatures and return to solid state when cooled. They can be remelted and reshaped. Thermosets are polymers, which are cured, set, or hardened into a permanent shape. The molecular chains of thermosets are cross-linked with covalent bonds. Elastomers are polymers consisting of long chain-like molecules. Chains are located in the structure in random manner, and they can recover from very large deformations without damages. Molecules are cross-linked, but this linking does not prevent the molecules from sliding past one another when deformed. [28-32]

Plastics are polymers with a number of added components. The components can be additives, fillers or other polymers, in which case they are called the polymer blends. The main purpose of the use of additives and fillers is to improve the properties of the end-products and to help in processing. Different additives are e.g. plasticizers, pigments, lubricants for the transportation in processing machines, ultraviolet stabilizers to protect polymers from sunlight, and fibres to improve stiffness and strength. [32] The most common plastics are polyolefins; polyethylene (PE) and polypropylene (PP). There are several different kind of polyethylens, differing e.g. by their density, specific weight and length and the form of the polymer chains. The most important polyethylens are PE-LD (low-density PE), PE-MD (medium-density PE), PE-HD (high-density PE), PE-LLD (linear low-density PE) and PE-X (cross-linked PE). PE and PP are thermoplastics, except PE-X, which is, though depending on the level of crosslinkage, typically categorized as thermoset. Other thermoplastics are e.g. polystyrene (PS), poly(ethylene-terephtalate) (PET), polyvinylchloride (PVC), poly(methyl-methacrylate) (PMMA), polycarbonate (PC), polyamide (PA), acrylonitrile-butadiene-styrene (ABS) and poly-oxymethylene (POM). Typical thermoset materials are e.g. polyurethane (PUR), unsaturated polyester (UP) and epoxy (EP). [33]

In addition to grouping plastics by their macromolecular structure, there are also other ways to categorize plastics, based on their generality and use. For example, they can be divided into volume plastics (PE, PP, PVC, PS) and engineering plastics (POM, PA, ABS, PET, PMMA, PC, etc). High performance, special plastics can be categorized as one group, including polysulfone (PSU), poly(phenyl-sulfone) (PPSU), poly(ether-sulfone) (PES), poly(ether-ether-ketone) (PEEK) and polytetrafluoroethylene (PTFE). [33]

A composite material is a combination of at least two materials, which are in separate phases and do not dissolve or melt into each other. In polymer composites, a thermoplastic or thermoset is the matrix material, which is reinforced by fibres or particles. When the reinforcements are nano-scale (at least one dimension <100 nm), the composite material can be called as nanocomposite [34]. When the sizes of the particles are restricted to nano-scale, the properties of material can be remarkably different from a macro-scale material consisting of the same substances [35]. Traditional composite structures can contain very high amounts of filler materials (even up to 60 volume-%), but with nanofillers the material properties can be changed with very low contents (<2 volume-%). Mechanical, thermal and other properties of nanocomposites are often clearly different than the properties of traditional composites. Nanocomposite can be tough and thermally resistant with high barrier properties. [36] Nano-filler materials include nanoclay particles, silicon oxide (SiO_2) particles, carbon nanotubes, graphene, cellulose-based nanofibres, chitin or chitosan nanoparticles and other in-organic substances [35].

Ceramics are inorganic compounds, classified into oxides, carbides, nitrides and silicates. An exception is diamond, which consists of pure carbon. They are crystalline in nature and very stable both thermally and chemically. Examples of typical ceramics are Al_20_3 for spark plugs and microelectronics and Fe_30_4 for magnetic memories used in computers and silicates: clays, cements and glass. [27]

Semiconductor materials have a resistivity between that of a conductor and that of an insulator. Their resistivity can be controlled; by applying an appropriate electric field they can be switched from conducting to non-conducting state. With this property, semi-conductors have formed the foundation of modern electronics. Silicon (Si) is the most important semiconductor material in electronics, but especially in optoelectronics the non-silicon technologies are growing. Other semiconductor materials are i.e. germanium (Ge), gallium arsenide (GaAs) and zinc sulfide (ZnS). [37]

Materials science is focused on studying the compositions, properties, structures, processing and usability of different materials. The properties of any material depend on various features: composition, microscopic structure, manufacturing processes, conditions of use and storage. Furthermore, material properties determine in which products the material can be used and they also dictate the product's performance, reliability and cost. [2; 28]

Materials science appeared as an independent branch of science at the end of the 1950’s, separating from the basis of physical metallurgy traditions. [2; 38] The achievements of materials engineering usually result from integration with other sciences. Due to this interdisciplinary nature of materials science and engineering, it is nowadays the key element in several fields of science and applications. For example, new innovations have arisen in the crossroads with chemistry, solid-state physics, process engineering, mechanics, electronics and medicine. [2]

3.1 Applications of engineering materials

Applications of engineering materials can be classified in six categories: structural, electronic, thermal, electrochemical, environmental and biomedical applications. In structural applications, mechanical properties and performance are the key factors. For example strength, stiffness and elasticity are important, if the structure must bear a load or stress. Structural applications are buildings, bridges, aircrafts, ships, machinery, pipes, containers, furniture, sport equipment, etc. Properties other than the mechanical ones are often also important, like low density in lightweight structures and corrosion resistance in outdoor applications. Materials in structural applications are typically metals, polymers, elastomers, concrete and composite materials. [27]

Electronic applications include electrical, optical and magnetic facilities, such as computers, electronic and optoelectronic devices, thermoelectric devices, motors, robotics, etc. All classes of materials are used in such products, but semiconductors form the basis of the technology and its functions. In thermal applications heat is transferred via conduction, convection or radiation. Heat transfer systems exist e.g. in buildings, industrial processes and machines. Typical materials in thermal applications are metals, ceramics and plastics. Electrochemical applications are facilities where electrochemical reactions are generated. Reactions can be either of oxidation or reduction type. Examples of applications are batteries, fuel cells and different industrial processes. Anode and cathode materials and electrolytes must be electronic or ionic conductors. [27]

Environmental applications can be defined as facilities or processes which protect the environment from pollution by removing a pollutant or by helping in the reduction of pollutants. For example, wind mills fabricated from metals and composites help in changing the energy source from fossil fuels to natural resources. Biodegradable materials can be used in some applications to reduce the use of fossil materials. Materials with the absorption capability, for example carbons, aerogels and other porous materials are often used in environmental applications. [27; 39]

Biomedical applications are used in the diagnosis and treatment of diseases. Implants, like prosthetic hip implants, heart valves, stents, and teeth implants have to be constructed from biocompatible materials [27]. Although metal implants have a long history, i.e., since 1920 as bone fixation materials, there are also limits and disadvantages in the use of them. Metallic devices are more rigid than bone, which can lead to bone atrophy or other problems. Metallic implants are usually removed in a second surgical operation, which increases the risk of infection. Bioabsorbable polymers have been developed since the late 1960s for biomedical applications. The most important bioabsorbable polymers are aliphatic polyesters, including polyglycolide (PGA) and polylactides (PLA), to be used as homopolymers or copolymers. They degrade as L-lactid acid and glycolic acid, which occur in normal cell metabolism, which is why they are well tolerated by human body. [40-43] Other biomedical applications are e.g. surgical and diagnostic devices, medical instruments and exercise equipment. [27]

3.2 New materials and technologies

What is the future of new materials and materials technology? How important the materials technology is seen for the future development of society?

In several studies, researches and strategies, materials technology has been mentioned in the context of future developments and strategies, e.g. in [1-4; 8; 44-49]. Especially nano- and biotechnology have been in the focuses of strategies during the 21st century. They belong to converging new technologies, which refers to the synergistic combination of nanotechnology, biotechnology, information technology and cognitive sciences [50]. New technologies are sought to develop tailored and hybrid materials to make complex, functional surfaces and applications [2; 3; 51-53]. New carbon materials and structures like carbon nanotubes, fullerenes and graphene are creating new possibilities in several application fields [54; 55], based on their useful properties, such as high electrical and thermal conductivity, high chemical stability, low thermal expansion coefficient, high lubricity and light weight [56]. The penetration of nanotechnology in industrial sectors is expected to grow, for example, in semiconductor industry, pharmaceutics and wood industry, and in industry related to new nanostructured catalysts [57].

Technological foresights of materials technology are usually analysed in literature by three different aspects; application based, topic based or task/process based. According to Dobrzański [2], forecasts for the future of markets and products cannot be made without the knowledge on materials science and engineering. In many inventions, practical applications are possible only when suitable materials are found. As an example, the helicopter was sketched in 15th century by da Vinci but realized only in the 1940's. Dobrzański sees that the contemporary development trends of materials science and engineering interests are synthesis and processing of materials, chemical composition and microstructure of materials, phenomena and properties of materials, behaviour of materials under operating conditions, and materials design and prediction their durability or life, concerning both existing and new materials.

Instead of this topic-based future thinking, the past and the future can also be seen by potential application fields. Manohoran [3] sees that the growth in global transportation is generating need for lightweight structural materials, like composites. The request for fuel efficiency has created a demand for light materials but also driven the development of new materials for batteries and fuel cells to be used in new types of vehicles. In medicine, the development of different biomaterials has increased strongly, for example, for drug delivery purposes, tissue engineering and for transmitting information. National defence has in many cases been the first application area of new materials, for example the sensor materials for chemical and biological threats, and armour and blast resistant materials. [3]

Manohoran also sees that there is going on a paradigm shift in the development of materials. Traditionally, the flow cycle of materials has been based on extracting materials from the nature, processing them to final form, using and then recycling or discarding. This flow cycle of materials represented the optimum use of materials and energy, on which most of the industrial revolution was based. Now we are finding ways to develop tailored materials for complex, functional applications, which include both economic and scientific opportunities. The challenge is to transform scientific innovations to productive and cost-effective technologies. Nanomaterials are not likely to lead to new products in cases where an entire value chain has to be developed, because the time-to-market is too long or the return rate of the investment is too low. It is more likely that they can be used successfully in products where nanomaterials can be integrated directly into an existing value chain. [3] Lot of similarities can be seen in the use of recycled materials. Even if the recyclate, e.g. the recycled plastic, would be cheaper than the original material, it is hard to find applications where the cost savings through material prices exceed other development and implementing costs of a new product. As a matter of fact, the cost savings are in many cases not sufficient even if only the material of the existing product is changed to recyclate. The use of recycled material may cause changes in material pre-processing and product manufacturing processes, in product quality and other changes during the whole product life cycle. In advanced, radical material innovations, the realization of the value potential requires the resolution of great technological and market challenges and big investments over a long period of time [58].

Schwartz [51] sees three main high-impact technologies in the future. He sees that the development of semiconductor materials and technologies will continue the strong influence to the integrated circuit (IC) sector. Like Manohoran, he sees that there will be new materials, which are designed and manufactured by computers and which can be used in many industries, such as transportation and energy. He also predicts that fuel cells and batteries for portable electronic devices will become general. Schwartz also looks back for the most important achievements in materials and processing technologies in the last decade (appr. 1995 to 2005). From the field of material development, functionally gradient materials (FGMs) are mentioned. They are composite materials in which the proportions of the constituent materials vary, so that there are no clear interfaces between different microstructures. With FG materials, special properties, such as very high temperature resistance can be created. Techniques for producing FG materials include different coating methods like chemical vapour deposition (CVD) and the high velocity oxyfuel (HVOF) method. The development of fullerenes, the solid carbon molecules with great stability, has a lot of possibilities for example in nanocomposites and in medical and electronic applications. In polymer science, liquid crystal polymers (LCPs) are seen as an interesting group. They maintain partly their rod-like microstructure in the molten state, differing from other plastics where molecules have a random configuration when melted. When processed in the molten state, the rod-like molecules are capable to get oriented in the flow direction and act like reinforcement fibres in the polymer structure. LCPs have very good mechanical and thermal properties, they are fire resistant and have good electrical properties. They can be used e.g. in LCDs, optical filters, as fibres, films, coatings, shaped components and in electro-optical applications. Also interpenetrating polymer networks (IPNs), nanoengineered machines, molecular nanotechnology, high-strength materials and nanostructures are regarded as interesting research fields. [51]

One interesting material group of functional materials are shape memory materials and polymers. A thermally induced shape memory effect has been described for different material classes, including polymers, hydrogels, metallic alloys and ceramics. They are used, for example, in medical applications. [59-61] Shape memory alloys (SMAs) have been investigated since the memory effect of titanium-nickel alloys (Nitinol) was recognized in 1963. Ti-Ni alloys are the most common SMAs and there are several Ti-Ni alloys with different trade names available on the market today. They are the most important commercial SMAs because of their good shape memory effect, processability, mechanical properties and biocompatibility. Although nickel is cytotoxic and allergenic, Ti-Ni alloys are quite bioinert and well tolerated by tissues. [61; 62] It has also an elastic modulus which is closer to the elastic modulus of bone than that of any other metal [63]. The shape memory effect of Ti-Ni alloys is based on martensite-austenite transformation at a certain temperature. When it is cooled down from a high temperature, i.e. the austenite phase, the crystalline structure transforms to the martensite phase and it can be easily bent and shaped. When the metal is reheated over its transformation temperature, it returns to its original shape. Ti-Ni alloys also have super-elastic properties. [61; 64] This means that if the SMA is deformed in the limited temperature area over the martensite-austenite transformation temperature, the original shape is restored immediately after the deformation force is removed. The transformation temperature can be adjusted to be near 37 °C, which makes Nitinol useful in medical applications. [61] Nitinol applications include compression bone staples used in osteotomy and fracture fixation in the craniofacial area, rods for the correction of scoliosis and expansion clamps in small bone surgery. [61; 64] Shape memory polymers (SMPs) have been investigated for actuation purposes from the end of the 1980s [65]. They have ability to store and recover from large strain deformities when pre-deformed at an elevated temperature, cooled to a lower temperature and reheated [66]. While shape memory metals can recover approximately 10 % strain, the unconstrained recovery strain for SMP materials can be up to 100 % [67]. Other advantages of SMPs compared with other active materials are that they are light, usually economical and can create complex geometries [66; 68]. A negative aspect of SMPs is that they can usually create only a very low recovery force [62]. A shape memory effect has been reported for quite few polymers, including polyurethane, poly(styrene-block-butadiene), trans-isopropylene, polynorbornene and a copolymer of p-dioxanone and ε-caprolactone, which is a biodegradable SMP [59; 62]. Most of the research is concentrated on the study of polyurethanes. Lendlein and Langer have developed self-tightening biodegradable sutures, which are shape memory polymers having covalently crosslinked polymer networks containing hydrolyzable switching segments [59]. A shape memory effect can be “loaded” to the SMP polymer by heating the SMP over its glass transition temperature and deforming it to the desired shape, and then cooling it down while maintaining the shape. The strain is gradually recovered with an increase in temperature. [66]

3.3 Materials technology in Finland

In Finland, materials technology has traditionally been based on two groups of materials, wood-based and metallic materials. The export of wood and wood-based materials has played a significant economic role already since the Middle Ages, whereas the increased significance of metal materials stems from the war reparations after the Second World War. Decisions made in the 1960s and 1970s also increased the basic production of metals in Finland sharply. The rapid growth of the electronics industry that started towards the late 1980s also gave a boost to the Finnish plastics industry, although in the light of the development of the past few years the impact of this boost of the production volumes of the plastic sector seems to have been short-lived. Nevertheless, it has created significant research and expertise of polymer-based materials in Finland, which has been channelled into new products, such as packaging materials and composite materials. The electronics industry has also brought about significant research into electronic and optoelectronic materials, which is gradually creating productive activities in this sector in Finland. [19]

Materials technology has been in the focus of several research programs of Tekes (the Finnish Funding Agency for Technology and Innovation) and Strategic Centres for Science, Technology and Innovation (SHOKs) in Finland. Tekes saw in 2008 that in creating new knowledge in Finland, the focus areas should be cutting-through key technologies and core expertise, which are needed to build end-user based processes and products. The focus areas were IC technology, break-through materials, biotechnology, business expertise, service know-how, and social competence. Nanotechnology materials, wood, metals, polymers, composite materials were mentioned as examples of break-through materials. [69]

3.3.1 Industrial materials technology expertise

When it is a question of industrial materials technology expertise in Finland, wood and wood-based materials are still essential for the Finnish national economy. Because of the raw-material base the industry is distributed rather evenly. The industrial manufacture of high value-added wood products such as furniture is particularly concentrated in the Lahti region. Traditional wood-processing industries, such as mechanical wood processing and the pulp and paper industry are currently undergoing a change that takes production from Finland closer to the sources of cheap raw materials and the users of the products. With the increasing globalization of the sector, Finnish wood-related materials technology needs stronger inputs in creating innovations and R&D in order to maintain its competitive edge in the long run. [19]

In the field of the primary metals production Finnish industry leans on the production of steels, stainless steels, copper and zinc, as well as nickel. On the global scale, Finnish primary production of metals is rather small, with the exception of stainless steel. In terms of its technological foundation and level of expertise, Finnish primary metals industry is highly advanced and its products are competitive in this respect. We also have some expertise-based technology and equipment exports. Geographically the industry is distributed along good transport communications on the coast of Western Finland south of Tornio and in the coastal areas of Southern Finland. [19]

Among the industry sectors that manufacture or use metal products, many of which of course utilize the whole range of materials technology, the most important for the national economy are the shipbuilding industry, the manufacture of wood processing machinery and equipment, the manufacture of power generation machinery, as well as the industries manufacturing rock drilling and crushing machinery. In the wood processing, energy and crushing sectors, intensive R&D has also been going on in materials and materials technology, which aims, among other things, at the production of more wear-resistant materials and components. Industry in this sector is distributed relatively evenly in Central and Southern Finland. [19]

In the field of polymer-based materials, Finnish industrial materials technology is concentrated mainly on the manufacture of plastic products instead of plastic raw-materials. The rapid growth of the electronics and telecommunications sectors in the 1990s also spawned a number of major companies manufacturing plastic products of this kind in Finland, but their production has moved outside Finland, closer to the volume market of these products. As a consequence, Finland nevertheless has considerable expertise in the production of these goods. Intensive R&D has also taken place in the field, especially in industries manufacturing and utilizing plastic films, which has resulted in sophisticated and competitive products, for instance, in foodstuffs packaging. Geographically the plastic products industry is distributed rather evenly in Southern Finland, although there is a strong concentration of plastic industry in the Lahti region. [19; 20]

In the field of ceramic and glass materials, the Finnish industry is focused on the manufacture of glass-based products such as window and packaging glass, as well as fibre-based insulating products (glass wool, rock wool, glass fibre). R&D in the sector has focused mainly on the manufacture of products rather than the development of the materials or materials technology itself. There is also industry in Finland that manufactures machinery and equipment for the glass industry and related expertise. The industry is mainly located in Southern Finland. [19]

Regarding composite materials, Finnish industry largely concentrates on polymer-based composites. There is manufacture of both basic materials (reinforcement fibres) and actual composite products in the field. Application ranges include tanks and pipelines for processing industry, boat construction, transportation equipment industry, sports equipment industry, and increasingly wind turbine industry. Intensive R&D is taking place in the field in both materials and manufacture of products. Geographically the industry is distributed in the eastern and western parts of Central Finland. [19]

Technology Industries published a large report [48] of development trends in material technology in 2005 in Finland. Technology industries represent 60 % of total Finnish exports and 80 % of total Finnish R&D-investments. They employ 290,000 directly in the sector, whereas the total employment effect is estimated to be around 700,000. [70] Finnish Chemical Industry and Confederation of Finnish Construction Industries also participated to the work. It was a materials technological foresighting report and a roadmap of main development paths, utilizing possibilities and innovations. The main aims were to create a synthesis of R&D needs in international materials technological roadmaps and business benefits, to study the views, priorities and demands of development of materials technology in Finnish industrial companies, to study the knowledge of challenges related to the use of materials in the industrial sector, and finally to create a synthesis of material technology related development trends, needs and technology politics for each industrial sector. In addition to companies, representatives of Finnish universities took part to interviews and were members of the steering group of the report project. [48]

The included industries and clusters were electronics and the electrotechnical industry, chemical industry, mechanical engineering industry, metals industry and building industry. The chemical industry sector included plastics industry. Most important material groups identified were steels, substrates for microelectronics and thin films, as well as polymers and polymer composites. Development paths for the processing of materials were also reviewed. Coatings and coating methods, bonding and joining techniques, modelling, simulation and testing were analysed to be the most important areas. The reduction of manufacturing costs was the most important target of development followed by life cycle costs, mechanical reliability, fatigue durability and usability. The main business challenge was customer orientation. Product safety, product performance and price were also at the top of business challenges. In all industries and clusters, the high prices of new materials were seen as the most important restraint for development. [48]

3.3.2 Materials research organizations

According the Tekes, materials research employs over 4,000 researcher in 250 research groups in Finland. Materials research is typically integrated to different technologies and industries. [47] Significant actors in the materials technology research and development are universities of technology and their faculties. The Technical Research Centre of Finland (VTT) also has a strong expertise in the materials technology research area. In addition, there are a number of enterprises offering testing and analysis services, in particular, in the field of non-destructive testing.

At Tampere University of Technology actual research into materials science and technology takes place in the Department of Materials Science. TUT's Department of Materials Science is the only institute of the field in Finland that covers research and education of all material groups within one unit. It provides instruction in metallic materials, plastics and elastomers, ceramic materials, composites, coatings, fibre materials and paper. It employs about 150 researchers and 8 professors. DMS is divided into seven operational groups: materials science, materials characterization, plastics and elastomer technology, metals technology, surface engineering, ceramic materials, fibre materials science and paper converting and packaging. The department also has activities in Lahti, Kokkola and Mikkeli. [71]

The Department of Biomedical Engineering conducts extensive research into biomaterials and tissue engineering at TUT. Materials research is also conducted at the Institute of Electronics with a focus on materials used in electronics, as well as at the Physics Department and Optoelectronics Research Centre, where the focus is on semiconductor-based optoelectronic materials. The Department of Chemistry and Bioengineering conducts material research related to photochemistry and the Department of Construction Engineering research related to building materials. [71]

At Aalto University, research into materials science is conducted mainly at the School of Chemical Technology and School of Engineering, especially in the Department of Materials Science and Engineering and Department of Engineering Design and Production. Plastic related expertise is found in Research Group of Polymer Technology in Department of Biotechnology and Chemical Technology. The Department of Materials Science and Engineering has professorships in materials science, material chemistry and corrosion, material synthesis and manufacture, process metallurgy, material modification and thermal treatment, functional coatings, as well as in material processing and recycling. During the last twenty years the department has, besides its core competence areas, focused on the research of silicon based materials, metal matrix composites, as well as functional materials. At the Department of Engineering Design and Production research into materials technology is conducted in relation to both materials technology for mechanical engineering and foundry technology. The focus in materials for mechanical engineering has in the past years been on materials for the nuclear power plant industry and issues concerning the welding of metals. Material research in the Department of Electrical Engineering focuses on materials used in electronics. Aalto University also conducts research covering all areas of wood processing technology. Also a multidisciplinary Centre for New Materials has been established in the university, combining several disciplines in the research of materials science and engineering, but currently the activities have been put on hold. It conducted mainly research related to functional polymer-based materials and nanomaterials. [19; 72]

At the University of Oulu, research into materials technology is done at the Laboratory of Materials Engineering, the Department of Mechanical Engineering, Faculty of Technology, as well as at the Laboratory of Process Metallurgy, Department of Process and Environmental Engineering. The research of materials technology focuses on the metallurgy of various metals, especially steels, and welding techniques. The Laboratory of Process Metallurgy focuses on the process metallurgy of steels and materials engineering related to the manufacture of steels. Material characterization takes place in the Optoelectronics and Measurement Unit, which concentrates mainly on the examination of biological materials but is also able to study the microstructure of other materials. [19; 73]

At the Lappeenranta University of Technology research into materials technology is conducted in connection with the mechanical engineering of the Faculty of Technology. The focuses of the research include fatigue of metal structures, laser welding, and welding metallurgy. The University is also engaged in research related to wood processing. [19; 74]

At the University of Turku, materials science research concerning surfaces of materials and their characterization is conducted at the Laboratory of Materials Science, Faculty of Mathematics and Natural Sciences. At Åbo Akademi research is related to the chemical processes of wood processing. Research of polymers is concentrated on the Laboratory of Polymer Technology. Åbo Akademi also runs a Centre of Functional Materials in co-operation with the University of Helsinki where materials and equipment for printed intelligent systems are developed on a multidisciplinary basis. The University of Jyväskylä conducts research related to nanotechnology and nanomaterials. [19; 75-77]

At the Technical Research Centre of Finland, research into materials technology is divided into three areas: functional fibre products, new materials, and materials and equipment for power plants. The focus in functional fibre products is on the development of new functional fibre products and their applications, such as packaging products. The research of new materials comprises the development of metal, ceramic, polymer, concrete and wood-based materials and their combinations over the entire value chain. Examples include metal matrix composites, reactive synthesis, and active and functional materials. Materials and equipment for power plants include the research and development of primary circuits for nuclear power plants, materials for conventional power plants and materials engineering for new energy technologies. [19; 78]

3.4 Material efficiency

The population growth and rising global standard of living have raised a concern for the sufficiency of natural resources. Consequently, the interest in the sensible use of natural resources has grown both in business and in the social and political life. Likewise the climate and energy issues currently play a central role in the national and international discussion on natural resources and the environment. As the demand of raw materials increases, their supply becomes scarcer and prices are soaring.

Environmental impacts of production and processing of materials are becoming more critical. In short, material efficiency means providing material services with less material production and processing. Allwood *et al.* have presented a white paper on material efficiency [1], where they present a set of opportunities which might remarkably reduce the total environmental impacts of the global economy. The focus is on engineered materials, and both resource efficiency based and product based approaches are used. In the resource efficiency approach, resources are measured with single weight measures. In the product based approaches, like life cycle analyse methods (LCA), global significance usually remains unclear, because the focus is on the improvements of a product. According to Allwood *et al*., "*material efficiency was normal practice prior to the industrial revolution, as the relatively high value of material compared to labour ensured that building and products were maintained, repaired and upgraded. However, since concerns over the environmental impacts of post-industrial revolution production have risen to prominence, material efficiency has received limited attention in contemporary analysis and policy".* The global demand for engineered materials has quadrupled from 1960's, and is still growing fast. [1] It is estimated that the demand for materials will be by 2050 at least double from the levels today. [47]

Engineered materials are derived from biomass (timber, paper), ores (metals, ceramics) and from oil (polymers). When or whether we will run out of raw materials, can be settled as follows: when will the price of non-renewable materials (oil and ores) constrain the use of them, and what rate of use of renewable biomass is biologically sustainable? [1] By IAE, 56 % of industrial CO_2 emissions is based on the production and processing of five materials: steel, cement, plastic, paper and aluminium. From global CO_2 emissions 36 % is coming from industry, so 20 % of all energy and process related emissions is related to materials. [47] Allwood *et al.* present four options to reduce CO_2 emissions per unit output: improvement of energy efficiency, yield improvement, increased recycling rates, and decarbonization of the global energy system. Figure 3 illustrates different strategies of implementing material and energy efficiency. The figure shows the strategies placed in the life cycle of a metal product. [1] It can also be applied to products manufactured from other materials, e.g. plastics.

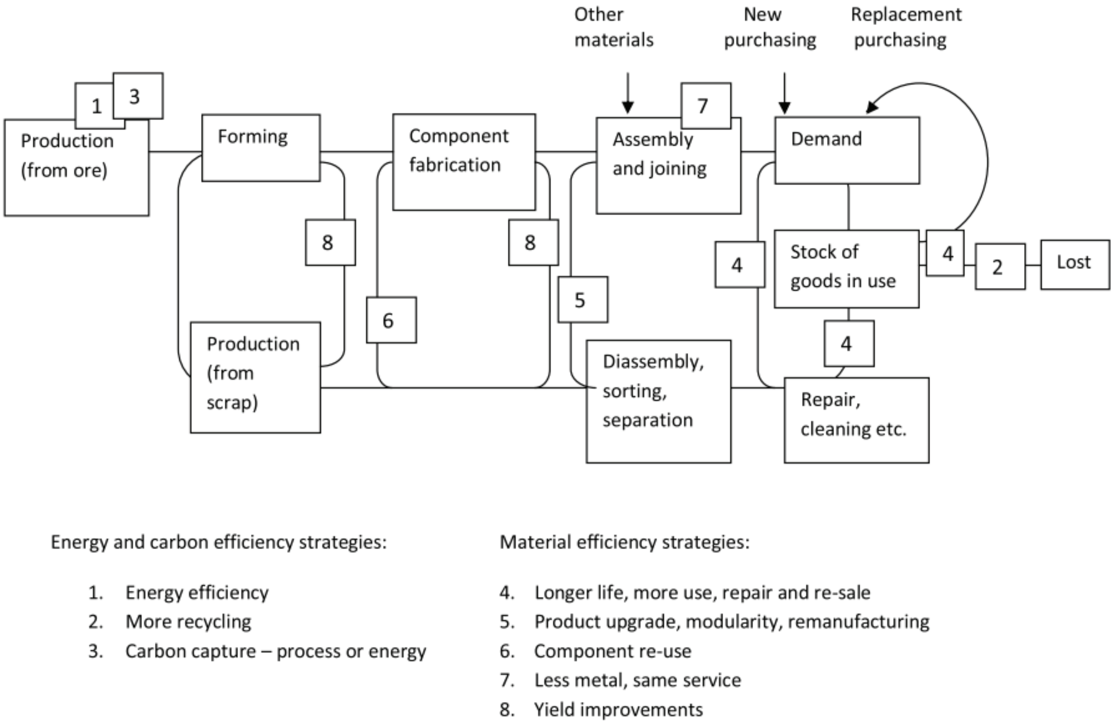


Figure 3. Conventional and material efficiency options [1].

In the raw material production phase the most important strategies are energy efficiency of the production and the carbon capture of the process or energy generation. In the forming phase of materials and in component fabrication, yield improvement is the main strategy, e.g. by using scrap or other waste flows of production processes. The re-use of components in manufacturing is also possible. Strategies concerning assembly and joining are modularity, remanufacturing and product upgrading. The product might also be manufactured using less materials, but without weakening the product's properties and functions. The strategies focused on the usage phase of the products are longer life and more use of the goods, and repair and re-sale of the product. If the product cannot be repaired, or its components and materials cannot be utilized in manufacturing the original product, improving the recycling rate with the same use of energy can be a strategy. [1]

Material efficiency and energy efficiency are often causally related. Although the definitions of energy efficiency are clear compared to material efficiency, the complex industrial sites and energy flows, multiple products and variable production rates make defining and measuring the energy efficiency difficult in practice [79]. In the most used frameworks of eco-efficiency by World Business Council for Sustainable Development (WBCSD) [80] and Müller and Sturm [81], the common items include energy consumption, water consumption, greenhouse gas emissions, ozone depleting substance emissions and materials consumption or total waste [82].

3.5 Public policies and strategies

The case study of this dissertation is situated in Lahti, Finland. To understand the drivers of the regional innovation policies and industrial needs, it is essential to take a closer look at public policies and strategies for material efficiency. Although it is a frequently used term, it still lacks clear indicators and tools for measurements. Concerning energy efficiency, for example, there is a horizontal so-called BREF publication (BREF = Best Available Techniques BAT reference documents) [83]. It covers different branches of industries in the EU and contains information on the best available methods and technical solutions as well as on the consumption and emission levels obtainable by them. The Ministry of Environment and Industry of Finland financed a Best Available Techniques (BAT) publication released in 2008 on national energy efficiency adapted for the Finnish conditions, whose contents correspond to those of the EU BREF [84]. In processing industry, material efficiency is usually determined by comparing the amount of produced waste to the total production as measured either by the value or weight of the production [85].

However, material efficiency is mentioned in several EU guidelines and directives. Already in 2003, the Commission published a communication on integrated product policy (IPP) that emphasized a life-cycle approach, market orientation, the commitment of different interest groups, constant improvement and versatile methods of regulation [86]. The EU Environmental Technologies Action Plan published in 2004 aimed at reducing pressures on natural resources by means of technology. The strategy on the sustainable use of natural resources was published in 2005 and EU's strategy for the prevention of waste and promotion of recycling in 2005. [87] The EU directive on ecological design (EuP) came into force in 2005 [88]. It set environmental design requirements for certain energy-using product groups to allow their free movement in the EU internal market. Furthermore, in 2008 the EU Commission presented an action plan concerning sustainable consumption, production and industrial policy that proposed measures for improving such things as the efficiency of the use of natural resources, supporting of eco-innovations, and utilization of environmental possibilities in business operations [87].

In Finland, the National Programme to Promote Sustainable Consumption and Production (KULTU) [89] was completed in 2005. The new National Waste Management Plan (VALTSU) also contains many guidelines for improving material efficiency [90]. Material efficiency was also discussed in the previous Government programme. In the interim review 3/2009 of the Government programme [91] the following objective was set as an aim: ”*Preparations for strengthening of the coordination of the natural resources policy will be launched with the objective of making Finland the leading country in the sustainable and economical utilization of natural resources and materials*”.

The Natural Resource Strategy for Finland [92] was finished in 2009 by the Finnish Innovation Fund Sitra. The strategy was prepared by a committee which included representatives from politics, administration, business, research organizations and the media. The vision presented for the year 2030 was to be leader in intelligent use of natural resources, to be realized with four key strategic goals: 1) Finland has a thriving bioeconomy generating high added value, 2) Finland utilizes and recycles material flows effectively, 3) regional resources generate both national added value and local well-being and 4) Finland takes initiatives and leads the way in natural resource issues. Six areas of change were defined for attaining the strategic goals; bioeconomy, material cycle, regional activity, international interaction, coordination and administration and expertise, and innovations and communication. [92]

In connection with both the goals and the areas of change it was stressed that the natural resources taken into use by society must be kept within the economic system as long as possible, so that they produce as large added value as possible and that only a minimum amount of valuable materials exit the economic system for good. The use of materials, sustainability of products and recycling possibilities are largely decided in the product design. The strategy also presented eighteen clear change steps and appointed organizations responsible for them. The change steps were related to such things as bio-expertise and business, management of material cycles, as well as regional strategies. The change steps also strongly emphasized product-based resource efficiency. The report made a proposal to establish a national expertise network for product-driven environmental management. It would support the integration of design for the environment (DfE) to business management systems and promote the deployment of EU's integrated product policy (IPP). It also suggested the creation and introduction of products based on material flows and life cycle analysis which would be suitable for the assessment of both material and energy solutions. [92]

The background report of the natural resource strategy [93] strongly emphasized the increased significance of material efficiency. The promotion of material efficiency through product life cycle analyses ranging from the sources of raw materials through processing and manufacture to consumption and utilization after use and final discarding was considered important. The report also stressed that the increasing demand of raw materials and the depletion of non-renewable natural resources as well as the increasing waste management and chemical costs would make the pursuit of material efficiency even more profitable in the future. According to the report, more than a half of a company's variable costs may be incurred directly or indirectly by the use of materials, so it pays for companies to devote increased attention to the systematic rationalization of the use of materials and material flows. Practical measures for improving material efficiency may apply not only to the use of raw materials and improved production methods, but also to the development of innovations across the entire product chain. Companies should exploit this savings potential, by for example, using new technology solutions and business models based on the scarce resources approach. [93]

The report also pointed out that besides direct benefits to companies the development of material efficiency creates opportunities for new kinds of services to develop the overall management of material flows. The services may be related, for instance, to improving the efficiency of supply chains, process control, waste management, resource management services, co-operation between service providers, and eco-efficiency analyses. [93]

In a preliminary survey for the establishment of the Material Efficiency Centre in Finland [94], the promotion of material efficiency was considered to be primarily a task of public administration, because at that moment it was not deemed to be economically viable. In the report, material and eco-efficiency as well as prevention of wastage refer to the same thing, which in retrospect seems a rather tight definition. Central tasks assigned in the survey to the Material Efficiency Centre included the coordination of projects, development and testing of operational models and concepts, provision of expert services, dissemination of information, consulting and training. [94]

The Ministry of Environment ordered a further study concerning the business and operational plans and the start-up programme of the Material Efficiency Centre [95]. Central tasks assigned to the service centre included the role of a developer of service tools and initiator of development on the market of material efficiency services for companies, sector organizations, public service providers and other organizations. Tools in this category included material efficiency audits, operational models, database and information services and so-called best practice models. The study also described the main contents of the operation of the service centre and preliminary budget. [95] Based on the surveys the idea of establishing a national material efficiency centre was presented in the Finnish Sustainable Production and Consumption Programme in 2005, and the unit was established in Motiva in 2008 by the financing the Ministry of Trade and Industry (currently Ministry of Employment and the Economy).

3.6 Materials technology and efficiency in the Lahti region

In the Lahti region there is a lot of manufacturing industry for which materials-technical expertise and material-efficient operation are key competitive factors. In particular, knowing the properties of materials and their processing know-how are part of constant development in many companies. Regarding wood processing technology, Lahti has significant furniture industry. In plastics industry Lahti is still a nationally significant area, although part of the production has moved outside Finland. In the metal products industry, the Lahti region is significant in the processing of stainless steel, manufacture of machinery and equipment for the wood processing industry, welding equipment and rock crushing machinery. In addition, the nationally most significant industrial actor in the recycling and reuse of metal materials is located near Lahti. Besides basic metal industry, the Lahti region has thus materials engineering industry that is significant even on a national scale in almost all material groups and areas of materials technology. [19]

For the industries material efficiency is becoming more critical. Especially in low-tech companies, the continuous development of energy and material efficiency of the production is an important competitive strategy. In continuous processes, like the extrusion of plastics profiles and pipes, the material costs represent a remarkable share of the total costs. Small changes in raw materials prices and efficiencies of the production processes can affect competitiveness dramatically.

University level educational and research expertise in the Lahti region is provided by Aalto University and TUT through their local activities. Aalto is also member in the Lahti University Consortium. Aalto focuses mainly on environmental engineering and related material issues, including the recycling and reuse of materials. TUT's operations cover product-driven development and utilization of material properties. Another actor in the Lahti region, in the field of plastics and plastic products engineering is Muovipoli Ltd, which provides research, development and technology expertise of plastic materials in the region. The university level competence profile of the region is complemented by the research and education activities of Lahti University of Applied Sciences in plastics engineering, wood and wood products engineering and textile and clothing technology. [19]

Materials technology and material efficiency are also part of the public policies in the Lahti region. In the regional plan of the Lahti region until 2035 [8], megatrends have been divided into social, ecological, political-economical and technological megatrends. Technological megatrends include eight trends:

1) role of information technology,
2) nanotechnology,
3) intelligent surfaces and materials,
4) automation,
5) combinations of technologies,
6) alternative energy resources and technologies,
7) penetration of environmental and energy issues to all sectors and
8) green jobs. [8]

It can be easily seen that materials and materials technology are directly or indirectly involved in a majority of these identified megatrends. The identified megatrends for next decades are mainly the same as in literature of early 2000s (e.g. [44; 96]). However, in the SWOT analysis of the regional plan, materials technology is not mentioned.

One of the opportunities mentioned in the SWOT is the development of eco efficiency, as well as design. One of the main aims and strategies is to develop lower energy consumption working and living practices; it is seen as one target that "*material efficiency is improved and that waste materials are returned to natural cycle with micro-local, or macro-sized waste treatment units, where raw materials are refined or degraded chemically or technically for reuse as pure energy, substances, materials, soil conditioner or part of ecological system*" [8]. It is quite surprising that no other technological megatrends except raising of environmental and energy issues can be seen in future strategies.

The competitiveness and economic development strategy for the Lahti region for years 2009–2015 defines the "spearheads" of know-how in the region as 1) environment, 2) design and 3) practical innovations. The vision of the Lahti region is to be Finland's most environmentally efficient and business-friendly area in 2015. Environmental efficiency in the strategy means that "*goods and services are produced with smaller energy and material inputs than before, products are made more long-lived or more suitable for recycling. Thus the efficiency of the use of both material and energy inputs is improved, which creates permanent competitive advantage. In practice, environmental efficiency creates piloting opportunities for new solutions for industrial equipment suppliers and the service sectors, and promotes the emergence of service business for traditional industrial enterprises.*" [7] Lahti Development Company LADEC Ltd (formerly Lahti Science and Business Park Ltd) focuses on the promotion of material-efficient operation, for example, through the national leadership of the Centre of competence for Environmental Technology and the Centre of competence for Housing. The Lahti region is not the only region in Finland with a strategic choice to focus on improving the eco-efficiency. A big challenge in regions is to find an apposite methodological approach and design reliable indicators to measure the development of eco-efficiency [97].

3.7 Plastic streams in the Lahti region

The Lahti region hosts one of the biggest agglomerations of Finnish plastics industries. Approximately 40–50 companies, representing 7 % of Finnish plastics companies are located in Päijät-Häme. Plastics industries in the region employ almost 1,300 persons, with a turnover of 282 million Euros (2011) [5]. In Finland the plastics industries employ 14,000 workers with a turnover of 3 billion Euros [98]. Plastics are the main engineering material in the Lahti region together with metals. Because of the unique characteristics and challenges related to the processing, use and recycling of plastics materials, also on the regional level, the plastic streams and industries of the region are viewed in more detail in this chapter.

The most important processing method in the region is extrusion. It is a melt processing technology for thermoplastics. In the extrusion process, the raw material is fed to the extrusion barrel, where it is plasticized with heat and a rotating screw. The melted plastic material is extruded through the die and cooled down with water or air. The extrusion method is a continuous process, used in manufacturing different profiles, pipes, sheets and films. The other main manufacturing technology of plastic products is injection moulding. In the injection moulding method, the plastic raw material is melted in the screw barrel like in the extrusion process. After plasticizing the material is injected through the nozzle to the mould with high pressure. The plastic part is cooled down in the mould and ejected. Extrusion and injection moulding processes are mostly used with thermoplastics, but they can be also applied with some thermosets. In addition to these two main production technologies, thermoforming and blow moulding are also in use in the region. Blow moulding is used in manufacturing plastic bottles and other hollow products. In thermoforming, plastic sheets or films are formed in an elevated temperature with a mould giving the desired product shape to the sheet. For example, different kind of panels, packages and covers are manufactured with thermoforming. Out of the main processing technologies only rotation moulding is not applied in the Lahti region.

The most general plastic raw materials are polyolefins; polyethylene (PE) and polypropylene (PP). The most important polyethylenes for plastic industries in the Lahti region are PE-LD, PE-MD, PE-HD, PE-LLD and PE-X. Other thermoplastic raw materials used by the industries on the region are e.g. PS, PET, PVC, PMMA, PC, PA, ABS and POM. Thermoset materials used in the region include PUR, UP and EP. Some high performance, special plastics are also used, such as PSU, PPSU, PES, PEEK and PTFE.

One benefit of thermoplastics is that they can be re-melted and re-shaped with heat and pressure to a new form. It means that thermoplastic production waste can in many cases be recycled and used as raw material in the same or another manufacturing process. The waste material can be crushed and used in a manufacturing process, typically as blend with virgin raw materials. The waste or side flows of the extrusion and injection moulding process are e.g. the mould channels, side cuts, flashes, materials and products from ramp-ups and other non-marketable products. In some cases the material should be washed and granulated before use. These services are quite often subcontracted. If the product is manufactured from one plastic, the recycling is quite easy and very commonly used option. In some manufacturing processes, all material can be used and no waste is created. By contrast, the recycling of the products, which are manufactured from several materials or plastics is more difficult. If there are metallic inserts in the product, removing them increases the recycling costs. If the product is manufactured using two or more plastics (composite or hybrid structure), it makes recycling more complicated, because different plastics require different processing parameters, like temperatures and pressures. For example, where the processing temperatures of PE-LD can be 160–180 °C, PA starts to melt at approx. temperatures over 220 °C, which makes their joint processing impossible in general. Typical hybrid structures are multi-layer films for food packaging. The separation of the plastics from the hybrid products is often very difficult and expensive. Because plastics are melt-processed the phases are often at least partly joined or bonded. Some separation methods are e.g. mechanical, thermal and chemical separation. Methods based on the properties of material are also used, based e.g. on density or colour.

Sometimes the plastic production waste (pre-consumer plastic waste) needs washing and granulating before use. These services are quite often subcontracted from recycler companies. Recycling companies deliver recycled plastics back to the original production unit, or sell the material to another user. In the Lahti region there is only one plastic recycler company. The main part of the pre-consumer plastic waste is delivered to be processed outside the Lahti region. The materials which cannot be utilized as recyclates are mainly delivered to energy utilization. Most of the plastics are highly suitable for energy production purposes. The heat values of plastics are at same level as that of oil.

The elementary MFA of plastic streams of the region is presented in Figure 4 on page 57. The figure shows the plastic inputs and outputs of the region, and the streams created and processed in the region.

Input flows of plastics to the region consist of products, components, raw materials and plastics waste. The raw materials used by the plastics industries typically come as granulates from the raw material producers, in the case of thermoplastics. Thermoset resins are delivered as two-component liquids, including resin and hardener. Some biopolymers are used in production in small amounts. Plastic components used by machinery engineering industries are typically outsourced from plastic product manufacturers, or the plastic parts are machined as such from semi-finished plastic products (sheets, rods etc.). The plastic products traded to the region include plastic pipes, other construction plastics, and plastic films. Typical products containing plastic parts are e.g. food packages, vehicles and electrical and electronic equipment.

Concerning the output flows of the plastic raw materials from the region, there is no manufacturing of thermoplastic raw materials in the Lahti region. There are some companies which offer recycled plastics. Some semi-finished plastic products, like films and sheets are traded.

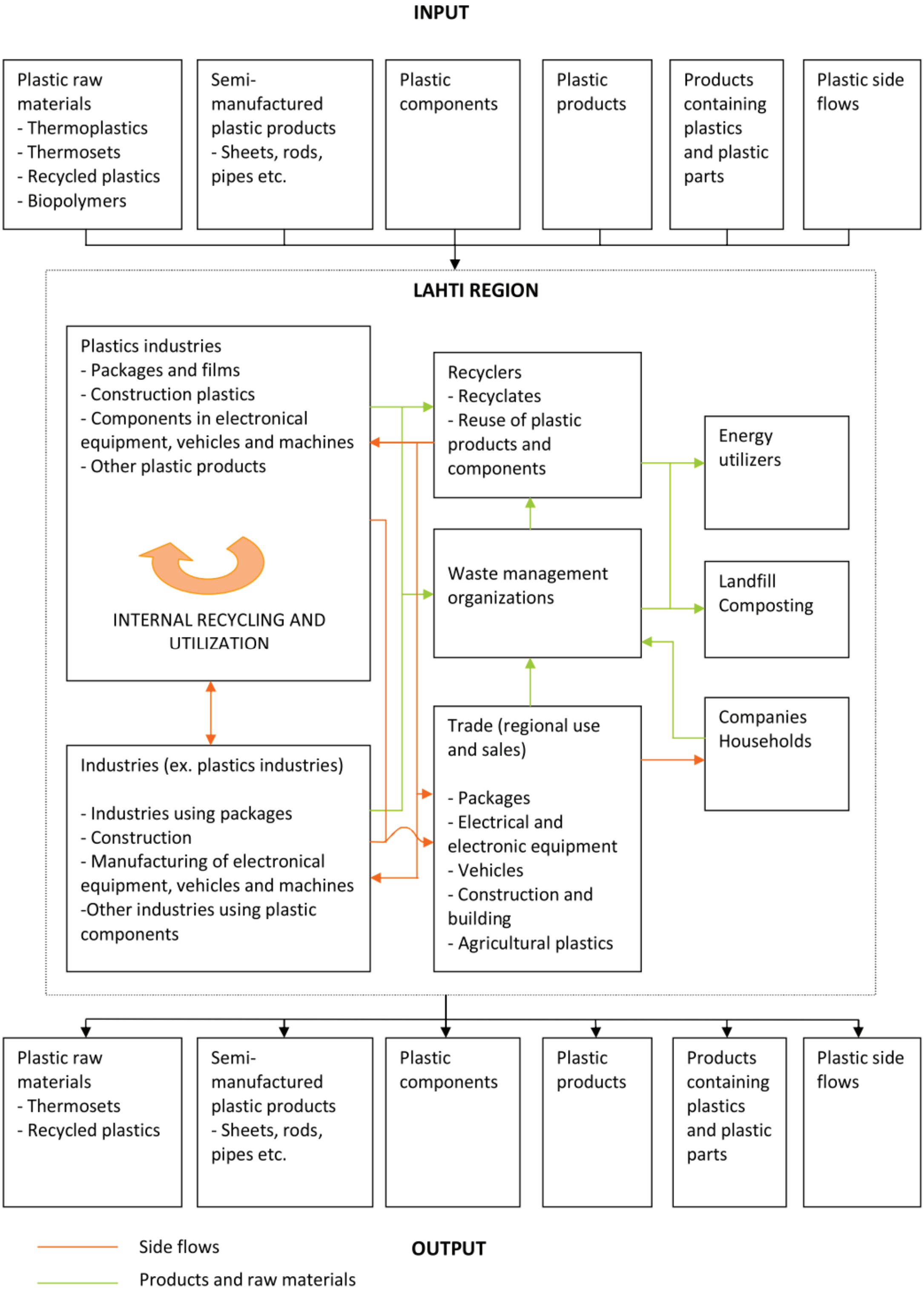


Figure 4. An elementary material flow analysis (MFA) of the plastic streams in the Lahti region [20].

The main internal plastic flows in the Lahti region from the point of view of industry are the production output and waste. The production waste of plastics industries consists of the waste created in melt processing stages and other process stages, e.g. in cutting and printing. By the utilization of plastic waste as material is typically meant the mechanical recycling of the waste. However, also in the reuse of the product or product part, the material is saved and used again, but without any material destructive handling. The possibilities of reusing plastic products at the end of the product lifecycle after the use phase are quite limited. Reuse is an option for some products for distribution purposes and packaging. With mechanical recycling the pre-consumer plastic waste or materials of post-consumer end-of-life products can be processed and used for their original or other purposes. The plastic production waste flows of industries are generally quite easy to recycle mechanically because of their purity and properties, which are usually well-known.

With plastics of municipal solid waste (MSW), recycling is much more complicated. The main problems of plastic waste streams of MSW are impurities and heterogeneity. Often energy recovery is the only option. Chemical recycling is not used in Finland because of high the investment costs compared to the relatively small amounts of plastics wastes. Plastics industries can utilize their production wastes

- straight in their own manufacturing processes without any additional processing stages,
- in their own processes with additional processes, like crushing, granulation or separation stages,
- in their own processes but with subcontracted treatment of their own product waste, including generally e.g. crushing, washing, separating and granulation processes or
- by using waste material of other manufacturing units or factories in their own production.

In the last option, material can be bought straight from another unit or from a plastic recycler. Recyclers can sell either recycled material, or they can sell products manufactured from recycled material. Buying plastic waste straight from other production units or factories is quite rare in Finland. Such co-operation between factories usually occurs in the regional context, because transporting of waste materials easily increases the cost of material too much compared to virgin materials.

The waste flows, which are used in the same production unit where the waste flow is created (internal recycling), depends considerably on the raw materials and the production technologies used. Industries using thermoplastics can recycle internally even up to 90 % of their wastes. Very challenging materials are composite and hybrid structures, whose use as recycled material is limited by the high separating costs, risks to the production equipment (e.g. metal inserts) and process stability (heterogeneity of the flows).

Because of the high caloric value (heat value) of plastics, the use of plastic waste in energy production is a generally used option. Energy can be produced in the form of steam, heat or electricity. Waste plastics can be recovered by blending them with other fuels or as such. Energy recovery is an option when the use as material is not economically or technologically possible or reasonable. Only very small part of the plastics waste of industry is landfilled. The industrial flows which are not utilized as material, are recovered as energy at a high rate. Because waste plastics are highly suitable for energy production, there are also some markets for this kind of waste.

The total amount of plastic waste in Finland is estimated to be 162,000 to 217,000 tons per year. The main waste stream containing plastics is the municipal solid waste. Most of the plastics in MSW are plastic or plastic containing packages. Other waste streams containing plastics are waste electrical and electronic equipment (WEEE), plastics in end of life vehicles (ELV), plastics in construction waste and agricultural plastic waste. [99]

In Finland, 49,000 tons of WEEE was created in 2007. In WEEE, about 22 % are plastics, both fire resistant and non-fire resistant plastics. [100] In Finland, approximately 65,000 cars were scrapped in 2012. In ELV, 9.1 percent are plastics (by weight) [101]. There is a major WEEE and car recycling company (Kuusakoski) located in the region.

In Päijät-Häme, the amount of landfilled waste has decreased remarkably (62 %) in the last ten years. In 2010, 22,000 tons of waste were landfilled, containing mostly MSW, industrial waste and construction waste. In Lahti region, the energy utilization of the waste decreases the amounts of landfilled waste. A great part of this energy waste is plastics. In 2010, 30 % (26,193 tons) of the total amount of municipal waste (87,311 tons) was utilized as energy in the Lahti region. [5]

As a summary in Päijät-Häme, the main plastic flows consist of the industrial flows and the municipal waste flows containing plastics. Industrial plastic waste is utilized as material or goes to energy utilization. The industrial plastic waste streams ending up to landfills are small. Industry based plastic energy waste is typically quite free of different contaminants, but its utilization as material is difficult, because the streams are heterogeneous. The main potential mechanism to improve the material efficiency of industrial plastic flows in the region is to find new streams, which could be utilized as material instead of energy recovery. These kind of actions are also in accordance with the waste hierarchy of the European Union. The plastic wastes of other industries than plastics industries are mainly tooling waste from giving final form to semi-finished plastic products. They go to energy utilization or are landfilled. The amounts are insignificant compared to the total amounts.

Post-consumer packages are the main plastic-containing waste group in household waste. The main problems for material utilization of the household plastic waste are contaminations and heterogeneity. Material utilization is seldom possible or profitable from the economical or environmental points of view. In the region the household packaging waste is mostly utilized as energy because of a separate collection system. The separately collected package waste from the sector of trade and logistics is rather clean and more homogeneous than household package waste. Material recycling is an option in some cases. The utilization of such waste as material has increased in recent years.

Despite the fact that the amounts of WEEE and ELV wastes created in the Lahti region are rather small, these streams are important to the region because there are significant recycling industries in the region. WEEE and ELV streams are also interesting because of the fact that recycling rates and targets will be tightening in Europe in the near future. For example in cars, the recycling targets can no longer be fulfilled by recycling other material than plastics (e.g. metals, glass and rubber). The utilization of plastic parts as material instead of energy recovery will become more general. The development of practices, processes, equipment and applications for plastics of waste cars is important in the future.

4 Innovation processes and systems

Innovations are connected to individuals but also to organizations. They can be for example technological, organizational and social. Traditionally, innovations were seen as unidirectional linear processes from fundamental research to applications, where each level produces outputs to the next level as inputs, but the current theories of innovation stress their existence as a result of co-operation in normal economic and social activities [18].

Kline [102] points out that successful innovation needs to satisfy both technical and market needs. A large part of patent innovations is never realized as a product, and vice versa, many beneficial characteristics of products cannot be realized because of technical or technological limits. In the innovation process, both technological and economic considerations are involved in a complex and variable system. [102] In industrial society the users and producers of innovations are often separated in innovation activities, especially in product innovations [103]. In modern innovation processes, the role of consumer is increased, and research and science are no longer seen as the main driving force in creation of new innovations [104]. In science and engineering, the research trend with new innovations is often built up at the confluence of other areas of R&D, launched by a scientific breakthrough or/and a societal need. For example, nanotechnology is originated from a better understanding of materials, chemistry, biosystems, simulations etc., and pushed forward by the societal or functional need to improve the products; space research is based on the needs of defence and global competitiveness and developments in jet engine, advanced materials and aeronautics. [96] Technological innovations are most commonly classified in technology, process and product innovations [105].

Innovations can be explored from different perspectives: the technology, or the company or other unit which exploits the technology. They might impact to individuals, the company or the whole industry or supply chain, being the social perspectives of innovations. Identifying the perspective of innovation is necessary to avoid misunderstandings and disagreements in analysis. [105] Innovations can also be characterized by their radicalness as technological, market and high-business level radicalness, related especially to the social dimension of innovations [106]. According to Sainio *et al.*, technology orientation affects all dimensions of radical innovations positively, whereas a customer relationship orientation has an effect on market and technological radicalness [106].

Because of the social nature of innovations, collective learning and the ability to interact and build up trusting relations between the innovating partners are required in co-operation processes [45]. The functioning of an innovation network instead of an individual's activities is more critical for innovativeness according to the current innovation theories and politics, promoting multi-actor, non-linear, interactive innovation processes and networks [45; 107]. Because of the complexities of these networks, innovations are hard to measure effectively [102].

4.1 Innovation systems

The industry-based approach is a commonly used approach in regional development work despite its limitations. Industries are seen as groups of companies in the same part of production chain. Because companies see each other as competitors, the co-operation level is low. [10] The cluster models have been the main working way of regional innovation policies. They are strongly based on Porter's work on the cluster theory. [10; 45; 108; 109] Porter defines clusters as "*geographic concentrations of interconnected companies and institutions in a particular field*". Clusters can be e.g. national, regional and state level economics with critical masses on unusual competitive success. Clusters include linked industries and other important entities for competition, like suppliers and infrastructure providers. Porter uses California's wine cluster and Italian leather cluster as examples. Clusters affect competition in three ways: 1. increasing the productivity of constituent firms and industries, 2. increasing the capacity for innovation and productivity growth and 3. stimulating new business formation that supports innovation. All these three influences depend on personal relationships, communication and interaction networks of individuals and institutions. Because the boundaries of clusters often cross the traditional industrial classification borders, they might be even hard to recognize. [108; 110]

Theories of regional innovation systems (RIS) have recently challenged clusters. It has been indicated that sharp focusing on one cluster does not develop regional competitiveness most effectively, and that regions with co-operation and synergy benefits of different industries are succeeding better than regions having a development focus on different industrial sectors without networking [10; 108; 109].

When innovations are characterized as processes in normal social and economic activities, the innovation environment and system are also under interest. A regional innovation system is a social system consisted of innovation networks located in a certain geographic area. They consist of universities, companies, development and education giving organizations, technology centres etc., aiming systematically to increase the innovativeness of a region. [16; 111-115] Cooke presented a systematic account of the idea and content of regional innovation systems, as well as the analysing conditions and criteria for empirical recognition [116]. The concepts of regional innovation systems were mainly originating from economic geography and regional science. Cooke analyses regional innovation systems with five key concepts: region, innovation, network, learning and interaction. By analysing these dimensions against the knowledge flows among firms and intermediaries (interactive governance), and against interfirm networking and learning it can be determined whether the system exists. Cooke sees several conditions for RIS potential. Infrastructural issues include regional public and private financing competence, controlling and policy of hard infrastructure, and knowledge infrastructure such as universities, research centres, science parks and technology transfer organizations. Regions having a higher RIS potential have a regional university–industry strategy, as compared to piecemeal innovation projects in lower RIS potential regions. Superstructural characteristics are divided into the institutional dimension, such as co-operative culture and interactive learning, into the organizational dimension for companies, e.g. worker mentoring and harmonious labour relations, and into the organizational dimension for governance. Cooke was stimulated by the regional problems caused by industry restructuring and low innovativeness, including Wales, where metallurgical and mining industries had been globally significant innovators, but which was at the end of its “region product life cycle” [116; 117]. The system of resource configurations and dynamic capabilities in regional innovation system by Harmaakorpi is presented in Figure 5.

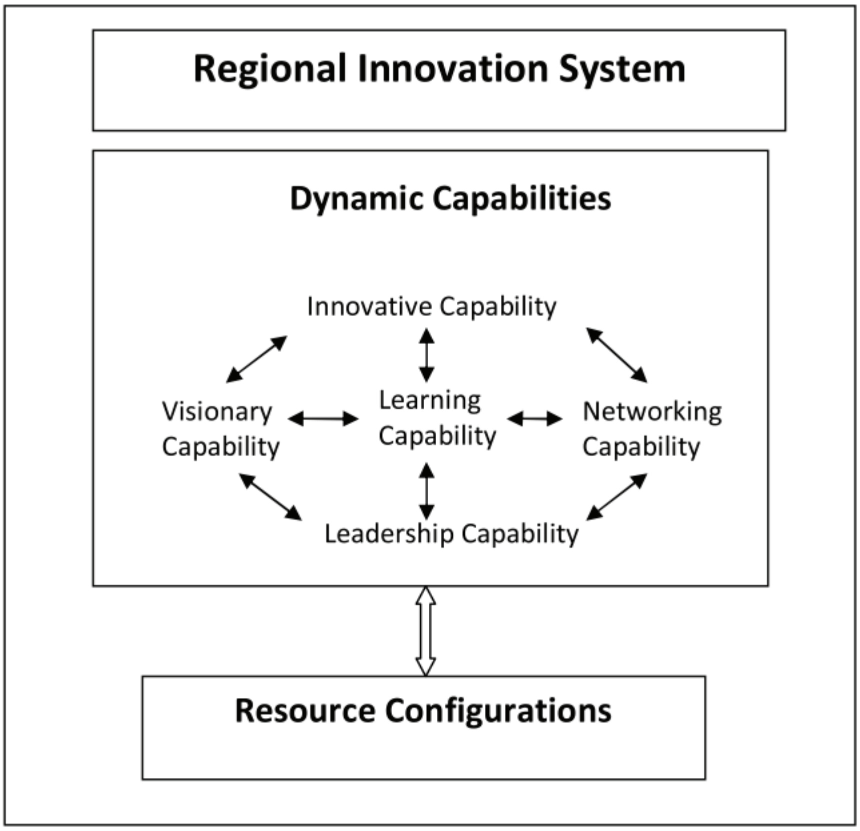


Figure 5. Resource configurations and dynamic capabilities in a regional innovation system [45].

There are also other defined innovation systems. Many of the systems are defined on a geographical scale. The national systems of innovation (NSI) frames innovation activities on the national level, including industries and companies, universities and other organizations, setting up scientific and funding priorities and other innovation policies [104; 117; 118]. Sectoral or thematic innovation systems are systems that can be defined as a set of products, individuals and organizations carrying out interactions for the creation, production and sale of those products and having e.g. a specific knowledge base and technologies [45].

Proximity is also closely related to innovation systems. The focus of innovation systems is often on geographical proximity, and Boschma [119] identifies five dimensions of proximity: cognitive, organizational, social, institutional and geographical proximity. He argues that also the other dimensions of proximity than the geographical one provide solutions for learning and innovations. Each dimension has positive and negative characteristics related to knowledge gaps, control of systems and individuals, trust (based on social relations or common institutions) and distance. Both too much and too little proximity may have negative effects on innovation.

4.2 Practice-based innovation policy

The open innovation model refers to an innovation network, where changing of thoughts and ideas freely plays the main role. In the open innovation model practical and theoretical knowledge is brought together systematically, so that problems are analysed and solved in a practical context. [10] The research and science is only one point of view in innovation processes. They are activated by several factors and take place in the multi-actor innovation networks. These processes are called the practice-based innovation processes. They can be defined as "*innovation processes that are triggered by problem-setting in a practical context and are conducted in non-linear processes utilising scientific and practical knowledge production in cross-disciplinary innovation networks*". [9] Combining knowledge from different disciplines and interests and knowledge interests from theory and practice are needed in such processes. In practice-based innovation processes the role of experts is different than in traditional knowledge-based innovation systems. The experts have to be interactive partners in the collective learning processes leading to successful innovations, instead of pure sources of information. The key issue of practice-based innovation processes is that innovations are created at unpredictable interfaces. [9; 107]

The term "practice-based" does not mean that innovations arise just from practical ideas. It means that the main challenges, problems and possibilities are defined in practical context. One characteristic is that it focuses in the front-end phase of innovation process. [10] Practice-based innovation processes can be seen important to companies and industries because of the connection between the business innovations and the practical business. A special challenge is to recognize the innovation potential based on technological development or changes in markets and customers and transform it to new business opportunities. Important is how innovation systems can support companies in the early stages of innovation processes, where the innovation potential can be found more often in the changes of the business environment, markets and customer interface than in technological development or commercialization of the research results. [23; 107; 120]

According to Harmaakorpi & Mutanen [121], in practice-based innovation processes knowledge production occurs in groups of people that have a common interest determined by the practical context in which the group is working. These people often have very different backgrounds and points of views; therefore also the specific problem they have in mind may differ, although they solve their problems within the same context. However, they have to have a common dialogue in a knowledge production process. [121]

In practice-based innovation models, the role of the scientific-technological knowledge can differ remarkably in connection with the creation of new innovations. Typically, universities have a less central role than in the traditional innovation activities, focusing on applying the scientific research results. However, universities usually still rely mainly in the production of research information, lacking suitable methods for supporting practice-based innovation processes. [121] There is need for a new kind of expertise and concrete tools for promoting and enabling the cross-boundary (cross-institutional, cross-sectoral, cross-regional etc.). innovation processes and for breaking the unidirectional linear processes from fundamental research to applications [107].

4.3 Innovation policy in the Lahti region

The Lahti urban region is the fifth largest region in Finland, and it has long been one of the most important industrial centres in Finland. For example the furniture and plastics industries and manufacturing of machinery and equipment have been significant employers in the region. The region suffered heavily from the economic recession in the 1990s with major changes in its social and economic structure. The rate of R&D investments is also relatively low in the region. [122; 123] At the industrial point of view, it can be seen that the Lahti region has characteristics of a mature technology ”branch plant” region, described by Cooke [117].

The scientific resources in the Lahti region are quite limited to produce new radical innovations. A local higher education infrastructure, currently consisting of Lahti University of Applied Sciences and Lahti University Consortium has been built in the last 30 years. However, Lahti is the largest Finnish region without its own university, although the Lahti University Consortium is a network of the local branch units of three Finnish universities. The relatively low R&D intensity, the middle-size of the region, the networked structure of the regional knowledge base and the closeness of the most competitive Finnish regions have given rise to a characteristic innovation policy model, which the region has systematically built up since the 2000s, based on the network-facilitating, practice-based innovation policy [107].

Tura & Harmaakorpi [107] see at least two main reasons for this strategic focus. The first is connected to the availability of regional resources. The network-facilitating innovation policy aims to multiply the resources attainable for the region. The focus is on searching of innovations especially from the interfaces of the different branches of regional economy and from the interfaces of the knowledge bases inside and outside the region. Second, expanding the point of view from the regional to the national level with this kind of policy model, it is possible "*to ensure the competitiveness and innovativeness of the regions without giving up the aims of the national innovation policy connected to the concentration and specialisation of the national knowledge infrastructure*". [107]

The innovation strategy presented in 2005 diverged from the strategies of other main cities in Finland; in other strategies the development of the innovation environment, strengthening of knowledge structure and trust to the power of research activities were the key elements (Table 9). [9; 10]

Table 9. The main differences in innovation strategies between Lahti and other university-containing main city regions in Finland [10].

Other main city regions in Finland	**Lahti region**
"Economy of greatness"	"Economy of mid-size"
Research-based innovation processes	Practice-based innovation processes
General networking rhetoric	Concrete tools of networking
Research-based university policy	Practice-based university policy
Human capital	Social capital

In the Lahti strategy, the main resources were addressed to promoting the linking of the best available knowledge to concrete, firm-based innovation processes. The aim was to become nationally the leading region in practice-based innovation processes. [9; 10]

4.3.1 Tools of practice-based innovation processes

There are several tools of practice-based innovation processes, which are applied in the Lahti region as part of regional development work by companies, research and development organizations and the public sector. In this chapter, some tools are shortly described. The most important tool for this dissertation study, the advisory professorship model, is described in the next chapter (Chapter 4.3.2).

The *innovation session method* is a process-like method meant for companies and organizations. The aim of the method is to produce, evaluate and further develop new innovation ideas, having its focus in the early stage of innovation process. With the participation of companies, experts, researchers and innovation operators new knowledge intensive business is promoted. The basic idea of the method is that the innovation potential is found in the interfaces of different industries and expertise fields by recombining know-how, research fields, technologies and industrial sectors to practice-based problems and challenges. [10]

The *innovation net* is a systematic method to find innovation ideas, which arise in normal actions inside an organization. Usually the organization culture and normal innovation promoting systems do not support the development of floor-level ideas. [10]

The *resource-based foresight process* is realized as a part of updating the regional innovation strategy. In the first phase the critical points of a region, as well as the megatrends and weak signals of the operational environment are identified. In the second phase the critical points are taken out of the regional context and analysed by outside experts, after which they are returned to the regional strategy process work. Technological foresight and the adaptation and modification of future knowledge in a user-based context play an important role in the process. [10; 124]

The innovativeness of an organization is usually measured by analysing the outputs (e.g. patents) or inputs (R&D costs) of the organization's innovation activities. The *measurement of innovation capability* means an attempt to analyse how the innovation system is functioning inside organizations; to analyse what happens between in- and outputs. The valuation model includes e.g. the evaluation matrix of innovation capability on the regional and company level. *Innoclub* is a co-operation forum for collective learning and promotion of research and development activities. It is based on thematic workshops on company-based cases. The main aim of the *innolink* method is to identify and develop practices for companies to find, develop and utilize ideas by utilizing the knowhow of organizational and individual learning mechanisms. [10]

4.3.2 Advisory professorship model

A model of *advisory professorship and innovation promoter* was introduced in the regional strategy of higher education in Lahti for the development of the regional effectiveness of the Finnish university system. It has been one of the most promising new models for university–industry co-operation developed in the Lahti region. The tool is a key application of the network-facilitating innovation policy, aiming to strengthen the links of the regional university and polytechnic activities to the regional innovation processes, and to the sources of high-level national scientific expertise. Building up co-operation and knowledge transfer with strong research centres in Finland is a way to integrate them to the regional innovation system and the practice-based innovation activities. The research fields essential to the Lahti region are linked to regional innovation system by forming strategic alliances with the university faculties, departments and professors. The advisory professors are university professors linked to the regional innovation system between the region and the allied universities and their faculties. The innovation promoters at the polytechnics are the experts in the network-facilitating innovation policy methods making links between the knowledge in their own organizations to the innovation processes and participating actively to the regional innovation processes. [107]

The advisory professorships are based on strategic co-operation relationships between the regional university players and the departments of Finnish or foreign universities, so called advisory units. A professor of advisory department is named as an advisory professor, with the main aim to formulate relevant research activities and groups based on the local needs and resources from the public and private sectors. The strategic co-operation relationship means that there is a long-term common will that advisory professors and departments are part of the regional innovation system in the Lahti region, and their knowledge will be utilized in concrete, regionally important research, development and education projects. [23]

The purpose of the strategic co-operation relationships and their resourcing is to provide the transfer of the high-level knowledge of the parent university to regional practice-based innovation processes, not to support the advisory professorship as such, or support the basic research. The financing of the advisory professors is targeted mainly to the advisory department, and it can be used either to support the regional actions of advisory professor or his/her researchers or research group. The financing input to each advisory professorship is terminable and meant for the build-up phase of the strategic co-operation. After the launch-up the co-operation is resourced mainly through other, more common national and international R&D financing instruments. [23]

The advisory professorships are typically financed by public and private sectors. It is an example of the ”Triple Helix” innovation approach. It underlines the importance of university–industry-government interactions in innovation processes [117; 125]. Cooke describes that in the Triple Helix “*entrepreneurial universities would increasingly see growing demand for knowledge transfer to industry, and through government, to society*” and further, “*it is proposed that industry and government will be prepared to pay more for privileged access to knowledge-based growth opportunities by funding more research, stimulating closer interactions among the three institutional partners, subsidising infrastructure (e.g. incubators and science parks) and stimulating academic entrepreneurship skills and funding*” [117]. Cooke takes one example from South Ostrobothnia, Finland, described and analysed by Sotarauta & Kosonen [126]. The Epanet-network in South Ostrobothnia is a co-operation network of Finnish universities, regional organizations and companies. The network contains professorships from at least six universities from Finland, which have founded research groups around research areas prioritized by regional players. [126] By Cooke, these new approaches “*recognise the weakness of universities per se as knowledge transceivers, but the centrality of research knowledge to future regional development potential*”. [117]

The advisory professorship model also displays characteristic features of the “knowledge activists” by Krogh *et al.* [127] and of the ”knowledge shuttle” described by Sotarauta *et al.* [128]. Knowledge activists are promoting the transfer of knowledge inside organizations. The knowledge shuttle means a person or group, which takes the responsibility to transfer and create new knowledge. The main aims of the knowledge shuttle are to act as a catalyst for creating new information, as a link between different actors and processes, and as a “salesman” and “adapter” of foresight information. [127; 128] The concept and actions of technology or knowledge brokerages [21] also have similarities with the advisory professorship model.

4.3.3 Regional innovation platform method

Harmaakorpi has described a regional development platform method (RDPM) for regional development in several publications [10; 45; 109; 120; 124; 129]. It has been applied in the Lahti Region, Finland in the beginning of the 2000s, when it was developed to support the regional competitiveness policy. The main reason to present it in this thesis is that there were interesting results connected to the research area of this study. By Harmaakorpi, regional innovation/development platforms may be defined “*as regional resource configurations based on the past development trajectories, but presenting the future potential to produce competitive advantage existing in the defined resource configurations. The central power of the development platforms can be found in exploiting distance as innovation potential, but synergy in the platforms is emphasised in terms of related variety”.* RDPM is based on theories of innovation systems and evolutionary economics, and it strongly stresses the meaning of informal and formal institutional structure in regional development processes to find new resource combinations. The concept is related to cluster theories, but its focus is more on the future potential of existing clusters and regional knowhow than in describing existing clusters. [10; 45; 109; 124; 129]

The regional development platform method consists of eight phases: 1) Analysis of the changing techno-socio-economic paradigm and benchmarking through the assessment of regional innovation system theories and conventions, 2) background study of the industries and areas of expertise in the region, 3) expert panels, 4) assessment of future scenarios, 5) definition of potential regional development platforms, 6) conceptualization of the regional innovation system, 7) search of core processes of the regional innovation system and 8) definition of the knowledge creation and management system. [9; 45]

The RDPM model was applied in Lahti in the beginning of the 2000s. The process is precisely described in literature [45; 109; 129]. In the analysis of statistical and empirical information, plastics, furniture and mechanical industries were seen as the strongest industries in the Lahti region. When the results of the analysis were assessed through megatrends, the most important potential resource configurations were, for example, the plastics industry combined with design and environment expertise and the visible development of materials technology, furniture industry combined with design expertise and ageing of people, machine and metal products industry combined with mechatronics and quality expertise and the development of nanotechnology, etc. The regional innovation system was conceptualized on the basis of the analysis. The expertise concept of the innovation system consisted of higher education services and the Science Park. The higher education services included the Lahti University Consortium together with Lahti Polytechnics. Lahti Science Park was suggested to be formed from the development Centre of Lahti (Neopoli Ltd), the Plastics Development Centre (Muovipoli Ltd), IT-Centre, Institute for Design Research, business incubators and the Centre of Excellence in Social Welfare. As a part of the work, thirteen core processes were defined to utilize the potential of the platforms. The development of plastics and materials technology was one of the core processes. [45; 109; 129]

4.4 Role of universities in regional innovation policy

The universities are in continuous changing interaction between the surrounding society and region. The role of universities in the creation of the regional competitive advantage has been analysed in literature e.g. through learning regions and regional innovation systems. [17; 113; 120; 130-134] In traditional regional innovation policies, universities have been very important factors in building a competitive advantage for successful regions in the post-industrial society, where success is strongly based on expertise and knowledge. The strengthening of innovativeness and innovative capability has become an important factor in creating a regional competitive advantage. There have also been internal changes in universities as a reaction to the new expectations. [23; 135-140]

Universities and their environment are changing towards closer substantial and practical connections with each other in new integrated and combined ways. Universities are part of the knowledge infrastructure, giving constructed advantage to the regions. Regional knowledge-based developments need interfaces between regional economy, governance, knowledge infrastructure and community and culture. [141]

The regional activities of universities have also been on focus in Finland, where they were brought up both in legislation and in the evaluation of university activities in the interaction of regions and the universities. [23; 142-144] New legislation concerning universities was affected by the growing role of the universities in the development of national, international and also regional innovation systems. The strengthening of the regional societal role of universities during the 1990s is not just a Finnish phenomenon. [17; 145-147] Regional activities and commitment are no longer a less important strategic option on the way to national and international success [107].

Regional success does not depend on the presence, size or scientific quality of universities. There are examples of small-sized universities affecting the well-being of their environment remarkably but also contrary examples. [23; 148-150] The regional effectiveness of universities seems to depend on the transfer mechanisms between a university and its surrounding region and its presence in the region with basic activities [107].

Tura [17] used a mechanism-based approach to analyse the dynamics of the regional effectiveness of universities. He used the analysis of Storper [16] about the traded and untraded interdependencies between a company and its environment. By Storper, traded interdependencies are dependencies of the availabilities of such things as raw materials, capital, subcontractor and markets. They partly explain the rationality of local agglomeration. Agglomerations also produce several informal local interconnections, including common values, norms and language, etc. These interconnections are called the untraded interdependencies, decreasing the indirect transaction cost by enabling more efficient behaviour [16]. According to Tura, there are at least four central traded mechanisms of regional effectiveness of universities:”

- *delivery: efficient transfer of knowledge, experts and education,*
- *accessibility: easily and efficiently reachable contacts to university,*
- *sharing of resources between university and region, and*
- *matching between demand and supply.“* [17]

By Tura, untraded-type effect mechanisms are the effects created by universities, being a part of the technological trajectories which cannot be transmitted from one region to another, including “*access to the local tacit knowledge base, social capital, access to the common cultural heritage, and common normative ground and “language” between university and region.*” On the basis on this classification, Tura sees two main policies in the development of university-region co-operation mechanisms. First, the university can develop more efficient practices to transfer knowledge between university and the region. This may mean better availability of the knowledge of the university to the region. The alternative policy is to strengthen the interdependencies related to proximity between the university and the region. This means more continuous forms of regional interactions in social, cultural and organizational network. [17] These two main policies of university–industry-region co-operation can both be recognized in the materials technology advisory professorship programme.

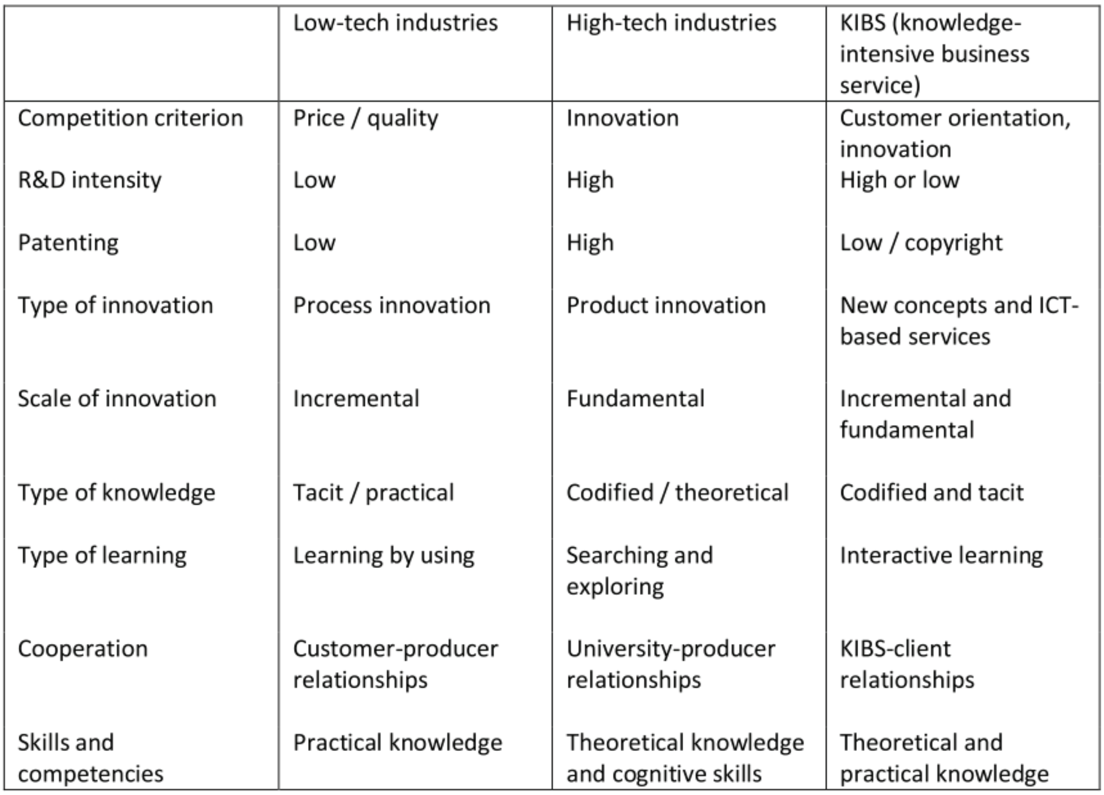
4.5 Innovation processes of industries

R&D expenditures are traditionally the most commonly used indicator in the estimation of innovation activities of an industry or a nation. Albeit they can be criticized quite easily (see e.g. Chapter 4.6.), they are commonly used in OECD-countries, also in Finland. The ratio of R&D costs to total sales is also used when categorizing industries to high-tech and low-tech industries. In high-tech industries, the R&D expenditures are more than 4 % of the turnover, while industries with R&D costs of <1 % of turnover are classified as low-tech industries. Companies spending 1-3.9 % are classified as medium high-tech and medium low-tech companies. [104; 151] However, OECD also remarks that the classification is relative: many manufacturing activities can be considered high-technology but categorized differently when looking at the current R&D intensity. Vice versa, high-tech-companies can also produce low-tech or medium low-tech products. [152]

The characteristics of high-tech industries are the commonness of generic knowledge bases, reliance on new technologies and scientific knowledge, and collaboration with the universities and other research organizations. Traditionally companies have developed research capacity to absorb the information purchased from research organizations. A new approach is that the aim of research capacity is to stimulate a process of joint creation of more fundamental knowledge. The contracts are seen more as rights to access the research organization network than an agreement of certain services, aiming at the exchange of tacit forms of knowledge between industry and research groups. [104; 153]

The characteristics of the innovation modes in low-tech industries, high-tech industries, and knowledge-intensive business services are presented in Table 10. Low-tech industries are mature industries whose technological opportunities may be limited. Their products are often low-complexity type and quite easy to imitate, and technological development processes are less incremental. Patenting is not a generally used option. One key strategy for low-tech companies is to increase the efficiency of production by investing continuously in production technology. The goal is to reduce costs and raise productivity; to give at least temporary advantage in the continuous price competition. The continuous development often realizes as incremental product innovation processes. The business activities are often extensively market-related with e.g. close partnerships with the customers, improved product design, a strong brand name and targeted marketing. With these kind of activities the access barriers for new competitors are created. [104; 154]

Table 10. Innovation models in low-tech industries, high-tech industries, and knowledge-intensive business services [104].



	Low-tech industries	High-tech industries	KIBS (knowledge-intensive business service)
Competition criterion	Price / quality	Innovation	Customer orientation, innovation
R&D intensity	Low	High	High or low
Patenting	Low	High	Low / copyright
Type of innovation	Process innovation	Product innovation	New concepts and ICT-based services
Scale of innovation	Incremental	Fundamental	Incremental and fundamental
Type of knowledge	Tacit / practical	Codified / theoretical	Codified and tacit
Type of learning	Learning by using	Searching and exploring	Interactive learning
Cooperation	Customer-producer relationships	University-producer relationships	KIBS-client relationships
Skills and competencies	Practical knowledge	Theoretical knowledge and cognitive skills	Theoretical and practical knowledge

Furthermore, the technological development in low-tech companies is mainly based on transferring the knowledge created in other industries or research organizations. The companies concentrate on the exploitation of existing technological knowledge instead of exploring new knowledge. Companies have close relations with the organizations creating knowledge: universities, polytechnics, etc. Participation to innovation networks is also quite common. The companies also need to have the capability to absorb information and knowledge, to have a good *absorptive and transformative capacity* of an organization. [154]

Concerning the university–industry co-operation in the linear innovation model, universities were seen as producers of new scientific information, which was refined into new products and processes. The process of knowledge transfer between universities and industries has been analysed by several empirical studies. For example, in some studies the academic results, publication and patents are deemed to be the most important input to the innovation processes of industries. This codified output seems to support actions and adoption of systemic knowledge, for example on fields of materials science and chemical engineering. By contrast, in some studies the collaborative and contracted research activities are seen as the most important knowledge transfer mechanism, especially in the absorption of interdependent knowledge in areas such as computer science and biomedical science. [155]

Questioning of the linear innovation model with the innovation systems approach also meant questioning the role of universities as launchers of technological development processes. Firstly, most innovations are not based on new scientific knowledge but on new combinations of existing knowledge. Secondly, new knowledge does not always lead to new innovations or applications. [102; 156] Recognizing this made policy makers increasingly interested in economical issues and the applicability of scientific results and knowledge exchange between universities and industry [156]. This has also led to new kind of financing mechanisms, where the emphasis is put on a greater relevance and efficiency of research.

One characteristic of the R&D laboratories of industries is that their activities are concentrated on solving the technological challenges of products, which often needs knowledge and information of several fields of science. These interdisciplinary research groups may have problems to communicate with the research teams of universities, which typically represent only one discipline. [157]

4.6 Measurement of innovativeness

The first systematic measures of innovativeness were typically focused on measuring the cost of R&D activities and other inputs of the innovation activities of companies. Later the measurement of innovation outputs, such as patents became general (see e.g. [158]. The input-type indicators are based on measuring inputs to innovation processes, like R&D costs and training and educations resources. The problem of the indicators based on R&D expenditures is that R&D costs do not retain all aspects of relevant innovation; e.g. innovation activities close to the markets are excluded. [159]

Perhaps the best known output indicators are the Oslo Manual and European Community Innovation Survey (CIS). The development work of Oslo Manual was led by EU and OECD and the first edition was published in 1992. It contained survey-based innovation counts focused on the technological product and process innovation in manufacturing. It was the basis for the several large scale surveys examining the nature and impacts of innovations in the business sector, like CIS. [160] The CIS survey covers areas such as new or improved goods or services, new process innovations, logistics or distribution methods. It also gives information on the characteristics of innovation activity by different indicators, e.g. innovation spending, effects of innovation, public funding, innovation co-operation, sources of information for innovation, main obstacles on innovation activity, and methods of protecting intellectual property rights. [161] The most common problem with output studies is that the innovation types they measure are limited, and they often underrate small and service companies [18; 162].

Because of the complex nature of innovation processes, the link between the outputs and inputs is called the “black box”. Already Kline & Rosenberg [102] wrote of the differences between economical and technological views in innovation processes: “*Economists have, by and large, analysed technological innovation as a “black box” – a system containing unknown components and processes. They have attempted to identify and measure the main inputs that enter that black box, and they have, with much greater difficulty, attempted to identify the output emanating from that box. However, they have devoted, very little attention to what actually goes on inside the box; they have largely neglected the highly complex processes through which certain inputs are transformed into certain outputs (in this case, new technologies). Technologists, on the other hand, have been largely preoccupied with the technical processes that occur inside that box. They have too often neglected or even ignored, both the market forces within which the product must operate and the institutional effects required to create the requisite adjustments to innovation*” [102].

The performance of the regional innovation system can also be approached through network and social theories, analysing the architectural features with the innovation potential of the networks [163]. The innovativeness of a region is highly dependent on the regional social capital. It can be divided into regional bridging, organizational bonding, and personal creative types of social capital [164]. Tura *et al.* presented their general conceptual framework to open the black box by paying attention to the components of the internal structure and dynamics of the regional innovation environment [18]. This conceptual framework of the evaluation of regional innovative capability (Figure 6, p. 81) is also used in the case study of this dissertation, in the question setting of the interview study on the innovation capability in the network of the MTAP programme, and in the results of the program.

The regional innovative capability can be defined as the ability of a regional innovation environment to exploit and renew regional resource configurations to create a sustainable competitive advantage by innovation activities [45]. By Tura *et al.*, a comprehensive evaluation of the regional innovation policy and capability consists of two main elements:"

1. *Evaluation of the functioning of the regional innovation environment by examining the inputs, as well as internal organisation and dynamics of the innovation environment.*
2. *Evaluation of the short-term results and long-term effects of the innovation activity."* [18]

The three lowest boxes of the figure represent the components of the evaluation of the regional innovation environment and capability; the other represents the evaluation of its results and effects. The evaluation of the functioning of the regional innovation environment includes three components: the institutional setup, internal dynamics, and the resources of the innovation environment. [18]

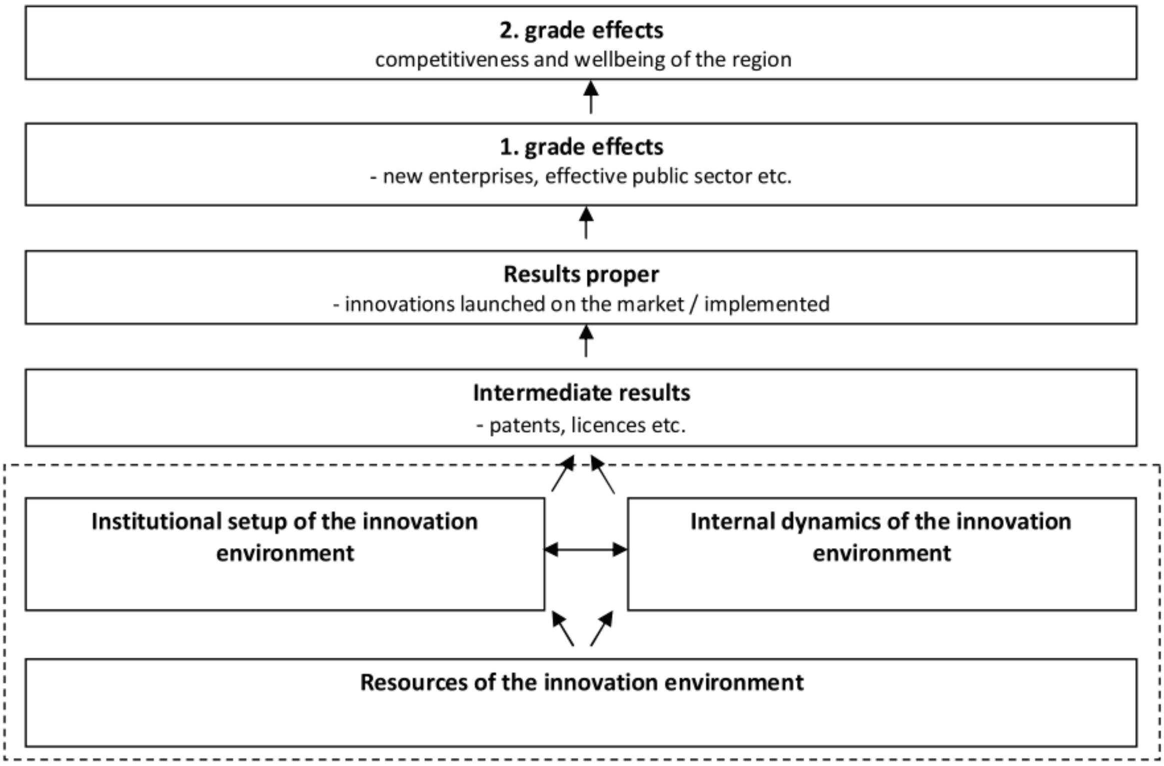


Figure 6. The conceptual framework for the evaluation of regional innovative capability [18].

The results are divided into intermediate results (patents, licences) and results proper (innovations launched on the market). The effects are divided into first and second grade effects. [18]

4.7 The network-based innovative capability evaluation matrix

By a conceptual analysis, Tura *et al.* presented their new framework for measuring regional innovation capability called the *Network-based Innovative Capability (NBIC) Evaluation Matrix* (Table 11, p. 82). It is meant as an internal tool for regions to follow up, evaluate and develop their innovation policies. The matrix is three-dimensional. The first dimension is the conceptual elements of innovative capability. It is divided into three sub-dimensions: openness or creativity, knowledge or expertise, and operationalization capability. The operationalization capability refers to the capability to launch new innovation processes by utilizing existing knowledge and expertise. [18]

The second dimension is the components of the functioning of the regional innovation environment. It includes the resources, institutional setup and the internal dynamics of the innovation environment. The third dimension is the levels of social reality in play in the regional innovation environment, divided into structural, social, cultural and intellectual levels. [18]

Table 11. Network-based Innovative Capability Evaluation Matrix [18].

		Structural level	**Social level**	**Cultural level**	**Intellectual level**
Resources	**Openness / creativity**	heterogeneity of resources of the innovation environment	generalised trust	cultural diversity	amount of the workers in creative jobs
	Knowledge / expertise	public R&D funding	participating in national and international R&D networks	culture for research and lifelong learning	level of education; scientific specialisation; R&D workers
	Operationalisation capability	support actions for commercialisation; risk funding	participating in national and international business networks	attitudes towards entrepreneurship	technological specialisation, business expertise
Institutional setup	**Openness / creativity**	structures for innovative and creative initiatives and activities	innovation networks surpassing the sectoral and organisational limits		
	Knowledge / expertise	research and education infrastructure	structures for connecting of specialised expertise to the innovation processes		
	Operationalisation capability	structure and casting of the mediator organisations	amount of the innovation related firm-level co-operation		
Internal dynamics	**Openness / creativity**		presence of multiple and contradictory views in innovation processes	visionary capability	
	Knowledge / expertise		processes of collective learning	absorptive capability	
	Operationalisation capability		leadership of the innovation networks	change-oriented development culture	

The matrix is meant only for measuring the innovative capability of a region, not for measuring the innovation performance or the evaluation of the functioning of the innovation policy. The matrix cannot be applied as a tool for evaluating how companies and organizations in a region have in general succeeded in their innovation activities. [18] In the case study of this dissertation the matrix is not used to analyse how the TUT as an organization has succeeded in the Lahti region. It is used to evaluate how the changes in available regional resources and public steering work in materials technology through the MTAP programme have affected the innovation capability and system. The matrix is utilized as a theoretical framework in the evaluation of sub-dimensions of the innovation capability of the MTAP network and thus its usability in university–industry co-operation.

5 The advisory professorship programme in materials technology

First in this chapter, the planning and building up processes of the advisory professorship model of materials technology are described, including the main aims and tasks defined for the programme. The financing of the programme and the main activities and results in university–industry co-operation are also presented.

Chapter 5.2 describes the activities of the regional development work part of the programme. The development of regional materials technological knowledge and network was one main aim of the programme. The programme has two development focuses and mechanisms: to transfer knowledge from outside of the region to the local environment and for developing the regional network. The main activity in the regional public development work was the planning process of the centre of competence for material efficiency and materials technology.

5.1 The planning and building up –process

By information of the main materials and research fields of materials science for local industries in the Lahti region (presented in Chapter 6.2), the competences of the main universities and other research organizations with activities in materials technology research fields in the Lahti region in 2007 were analysed. The main results of the analysis were summarized in the same report of the author for the purposes of regional development as for the results of the demand [12]. The key local players were TUT, Helsinki University of Technology (HUT) and Lahti University of Applied Sciences (LUAS).

It was summarized that the benefit of the DMS of TUT was the technological competence in all main industrial materials to be found inside one department. The TUT DMS was established in 1969, and it provides instruction in metallic materials, plastics and elastomers, ceramic materials, composites, coatings, and fibre materials. At the moment (2012), about 40 % of the experts of materials science and engineering are trained at the DMS. It is the only university unit in Finland offering education in all main material groups. It employs about 150 researchers and 8 professors. The DMS is divided into eight operational groups: materials science, materials characterization, plastics and elastomer technology, metals technology, surface engineering, ceramic materials, fibre materials science, and paper converting and packaging.

Other strengths of the TUT DMS were the good relations to local industries, and testing and research equipment. The emphasis of the research was on process development, manufacturing methods and new materials. In addition to materials specific research, TUT had knowledge of research fields concerning all materials, e.g. wear research, materials characterization and surface engineering.

Helsinki University of Technology (at present Aalto University) also has strong expertise and knowledge in all main materials, including metals, polymeric materials and ceramic materials. Research connected to new materials and material chemistry are the strengths of HUT, whereas TUT is seen more concentrated on the development of processing methods. HUT also has knowledge of materials recycling and environmental expertise of different materials. The strengths of Lahti University of Applied Sciences are applied research of plastics, wood and furniture. It also has good laboratory facilities and testing services. Design was seen as one of key sectors of LUAS, related to all materials.

In 2007 there were two professorships in materials research sector at Lahti University Consortium: professorship of TUT in plastics technology and advisory professorship of HUT in materials technology, specialized in design for the environment. Also some other professorships were related to materials, e.g. the professorship of waste management at HUT Lahti.

The chapter gives an example of how materials technology related co-operation between universities could be managed in the region (Table 12, p. 86). The idea of the table is to divide materials technology related knowhow and expertise into vertical and horizontal sectors. Vertical knowhow is materials specific knowledge: metals, plastics, etc. Horizontal knowhow is research fields connected to all materials, such as processing, recycling, coating and environmental analysis. In the example table, TUT is the main player supplying vertical knowhow for the regional demand. HUT supports the supply with horizontal, research field based expertise. LUAS completes the picture with knowledge in both sectors. In Table 12 the demand for materials research services by the companies is also numerically marked and cross-tabulated with the core expertise fields of the universities.

Table 12. An example of covering the materials research demand by the region's research organizations.

		VERTICAL					
HORIZONTAL		TUT	TUT	TUT, LUAS, HUT	TUT, LUAS	TUT	TOTAL
		Metals	Plastics	Wood	Fibres	Ceramics	
HUT,TUT	Fundamental research and material development	4	3	2	1	1	11
TUT,HUT	Process development	3	3	1			7
TUT,HUT	Recycling and recovering of materials	1	3	1			5
HUT	Material efficiency	1	1				2
HUT	Life cycle management and LCA		2				2
TUT, LUAS	Testing services	6	3	3	2		14
TUT, LUAS	Prototypes and trial manufacturing	2	2	1			5
HUT,TUT	Material chain management	2	2		1		5
HUT	Environmental related material research	1	2	1			4
HUT,TUT	Joining methods	3	1	1			5
TUT	Composite materials	1	2	1	1	1	6
HUT,TUT	Material chemistry	1					1
TUT	Coatings		3	3		1	7
TUT	Surface treatment	1	1	3			5
	TOTAL	26	28	17	5	3	

The vertical demand was seen to be best fulfilled as follows:

- Professorship of TUT in plastic processing technology specialized in the extrusion process
- Advisory professorship with TUT DMS, covering all materials: metals, plastics, ceramic materials, fibres and biomaterials
- Demand for knowhow of wood materials supplied by HUT Department of Forest Products Technology, TUT and LUAS
- LUAS contributing to TUT in the vertical sector of fibres

The answers also revealed a demand for research and consulting services of metals. There was a need for short-time subcontracted research work, since the operation model of universities is often too heavy: short studies, material surveys and testing services. In the plastics sector Muovipoli Ltd offered such services, and an option was given to branch out the services of Muovipoli to cover also other materials than plastics, and to increase collaboration with Lahti Science and Business Park, for example, with ownership arrangements.

It was also pointed out that there was a quite remarkable need for testing services in the Lahti region, and the development of regional laboratory activities was seen important regarding all main material groups. The services of LUAS and Muovipoli Ltd and their networks were seen to play the main role in the development work. Most companies had a need for university-level testing services; therefore the participation of universities to the development work of laboratory services was seen valuable. In the testing of plastics, the co-operation between LUAS, TUT and Muovipoli Ltd was seen important to be developed further. According to the interview study, the companies had a clear need for testing of metals, mostly condition and corrosion testing of materials and products, and mechanical testing. Because the fields of know-how in materials technology were fragmented to several organizations in the Lahti region, it was also suggested a responsible organization for coordinating the materials technology related co-operation between companies, universities and other organizations. In strategy of the city of Lahti for years 2009-2015 [7], such kind of activities were assigned to Lahti Science and Business Park (LSBP).

5.1.1 Main tasks and aims of the MTAP programme

On the basis of the results, LSBP, TUT DMS and the companies started planning and negotiation process of the advisory professorship programme in materials technology. The operational model of the MTAP programme was agreed with TUT, LSBP, Muovipoli Ltd and industrial companies to enable the utilization of materials technology related knowhow of the DMS of TUT. It was based on two main operational areas; the regional activities in Lahti, and the activities of advisory professorships of the DMS at TUT. It was defined that the main aim was to activate materials technology related research and R&D activities in the Lahti region and to develop companies' materials technology related knowhow and networking and co-operation between firms and universities.

The main regional tasks and aims were defined as follows:

1. Co-ordination and activation of research and R&D-projects in local industry, especially in financing companies together with advisory professors.
2. Acting as a regional link to main university and its professors, researchers, and testing and laboratory services of DMS.
3. Participation to pre-studies and planning of R&D projects of industries, related to materials technology. The projects can be individual and joint projects. If realized, the activities of these projects are not part or tasks of the MTAP programme. To enhance the co-operation and networking of materials technology related research and R&D activities between universities, polytechnics and education-giving organizations.
4. To promote actions of TUT in the region as part of the Lahti University Consortium and to strengthen materials technology knowhow in the Lahti region.
5. Co-operation with LSBP in development of materials technological knowhow on the basis of regional development plan and strategies, and co-operation with Muovipoli Ltd in developing plastics industry in technologies and expertise.

The main tasks and aims of advisory professors in the DMS of TUT were defined as follows:

1. Through the advisory professorship programme of the DMS, companies have the possibility to utilize the expertise of professors of the DMS in different development projects; in planning, realizing and guiding the projects.
2. Through the MTAP programme, the whole expertise of the TUT DMS is made available to the Lahti region and its companies. In the beginning of year 2008, 12 professors were working at the department, covering the research fields of different materials and technologies widely.
3. The need of the companies participating to the programme defines the utilization level of different professorships. The MTAP programme will also help maintain the professorships of melt processing technologies of plastics, especially maintaining and further developing the professorship of extrusion technology in TUT and promoting the development of its research and generation of R&D projects.
4. Co-operation with the national network of Laboratory of Plastics and Elastomers of TUT (in Tampere, Nastola, Vammala, Seinäjoki, Jalasjärvi, Kokkola, Mikkeli) will offer a possibility to use all resources of the network. The network reduces the utilization threshold of research equipment, and helps companies in the Lahti region to participate to projects generated by the network.
5. The MTAP programme will cover, among other things, the following research fields of materials technologies:
    - Technical use and applications of plastics
    - Extrusion, injection moulding and other melt processing technologies of plastics
    - Characterization of materials and mechanical behaviour of materials
    - Plastic composites, including wood plastics composites and fibre reinforcements
    - Metals and ceramic materials
    - High temperature behaviour of materials
    - Coating technologies and functional surfaces
    - Foundry engineering
    - Modelling and simulation
    - Nanostructures and –materials

- Recycling and reuse of plastics and use of biomaterials

A steering committee of the programme was also set up, including the representatives of all financing companies, professors of TUT and Lahti Science Park. Later also a professor of HUT was invited to the steering committee. Meetings of the steering committee were arranged two or three times per year. Tasks and rules for the steering group were also defined, which were discussed and decided in first the meetings. The main tasks and aims were identified as follows:

1. The main aim of the steering group of the MTAP programme is to help in the development of materials technology related knowhow in the Lahti region and in its companies, and to promote the co-operation between universities and companies related to materials technology.
2. The steering group follows and directs the activities and operations of the MTAP programme, so that the activities follow the aims and tasks described in the plan of the MTAP programme for 2008–2012.
3. The steering group does not deal with or process financing reports, because such liabilities belong to the steering group of the ELITE project.

The composition of the steering group was public. Issues discussed in the steering group were public; if there were confidential issues, the confidentiality was agreed. All the technological or other issues in meetings between TUT and companies were confidential by default and were not discussed in the steering group meetings without the company's consent. In the steering group, different development and project ideas of firms and research organizations could be discussed and evaluated. The steering group could make suggestions concerning the further development of the ideas.

The aims and tasks of the MTAP programme have characteristics of both traded and untraded mechanisms of university–industry co-operation, described by Tura [17]. Some tasks are clearly connected to *development of more efficient practices to transfer knowledge* between the university and the Lahti region. For example, an important regional task was to be a regional link to the main university and its professors, researchers, and testing and laboratory services in the DMS. Also the possibility to use the expertise and knowledge of professors and other research resources can be categorized mainly as enhancing the knowledge transfer between the university and the companies.

However, the main part of the tasks can be seen representing the mechanisms to *develop continuous forms of regional interactions* in a social, cultural and organizational network. The ultimate aim was to create untraded new knowledge and expertise in the field of materials and materials technology in the Lahti region (by the traded resources of TUT). For example the following four tasks represent the development of untraded mechanisms:

- Activation of R&D projects in local industry
- To enhance the co-operation and networking of materials technology related research and R&D activities between universities, polytechnics and education-giving organizations.
- To promote actions of TUT in the region as part of the Lahti University Consortium and to strengthen materials technology knowhow in the Lahti region.
- Co-operation with LSBP in development of materials technological knowhow on the basis of regional development plan and strategies and co-operation with Muovipoli Ltd in development of plastics industry in technologies and expertise.

Regional activities have a lot of similarities with the actions and concepts of technology or knowledge brokerages. The role of a broker is often the connector of organizations, technologies and industries, transferee and combiner of knowledge and information and stimulator of innovations [21].

5.1.2 Financing of the MTAP programme

The MTAP programme was a part of two larger EU funded projects of LSBP: ELITE and ELITE2. The ELITE projects were umbrella projects, whose main aim was to strengthen the research activities supporting the regional industrial and innovation policy and strategies. In the Lahti region's competition and business strategy for 2009–2015 environment, design and policy-driven innovations are defined as the spearheads of know-how in the region. The ELITE projects aimed at supporting the development and actions of these research fields by financing the work of professors and research groups of universities in the Lahti region. The professorships financed by the ELITE projects were:

- Innovation research professorships of LUT
- Waste management professorship of Aalto University
- Design professorships of Aalto University
- Environmental biotechnology of Helsinki University
- Materials technology advisory professorship programme of TUT

The ELITE projects were financed by the European Union, City of Lahti, Regional Council of Päijät-Häme, and companies. They were co-ordinated by LSBP. The total budget of the ELITE project (years 2008–2009) was € 0.7 million and the budget of ELITE2 (years 2010-2013) 3.3 million Euros. The budget of the subproject TUT MTAP programme was € 0.6 million for 2008–2012.

5.2 Activities in university–industry co-operation

To understand the innovation network of MTAP programme and its dynamics better, it is useful to take a look at the nature of the collaboration and the main activities of the programme, which are summarized in Table 13 on page 93. One main aim of the MTAP programme was to activate materials technology related R&D projects of companies and universities. The total amount of the projects planned in MTAP programme during years 2008–2012 was eighteen with a total budget of 3.4 million Euros. Eleven of the projects, with a total budget of 1.1 million Euros were research or education projects of the university (TUT). Seven projects were research and development projects of the companies with a total budget of 2.3 million Euros. Two of the research and education projects were joint projects with other universities, but only the subproject of TUT was planned in the MTAP programme, and only the budget of TUT subproject was counted in the total budget. Outside funding was applied for all projects. The most typical possible financiers were Tekes and the European Regional Development Fund (ERDF). Twelve of the projects received outside financing and started. The total budget of these projects was 2.2 Million Euros. The budget of research projects was 0.6 million Euros (8 projects) and that of product development projects 1.6 million Euros (4 projects).

The total number of technological pre-studies and reports was 25. Most of them (21/25) were related to materials and process technological targets of development actions. Most of the pre-studies concerned the characterization and the properties of materials (9 studies) and the selection and availability of materials (7). Manufacturing and processing technologies, including new available technologies were also interesting fields for the companies (6 studies). The scope of four pre-studies was wider and they were not company-related. In addition to these written pre-study reports, 30–50 smaller investigations and research processes were realized. Most of the projects and pre-studies were related to plastics technology. Coatings, metals and composites were also among the research topics.

Table 13. MTAP programme activities 2008–2012.

	n	**Total budget [€]**	**% n**	**% of total budget**
Projects planned (total)	*18*	*3,412,891*	*100*	*100*
Projects planned (R&D projects of companies)	7	2,325,170	39	68
Projects planned (research projects of universities)	11	1,087,721	61	32
Projects started (total)	*12*	*2,206,840*	*67*	*65*
Projects started (R&D projects of companies)	4	1,633,420	57	70
Projects started (research projects of universities)	8	573,420	73	53
Studies and research reports (total)	*25*		*100*	
Studies and research reports (company-level)	21		83	
Studies and research reports (common)	4		17	
M. Sc. Thesis	9			
M. Bc. Thesis	1			
Other research processes	30			
Seminars	3			
Seminars (participants)	203			
Companies participating to the MTAP-model (total)	*18*		*100*	
Companies funding and participating to the MTAP-model	8		44	
Companies participating to the MTAP-model	10		56	

Three seminars were also arranged in Lahti and were participated by 203 persons. The topics of the seminars were: ”New materials technology and product design” (21.10.2010), “Materials, environment and design” (7.6.2011) and ”Science and products – Plastic technology today” (17.11.2011).

In the first seminar ”New materials technology and product design”, the focus was on new materials and materials technology and their applications. The aim of the seminar was to bring the latest achievements of materials science and technology to the awareness of product designers and R&D personnel. Examples of interesting issues were wear resistant surfaces, biopolymers, nanocomposite materials, antibacterial surfaces, and design presented by five professors. Two examples of applications were introduced by the companies. The first one was an example of the utilization of waste materials in a new product, the extruded wood-plastic composite (WPC). The other one was new fibre-plastic hybrid package material.

In the “Materials, environment and design” seminar, the focus was on the presentation of actual projects connected to the environmentally benign use of materials. The importance of material selection and decisions in the product design process were discussed in the context of helping the recycling of the product after it usage.

In the ”Science and products – Plastics technology today” seminar, new plastics technology was presented from the perspectives of science and applications. There were presentations by professors concerning composites, biopolymers and the modification of the properties of plastics. In company presentations, biodegradable wood-plastic composite casts for fixing bone fractures, biodegradable surgical implants for bone fixation and other purposes, wood plastic composite boards, and controlling the static electricity in plastic products were presented. Students of the doctoral school of plastics presented their research work related to such things as metal-plastic hybrid structures, carbon nanotubes and extrusion of biodegradable fibres.

5.3 The activities in regional development work

Through the MTAP programme TUT participated in the public development work of materials technology and material efficiency related issues in the Lahti region. This purpose of the work was already defined in the original project plan of the model. The aims and tasks connected to this area were defined as follows in the project plan:

- to enhance the co-operation and networking of materials technology related R&D activities between universities, polytechnics and education-giving organizations
- to promote actions of TUT in the region as part of the Lahti University Consortium and to strengthen materials technology knowhow in the Lahti region
- the co-operation with LSBP in developing materials technological knowhow on the basis of regional development plan and strategies and co-operation with Muovipoli Ltd in developing plastics industry in technologies and expertise

The main part of this public development work was connected to the activities and role of Lahti Science and Business Park as a developer of cleantech, design and housing sectors. There was also work related to the development of co-operation between universities, polytechnics and educational organizations. In the planning process of the centre of competence for material efficiency and materials technology, the position of the Lahti region nationally in materials expertise was analysed, as well as the materials technology related research and infrastructure resources in the Lahti region. A public report is also available, where the results and activities are described in more detail [19]. The author of this thesis was the main resource of the work and the corresponding author of the report. The author's contribution to the study was to study the material efficiency on the national and regional level, to participate to positioning the Lahti region in materials technology and efficiency, and to make a suggestion of the operation model of the competence centre of materials efficiency and technology. The report was financed by the Regional Centre Programme.

The objectives and stages of the study were defined as follows:

1. Charting the expertise related to materials technology and material efficiency nationally and establishing the position of Lahti in the national framework
2. Charting the infrastructure in the Lahti region related to materials technology and efficiency and defining an operational model for its efficient use
3. Defining an operational model for the centre of competence

The definition and design of the operational concept of the centre of competence involved a lot of discussions with the main parties and interest groups. The steering committee consisted of members widely representing universities, companies and development organizations in Lahti and in Finland. To take the opinions of enterprises in the Lahti region into consideration, an enterprise inquiry was made concerning the regional development of material efficiency and the idea of a joint regional laboratory. The inquiry was sent to ten enterprises and responses were received from six. [19]

The position of Lahti region nationally in materials expertise

It was analysed that research and education into materials technology in Finland cover the entire field of materials technology fairly well. Composites and composite materials have also emerged as new developing areas in the research. Out of the major university level actors in materials technology (TUT, HUT and VTT), TUT and HUT were present in the Lahti region. The research and education activities of LUAS in plastics engineering, wood and wood products engineering and textile and clothing technology complemented the region's materials technology expertise very well. The strong design expertise of LUAS was clearly related to materials technology, and the interface between these two areas of expertise contained potential for new innovations. Another interface between areas of expertise which was analysed to offer potentials for innovative approaches on the national and even international level in the Lahti region was the junction between the materials efficiency expertise of HUT and that of TUT. [19]

The material engineering industries in the Lahti region includes wood products industry, plastics industry and metal products industries. In addition, the nationally most significant group specialized in recycling and supplying metals for reuse is located in the region. Thus the material engineering needs of the industry in the Lahti region cover almost the entire field of materials technology, with the exception of composites and composite materials. There was also a demand for testing and analysis services for companies. There were already some actors and expertise to meet the above mentioned needs in the region, but the scattered nature of the services and also their lack of recognition in the business sphere impeded their effective utilization. Thus, there was a social demand and potential opportunities for network-based centre that offers education, research and testing services focusing on materials engineering and materials efficiency in a systematized and co-ordinated way according to the one-stop-shop principle. It was concluded that *"the development of Lahti region, from the point of view of both business* *enterprises and research institutes, is best served by the region's focus on developing and combining materials technology & design for recycling on both national and international level".* [19]

In the field of material efficiency, both on the national and international level, increasing attention in material efficiency was given to product-based resource efficiency, where the entire life cycle of the product was taken into account. This was evident, for example, in the recent Natural Resource Strategy for Finland, which stressed the importance of the promotion of material efficiency through product life cycle analysis from the sources of raw materials to the final disposal of the product. Practical measures for improving material efficiency may apply, besides the use of raw materials and improved production methods, to the development of innovations across the entire product chain. On the national level, Motiva and the Material Efficiency Centre incorporated into it as developers and promoters of material efficiency played a key role. Motiva also played a central role in the development of the product-based resource efficiency network called for in the Natural Resource Strategy for Finland [165]. It was analysed that the Lahti region has a high potential to become an Eco Design model area, from which expertise and procedures can be transferred to other parts of Finland. [19]

In the Lahti region, research and education related to environmentally friendly product design were offered both by LUAS and the Lahti Unit of HUT. The region had also exceptionally strong expertise in design; the expertise of the Institute of Design of LUAS was also recognized internationally. The Lahti Unit of TUT mainly conducted research into the environmental effects of plastic and plastic composite products. It was concluded that *in a national perspective, the concentration of the material efficiency expertise of Lahti on product-based resource efficiency and, above all, the combination of design and material recycling expertise (so-called "Eco Design, Design for Environment") is most expedient.* [19]

Concentration on the combination of design and material efficiency did not, however, preclude other material efficiency development measures important for the region. For example, LSBP had founded a regional environmental expert group consisting of the region's university actors. One of the group's main goals was to create a common environmental efficiency programme and project entity between universities. Regional input-output-based material efficiency analyses were seen well-suited for national strategies. It was seen that Lahti region has potential to develop into a national ”pilot area” for material efficiency that develops practice-oriented operational models and expertise to be transferred to other parts of Finland. [19]

The business inquiry also supported the above mentioned idea. The respondent companies were the leading material processing enterprises in the region, so the responses can provide some guidelines despite the small number of the respondents (six). All areas of material efficiency were addressed equally in the responses. The enterprises rated the following as the key areas of material efficiency:

- Recycling or productification of production waste
- Optimization of material use in products
- Utilization after use (reuse, material recycling, energy recovery). [19]

Infrastructure related to materials technology and efficiency in the region

To create a picture of the existing testing and laboratory services in the Lahti region, a survey of existing materials technology infrastructure was performed using both a written inquiry and an oral interview. The target group was the units of educational institutions specialized in materials technology in the region as well as parties offering laboratory services. Only the infrastructure existing in the region was taken into account in the inquiry. The survey did not chart the infrastructure of the mother universities of the university units in the area, which are also available to the units in the region. [19]

Tables 14 and 15 present a summary of the research methods and equipment stock used by the respondents. The tables also indicate the number of equipment used for materials technology testing. The list also presents a rough estimate of the equipment that could be partly or indirectly be utilized in materials technology research. There are probably more methods or equipment partly or indirectly usable for material technical testing than listed in the tables. [19]

Table 14. A summary of research methods of materials technology in the Lahti region in 2009 [19].

	Location	All methods [N]	Material technical research methods [N]	Indirect/applied methods [N]
LUAS Plastics Engineering	Lahti/Stå 10	25	25	-
LUAS Techno-chemistry / Environmental technology	Lahti/ Niemenk.	> 50	3	3
LUAS Clothing technology	Lahti/Stå 10	19	19	-
LUAS Mechanical and production Engineering	Lahti/Stå 10	3	3	-
LUAS Furniture testing (Wood technology)	Lahti/Stå 10	28	28	-
University of Helsinki, Department of Environmental Technology	Lahti/ Niemenk.	18	-	3
TUT and Muovipoli Ltd	Nastola			
Testing equipment		14	14	-
Standards		65	65	-
Ramboll Analytics Ltd	Lahti/ Niemenk.	73	-	13
Lahti Precision	Lahti/Ahjok.	5	-	5

The number of different testing methods in materials technology was highest at the joint laboratory of TUT and Muovipoli, where it was possible to use 65 different methods with 14 pieces of testing equipment. The equipment in the laboratory is mainly for mechanical testing of plastics. LUAS Furniture testing laboratory offers the material and testing services of furniture with 28 research methods. In LUAS Plastics Engineering laboratory, 25 material technical research methods are available. Besides the actual laboratory inquiry, companies were asked about their opinions in connection with the business inquiry. In the business inquiry five out of six companies were in favour of the idea of a common regional materials technology research laboratory operating on the one-stop-shop principle. [19]

Table 15. A summary of the equipment stock of different organizations [19].

	Equipment stock	Remarks
LUAS Plastics Engineering	Mechanical and thermal testing of plastics, tooling methods	
LUAS Techno-chemistry / Environmental technology	Chemical and environmental engineering testing	
LUAS Clothing technology	Clothing technology testing, software	
LUAS Mechanical and production Engineering	Mechanical testing	
LUAS Furniture testing (Wood technology)	Furniture testing (material and product testing)	The only accredited one in Finland
Univ. of Helsinki, Dep. of Environmental technology	Environmental research, soil and waterways	
TUT	Material engineering tests	Standard conditions
Muovipoli Ltd	Mechanical testing of plastics, tooling	Standard conditions
Ramboll Analytics Ltd	Environmental testing	
Lahti Precision	Calibration	

On the basis of the survey the parties engaged in research and testing in the region were in favour of the development of functional co-operation, provided that certain boundary conditions are taken into account. Examples of them were ensuring the availability of equipment for education and creation of workable conventions. Sharing operating and maintenance costs between different actors and the resulting cost savings were seen as the most important advantage. A thing to be considered in the development of the co-operation was the differences between publicly supported and private services and their effect on the competition situation. [19]

Proposal for an operational model of the centre of competence

An operational model for the materials technology related competence centre was also proposed. It was suggested that the centre of competence would be a network-like actor consisting of the materials technology and efficiency functions of the different parties (Figure 7). The goal of the centre's operation was to be a national pioneer in combining design, material efficiency and materials technology into competitive products. The centre's operation comprises a common project base and a joint test laboratory offering material engineering research and test services. At the core of the centre is a team working in the LSBP that develops and coordinates the operation of the network. Some functions of the region's development organizations Muovipoli Ltd and the Lahti Science and Business Park Ltd are merged. [19]

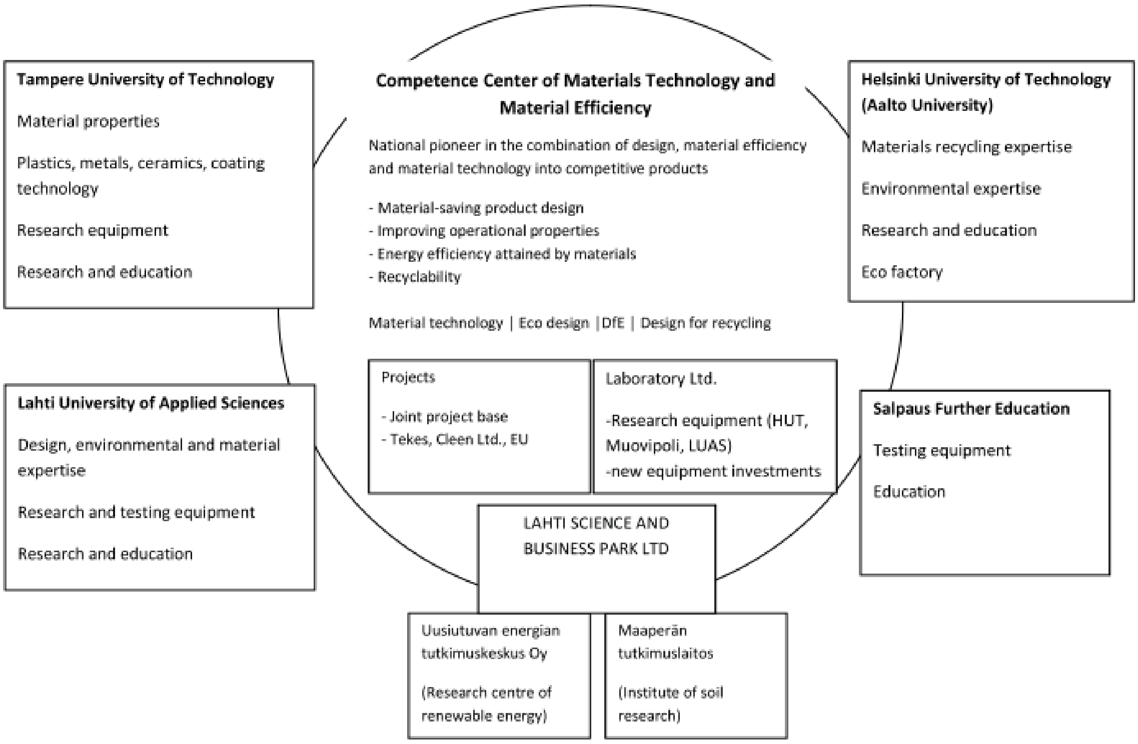


Figure 7. A model for the centre of competence on material efficiency and materials technology [19].

The mission of the joint laboratory for material efficiency and technology was specified to provide testing services in the area of materials technology for industry and research institutes in the region. It was proposed that the laboratory should function primarily on a centralized model, where functions are mainly located in one place. However, laboratory equipment may also be located in other outlets or branch offices if they are needed, for instance, in teaching. It was suggested that the laboratory for material efficiency and technology should be networked so that one party acted as the coordinator of the network. All interaction with companies and others in need of the services were suggested to go through the coordinator, with the one-stop-shop principle. The coordinator would convey the service need to the service provider in the network based on a mutual agreement of the actors. The equipment stock of mother universities and other collaboration partners would also be available for testing activities. [19]

The design and preparation work included separate agreements for the participation of the parties in the implementation of the joint laboratory, definition of the operational model including locations, equipment and personnel, specification of the ownership base, investment needs and financial planning. It was agreed that the business idea of the centre would be offering high-level laboratory and research infrastructure for the purposes of research, education and development stages of new technologies and products. Conceptually it was connected to the regional "CleanDesign" thinking: a term which was used in the Lahti region's public development of the design sector with an environmental focus. The centre would operate the regional materials technology related joint laboratory activities of universities, other educational institutions and companies; administer and maintain the laboratory equipment and offer laboratory, testing and expert services of materials to enterprises. As a totally new service, *prototyping* services were planned to support the development of regional design sector. The main outside clients would be the industrial sector (furniture and plastics industry, machine industry), design and engineering offices, and education and research organizations.

6 Research materials

In this chapter the research materials are presented. Chapter 6.1 presents research materials related to evaluation of the innovation environment. The research materials of materials technological part are in Chapter 6.2.

6.1 Innovation environment

The research material in this chapter is presented as such, by answers in each question. In the discussion part in Chapter 7.1, the answers are divided into three categories representing the different sub-dimensions of innovation capability and then analysed.

There were several questions to provide information on the innovation environment and social level of innovation capability. First, the co-operation network was described by the companies (Q1). Answers are presented in Table 16 (translated from Finnish). The original questions in Finnish are in Appendix 2.

Table 16. Answers describing the co-operation network.

Answer code	Q1: The description of the co-operation network. What kind of a network it has been, with whom the co-operation has been done (professors of advisory unit, regional research manager, researchers, etc.)?
A1-Q1	Mostly contacted through the research manager. Managing director and company have also been contacted on different levels of organization of TUT, also direct contacts to researchers.
A2-Q1	Research manager and professors
A3-Q1	Research manager and professors of TUT. From the company's side there are also many persons as contact area. Co-operation with TUT has become closer. Indirectly through creation of knowledge and network-found paths to commercial players.
A4-Q1	TUT: research manager and professor *[professor's name removed]*. At companies' side *[three persons, names removed]*. No direct contacts to researchers.
A5-Q1	Aalto University and Tampere University of Technology (research manager and researchers)
A6-Q1	Mostly the local contact person, in some cases direct contacts to professors and researchers of TUT.

Firms were typically contacted by the regional contact person of TUT. Almost all of the companies had typically also contacts to one or two professors. TUT was mostly in contact with one contact person of the company but also with several other persons at several organization levels. With one company, the collaboration network was much wider than with others.

Table 17. Answers describing information and inputs to companies.

Answer code	Q2: How has the advisory professorship model been utilized (e.g. fast inputs, researches/investigations, planning and preparing of R&D processes)? In what kind of product development model the gained knowledge has been utilized (e.g. experimental or systematic innovation model)?
A1-Q2	Studies and investigations. Systematic model.
A2-Q2	Fast inputs, studies and investigations.
A3-Q2	Analysis services, fast inputs (fast quick answers), couple of technological prestudies.
A4-Q2	Fast inputs, studies and investigations. No planning of R&D projects. Most valuable commercial value on characterization of materials and *[product name removed]* tests. Utilized more on commercialization. Systematic innovation model.
A5-Q2	Fast inputs, planning and preparation of RD-processes. The product development model is systematic. Actually no product development projects but technological projects (manufacturing, etc.).
A6-Q2	Fast inputs and studies. Time saving, the right contacts.

As a description of the information and inputs to the companies (Q2), companies use TUT as provider of studies, clarifications and “fast inputs” (Table 17). The identification of research needs (Q3) was company-based or made in co-operation (Table 18).

Table 18. Answers identifying research needs.

Answer code	Q3: How has the identification of research needs taken place – at the company, at the university, together?
A1-Q3	Original needs have come from the company, but further planning has usually been done together.
A2-Q3	Need specification is company based
A3-Q3	Together
A4-Q3	In the company
A5-Q3	In the company, at the university and together
A6-Q3	In the company. Research is conducted according to strategic aims.

Five of six of the companies utilized the knowledge provided by the programme mainly as part of their existing innovation and R&D processes (Q7). In one case, the focus was more concentrated on creating totally new processes (Table 19).

Table 19. Answers on characteristics of innovation processes.

Answer code	Q7: Have the projects created through the programme been part of larger processes – have they led to new ones or been linked to processes which have already existed?
A1-Q7	Part of larger processes which usually have existed.
A2-Q7	Part of existing processes.
A3-Q7	Have led to new projects, but have also been connected to already existing processes.
A4-Q7	Both kind of projects, maybe more focused on the creation of new ones.
A5-Q7	Yes. More focused on already existing processes.
A6-Q7	Have been part of a larger project *[project name removed]*. Mainly projects which have already existed.

At structural and social level of the innovation capability (Q6), the role of TUT was clearly the supplier of research and university level knowledge. The companies saw that the programme increased the heterogeneity of information (Table 20).

Table 20. Answers on characteristics of information.

Answer code	Q6: What is the role of the advisory professorship model compared to utilization of other external/internal expertise? Has the gained information increased the heterogeneity of the knowledge available?
A1-Q6	The role of a research organization. If it hadn't been available, the knowledge would not have been supplied separately. Has increased the heterogeneity of information.
A2-Q6	Yes, partly increased the heterogeneity of information. A research-oriented role. Co-operation has increased activities that have improved knowledge.
A3-Q6	Its own research-oriented role. Increased the diversity and reliability of information.
A4-Q6	The knowledge would not have been found inside own organization. A research-oriented role.
A5-Q6	Yes, diverse information on the same phenomenon from own organization and the university. The role of university as a provider of deeper/broader knowledge.
A6-Q6	The role of a research organization. Co-operation with university in testing and research is easier when there is an organized information channel (one person).

The tools and methods of co-operation (Q4) were normal meetings, discussions, e-mails, reports, etc. With one company regular big meetings were arranged with typically 10–15 participants (Table 21).

Table 21. Answers on tools and methods of co-operation.

Answer code	Q4: How have the interactions been realized in practice – the most efficient communication channels?
A1-Q4	Direct communication, reports
A2-Q4	Regular, large co-operation meetings, e-mailing, phone
A3-Q4	E-mailing, calls, meetings
A4-Q4	-
A5-Q4	Projects, meetings, etc.
A6-Q4	Direct contacts, e-mail, phone, meetings

Concerning the cultural level of innovation capability, there was a question of the internal dynamics and absorptive capacity of companies (Q5). Every company saw that information had moved quite well inside their company. There were some differences in the capability to utilize the research results in the innovation processes of the companies. The polarization of information was mentioned in one case. The form of delivered research knowledge also affected the ability of the companies to absorb the research information (Table 22).

Table 22. Answers on internal dynamics and absorptive capacity.

Answer code	Q5: How has the co-operation with advisory unit been organized inside the company – how are the information of the model and its results moved forward in the organization (leadership, catchers?) Has the organization had the capability to absorb knowledge gained through the model?
A1-Q5	Knowledge has been spread well especially in the development team and organization. Knowledge has been spread through one person's activity. There has been capacity to absorb.
A2-Q5	Has had the ability. Teams of *[two names removed]* have known about the model, and people have been informed of the model. The utilization of the model varies between the teams, team of *[name removed]* well, *[name removed]* within the limits of resources.
A3-Q5	In the framework of the project organization the information has moved forward well. Also the *[a product name removed]* example has been used in communication, There has been the ability to absorb.
A4-Q5	The usability of information is affected by the nature of provided information and the presentation format (e.g. the form of reports). There was information of the model, but maybe it might have been even more extensive. In principal there was capacity to absorb, but the nature of information also affects this.
A5-Q5	Gained knowledge was utilized well and has been moved in the organization. Maybe the awareness of the model and its possibilities might have been spread wider.
A6-Q5	It has moved. Through production and engineering department forward. Polarization of information; plastics at midpoint.

Regarding the impacts on the research culture or absorptive capacity of information (Q13), there were several different answers. The answers are presented in Table 23.

Table 23. Answers on impacts to research culture.

Answer code	Q13: Has the model had effects on the research culture of the company or on the characteristics of the research culture? Has the model improved the absorptive capacity of knowledge?
A1-Q13	Maybe increased the research orientation.
A2-Q13	Yes. Different methods of gaining research knowledge can be used. You don't have to do everything by yourself.
A3-Q13	No
A4-Q13	Has not changed the characteristics but tightened the already existing co-operation.
A5-Q13	At least in theory but very hard to measure.
A6-Q13	Through confirming the knowledge.

Answers to Question 14 are presented in Table 24. Two companies saw that there was an impact on technological specialization, a direct impact in one company, and in another an indirect one based on the development of their own special knowledge (Q14).

Table 24. Answers on impacts to technological specialization.

Answer code	Q14: Has the model had effects on technological specialization?
A1-Q14	Yes: The utilization of *[waste material name removed]* has increased specialization
A2-Q14	No
A3-Q14	No
A4-Q14	No
A5-Q14	Indirectly through the development of own special knowledge
A6-Q14	No

Concerning the intermediate and proper results (Q8), in four of six companies new products, services or product improvements were created as a result of the programme. In two companies, process improvements were made. All of the companies saw that the model had created new know-how, expertise, data, information, knowledge and knowledge networks (Table 25). The companies saw that some results might have been attained partly without the programme but they would certainly take a longer time (Q9) (Table 26).

Table 25. Answers on new knowledge and innovations.

Answer code	Q8: In what kind of results the projects have ended: have they created – New IPR (or IPR affected by the projects)? – New products /services/product improvements? – Renewing of the manufacturing processes? – New knowledge? – Increase of data or information/control of information? – Expansion or intensification of knowledge transfer channels?
A1-Q8	– No, no patents – Yes, *[a product name removed]*, *[a material name removed]* materials – Yes, new equipment – Yes, especially in *[development field removed]* – Yes – Yes
A2-Q8	– No – Yes, product improvements – Yes – Yes – Yes – Yes
A3-Q8	Has been created, not patented, but confidential information – One new product – -- – Yes – Yes – Yes
A4-Q8	– Not directly – No – No – Yes – Yes – Yes
A5-Q8	– No – Maybe some product improvements, e.g. *[a product name removed]* – No – Yes – Yes – Yes
A6-Q8	– No – No – No – No – Yes – Yes

Table 26. Answers concerning effects on innovations.

Answer code	Q9: Would these results have been created without the model/in what time?
A1-Q9	Maybe some of the results would have been created, but now in a shorter time, however.
A2-Q9	Surely, and perhaps in same time, but now at least more efficiently. Or maybe they might not have been realized at all.
A3-Q9	Getting confirmation, maybe shortens time through the elimination of uncertainties.
A4-Q9	Already started from the *[a project name removed]* project, the same results would not have been achieved, and the results would been achieved in a longer time.
A5-Q9	Would probably have been attained, but in a much longer time.
A6-Q9	Would partly have been created, but most probably in a longer time.

In one case, a pre-study led to a new important plastic part of a new product which is now on the market with new turnover (Q10). In one case, the results strongly affected the success of a product development project related to material efficiency and use of recycled materials. The product is now in production, and in the internal use of a corporate group. The solution decreases costs and has a positive effect on profits. Two companies saw that there are some product improvements, but it is impossible to estimate their effects on the turnover (Table 27). All the new products or product improvements were related to plastics.

Table 27. Answers concerning effects on turnover or profits.

Answer code	Q10: Effects on turnover/profits?
A1-Q10	One new product which is coming to the market.
A2-Q10	No
A3-Q10	Through decreases in material losses has directly affected profitability. Indirectly through image might have affected the turn-over.
A4-Q10	No direct effects
A5-Q10	Very hard to measure
A6-Q10	No direct effects

Answers on other influences (Q11) are presented in Table 28. Among the mentioned effects were positive effects through development of knowledge and know-how.

Table 28. Answers concerning other influences.

Answer code	Q11: Other effects (e.g. image, long-term effects on competitiveness)
A1-Q11	Through development of knowledge. Long term effects related to understanding features of products and improvement of long-term properties.
A2-Q11	No
A3-Q11	Using the best resources as part of activities of the company.
A4-Q11	Might have affected turn-over indirectly through image.
A5-Q11	The development of know-how have positive effects in the long run.
A6-Q11	No

The main new network (Q12) in the opinion of the companies was the steering group work. New networks were also created between companies, and in one case the project activities increased international co-operation inside a corporate group (Table 29).

Table 29. Answers on new networks.

Answer code	Q12: Participation to national/international networks. Has the model brought/created new networks or innovation processes, crossing the organizational borders?
A1-Q12	The model is utilized on the international level through company's own activities, in international co-operation. Some co-operation with *[a company name removed]* through the MTAP-network.
A2-Q12	Yes, the MTAP- network
A3-Q12	Has created new contacts between companies
A4-Q12	The MTAP "gang"
A5-Q12	No
A6-Q12	Maybe at least one (*[a company name removed]*)

A theory-based content analysis of the answers is presented in the Chapter 7.1. In the analysis, the network based innovative capability matrix is used in the evaluation of the three sub-dimensions of innovation capability: openness/creativity, knowledge/expertise and the operationalization capability.

6.2 Materials technology in industrial companies of the Lahti region

This chapter presents research material on materials technology in industrial companies in the Lahti region. The analysis and discussion of the answers are part of Chapter 7.2.

6.2.1 Priorities and usages of materials

According to the answers, the main material groups for companies were metals and plastics, which were used by 67 % of the companies. Wood was used by 47 %, textiles including fibres by 27 % and ceramics by 20 % of the companies. The most used material (67 %) was steel, including stainless and acid-proof steel. Thermoplastics were the second largest material group; they were used by 60 % of the companies. The most important thermoplastics are polyethylene (PE) and polypropylene (PP). The usages of aluminium and timber were 47 % each. Alloys, engineering plastics, rubbers and thermoelastomers were used in 40 % of companies. (Figure 8).

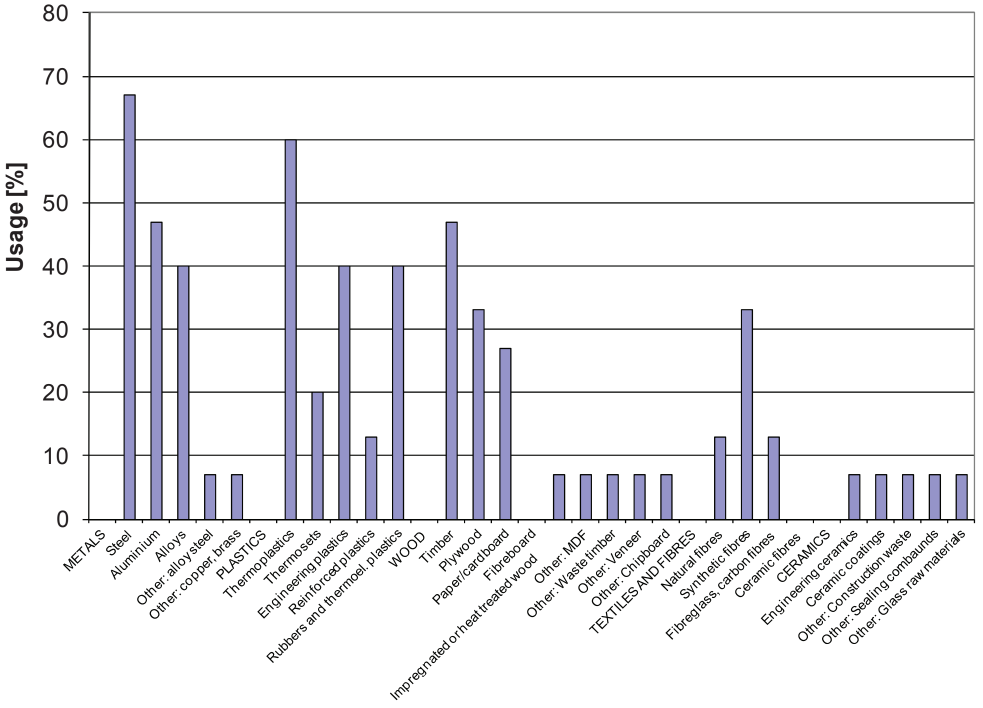


Figure 8. Percentual usages of materials by the companies.

The priorities of material groups and materials are presented in Table 30. Priority numbers were calculated between main material groups and also inside each material group. They were calculated as a mean of given priorities/number of companies used.

Table 30. Priorities and usages of materials and material groups in the companies.

	Usage [N (%)]	PNMG (mean)* (SD)	PNIMG (mean)** (SD)
METALS	**10 (67)**	1.8 (1.36)	
Steel	10 (67)		1.1 (0.33)
Aluminium	7 (47)		2.0 (0.63)
Alloys	6 (40)		3.2 (0.5)
Other: alloy steel	1 (7)		2.0
Other: copper, brass	1 (7)		4.0
PLASTICS	**10 (67)**	2.0 (0.94)	
Thermoplastics	9 (60)		1.4 (0.55)
Thermosets	3 (20)		2.0 (1.41)
Engineering plastics	6 (40)		2.67 (1.15)
Reinforced plastics	2 (13)		3.0
Rubbers and thermoelastomers	6 (40)		2.5 (1.29)
WOOD	**7 (47)**	2.1 (1.21)	
Timber	7 (47)		1.4 (0.89)
Plywood	5 (33)		2.3 (0.58)
Paper/cardboard	4 (27)		2.7 (2.1)
Fibreboard	0 (0)		0.0
Impregnated or heat treated wood	1 (7)		4.0
Other: MDF	1 (7)		0.0
Other: Waste timber	1 (7)		1.0
Other: Veneer	1 (7)		2.0
Other: Chipboard	1 (7)		0.0
TEXTILES AND FIBRES	**5 (33)**	2.8 (1.71)	
Natural fibres	2 (13)		0.0
Synthetic fibres	5 (33)		1.5 (0.71)
Fibreglass, carbon fibres	2 (13)		1.0
Ceramic fibres	0 (0)		0.0
CERAMICS	**3 (20)**	3.3 (0.58)	
Engineering ceramics	1 (7)		1.0
Ceramic coatings	1 (7)		2.0
Other: Construction waste	1 (7)		1.0
Other: Sealing compounds	1 (7)		1.0
Other: Glass raw materials	1 (7)		1.0

*Priority number of material groups, mean value, calculated as (priority number)/(number of companies used)

** Priority number inside a material group, mean value (priority/companies used)

The standard deviations of the priority numbers were also calculated. In some cases a company did only mark the usage of materials without priority number. These answers are not included in priority numbers or standard deviations. Thus, the priority number of the used material can also be zero (e.g. natural fibres). In Table 30, the priority number is also reported with only one answer. That means that there might be materials with a high priority, although only one company uses the material.

In the priority classification, metals were seen as most important material, followed by plastics, wood, textiles and fibres, and ceramics. The differences between metals, plastics and wood are quite small with wide standard deviations. The most important metal was clearly steel. In plastics the priority order was thermoplastics, thermosets, rubbers and thermoelastomers, engineering plastics and reinforced plastics. Timber, plywood and paper/cardboard were important wood materials.

6.2.2 The demand for materials research services

The summary of answers related to demand for materials research services is presented in Figure 9. Material testing and analysis services were used by 80 % of the companies in the past two years. The services were bought mostly from commercial research services (60 %). Product testing services were subcontracted by 73 % of the companies. Research work or thesis work at universities or universities of applied sciences had been utilized by 46 % of the companies. Theses in polytechnics (33%) were more popular than theses in universities (20%), but the other research work was done more in universities (60%).

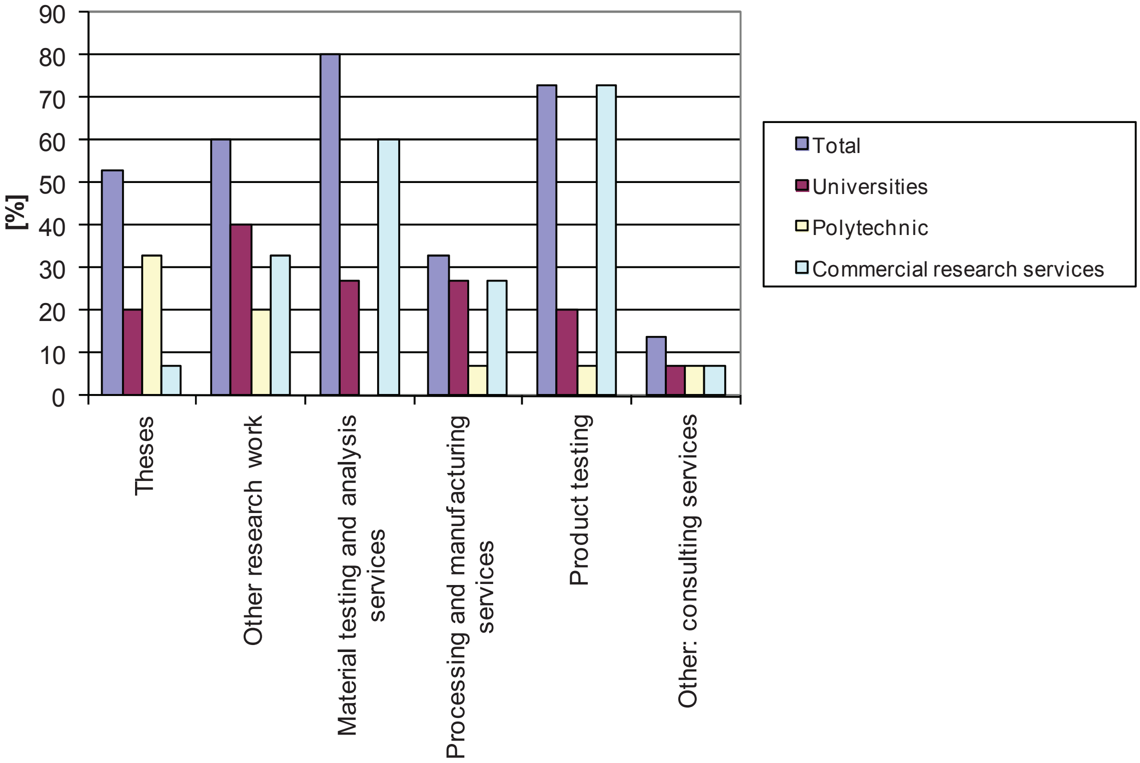


Figure 9. Materials research services utilized by the companies during 2005–2007.

The answers of the future demands are summarized in Table 31. The companies believed they were utilizing mostly testing and analysing services. The next most important services to be bought from outside were fundamental research and material development, followed by process development services.

Table 31. Demand for materials research services by the companies.

	Metals [N (%)]	Plastics [N (%)]	Wood [N (%)]	Fibres [N (%)]	Ceramics and glass [N (%)]	Total [N]
Fundamental research and material development	4 (27)	3 (20)	2 (13)	1 (7)	1 (7)	11
Process development	3 (20)	3 (20)	1 (7)	0 (0)	1 (7)	8
Recycling and recovering of materials	1 (7)	3 (20)	1 (7)	0 (0)	1 (7)	6
Material efficiency	1 (7)	1 (7)	0 (0)	0 (0)	0 (0)	2
Life cycle management and LCA	0 (0)	2 (13)	0 (0)	0 (0)	0 (0)	2
Testing services	6 (40)	3 (20)	3 (20)	2 (13)	1 (7)	15
Prototypes and trial manufacturing	2 (13)	2 (13)	1 (7)	0 (0)	0 (0)	5
Material chain management	2 (13)	2 (13)	0 (0)	1 (7)	0 (0)	5
Environmental related material research	1 (7)	2 (13)	1 (7)	0 (0)	0 (0)	4
Joining methods	3 (20)	1 (7)	1 (7)	0 (0)	0 (0)	5
Composite materials	1 (7)	2 (13)	1 (7)	1 (7)	1 (7)	6
Material chemistry	1 (7)	0 (0)	0 (0)	0 (0)	0 (0)	1
Coatings	0 (0)	3 (20)	3 (20)	0 (0)	1 (7)	7
Surface treatment	1 (7)	1 (7)	3 (20)	0 (0)	0 (0)	5
TOTAL [N]	26	28	17	5	6	82

When the results are compared between material groups, it can be seen that external services related to plastics are slightly more probable than services related to metals (plastics 28 mentions, metals 26 mentions). There was also some need for research services related to wood (17 mentions). Among individual research areas the most important ones were:

- Metals: Testing services (6 mentions)
- Metals: Fundamental research and material development (4 mentions)

6.2.3 Importance of materials research fields

A summary of the answers is presented in Table 32. The most important fields of materials research were fundamental research and material development and material recycling/recovery. They were followed by process development, material efficiency and characterization and testing. Surface treatment, coating, joining methods and the material chain management were also among the research topics that were seen as important.

When the results are compared between material groups, materials research connected to plastics was the most important (39 mentions). The second most important were metals (32 mentions) and wood (25 mentions). The results were quite unexpected, because only two of the 15 companies were plastics processing companies.

Table 32. Answers on the most important materials research fields for the companies.

	Metals [N (%)]	Plastics [N (%)]	Wood [N (%)]	Fibres [N (%)]	Ceramics and glass [N (%)]	Total [N]
Fundamental research and material development	3 (20)	5 (33)	3 (20)	0 (0)	1 (7)	12
Process development	3 (20)	4 (27)	2 (13)	0 (0)	1 (7)	10
Recycling and recovering of materials	2 (13)	5 (33)	3 (20)	1 (7)	1 (7)	12
Control of material streams	1 (7)	0 (0)	1 (7)	1 (7)	0 (0)	3
Material efficiency	3 (20)	4 (27)	2 (13)	1 (7)	0 (0)	10
Life cycle management and LCA	1 (7)	3 (20)	1 (7)	1 (7)	0 (0)	6
Characterization and testing	3 (20)	4 (27)	1 (7)	1 (7)	1 (7)	10
Material chain management	3 (20)	4 (27)	1 (7)	1 (7)	0 (0)	9
Environmental related material research	1 (7)	3 (20)	2 (13)	1 (7)	0 (0)	7
Joining methods	3 (20)	2 (13)	2 (13)	2 (13)	0 (0)	9
Composite materials	0 (0)	2 (13)	0 (0)	1 (7)	1 (7)	4
Material chemistry	2 (13)	1 (7)	1 (7)	0 (0)	0 (0)	4
Coatings	3 (20)	1 (7)	3 (20)	1 (7)	1 (7)	9
Surface treatment	4 (27)	1 (7)	3 (20)	1 (7)	0 (0)	9
TOTAL [N]	32	39	25	12	6	114

Among individual research areas the most important ones were:

- Plastics: Fundamental research and material development (5 mentions)
- Plastics: Recycling and recovery of materials (5)
- Plastics: Process development (4)
- Metals: Coatings (4)
- Plastics: Material efficiency (4)
- Plastics: Characterization and testing (4)
- Plastics: Material chain management (4)

6.2.4 Possibilities and challenges of materials research

Concerning the possibilities and challenges of materials research, very different issues were named (Table 33, p. 119). Examples of material and production technology related topics were the pressure to decrease product weight but increase the mechanical properties of a product, and the structural strength of products. Other properties, like heat resistance and thermal behaviour of metals and alloys, durability of sealing materials, antifriction surfaces and erosion, corrosion and abrasive abrasion of materials were also mentioned. The material properties critical to recycling, such as purity and availability were seen as important. The optimization of development and manufacturing processes of plastic products, surface treatment, and joining of metal and plastic parts were among the production technology related issues emphasized.

Table 33. Answers to the question of the most important possibilities and challenges of materials research by the companies in 2007.

Answer code	What are the most important possibilities and challenges of materials research by the companies?
A1	Increasing the knowledge of material properties and especially the possibilities of new materials
A2	Recycling
A3-1 A3-2 A3-3 A3-4	3D modelling so that the dimensional accuracy is as good as possible. Cost effective heat resistant materials in *[a product name removed]* Manufacturing of big-sized plastic parts cost-effectively Joining metal and plastic parts
A4-1 A4-2 A4-3	Surface treatment Environmental aspects Development of materials, process development
A5	The selection of materials is challenging: Several suppliers, several materials suppliers with standard *[material name removed]* which are different, because standards allow certain tolerances. With *[material name removed]* suppliers, the batches are big, they have their own product development
A6	Development of new competitive materials
A7-1 A7-2 A7-3 A7-4 A7-5 A7-6	Thermal properties of metals and alloys. Erosion-corrosion, abrasive wear. Antifriction surfaces Additives, catalysts Moulding properties and thermal resistance of plastics. Durability of sealing materials.
A8	-
A9-1 A9-2 A9-3 A9-4 A9-5	Globalization of research and development Research, design Testing of functionality Special *[material name removed]* Industrial activities in *[name of a business removed]* have moved out from Finland and are not coming back. Product testing is a possibility where research is still needed and developed.
A10-1 A10-2 A10-3	Eco-friendliness, free of emissions Structural strength In general: recyclability, eco-friendliness
A11-1 A11-2	Enhancing the use of renewable materials in products (sustainable development) Bio-based, natural and recyclable materials.
A12	Selection of materials and alternative materials.
A13-1 A13-2 A13-3	Recycling possibilities of materials Non oil-based plastic raw materials Intelligent and active materials
A14-1 A14-2 A14-3 A14-4	Aseptic safety of materials Antibacterial properties Alternative materials, metals to plastics Continuous problem: the product has to carry bigger stresses but the weight of products cannot increase
A15-1 A15-2 A15-3	Optimization of supply chain Materials recycling related issues: purity; availability, feeding Optimization of development and manufacturing processes of plastic products

The answers of this open question are analysed in Chapter 7.2. Analysis is made from the view of regional viewpoint by classifying the answers according the focuses of development strategies.

6.2.5 Investments in materials technology related R&D

When the companies were asked about their interests to invest in materials technology related research or development in the near future, 40 percent told that they were going to invest remarkably to internal R&D. A high share, that is 80 % of the companies were going to invest in university level research, both fundamental research and applied research (Table 34).

Table 34. Investments in materials technology related R&D in the near future.

Type of resource input	No investments [N (%)]	Some investments [N (%)]	Remarkable investments [N (%)]
Internal R&D	1(7)	8(53)	6(40)
External R&D services	2(13)	12(80)	1(7)
Research services from universities	4(27)	8(53)	2(13)

Question seven also asked an estimation of possible financing for university-level research in materials technology. The estimations were between 0-10 000 Euros/year. The opinion of most companies was that when the research work is subcontracted from universities as part of their own R&D projects, the investments can be considerably larger.

7 Discussion

First in this chapter, the characteristics and dimensions of the innovation capability of the university–industry co-operation network are analysed. In the regional development context the results are analysed with two different methods in Chapter 7.2.

7.1 Evaluation of the innovation environment

The main research problem of the study concerned the main inputs, functions and internal dynamics of the innovation environment and possible results (outputs) and effects of the innovation activities of the network in materials technology advisory professorship programme. Chapter 6 presented the research material related to this research problem. In this study, the evaluation of the innovation environment is based on measuring both the inputs to innovation processes and some of the outputs.

7.1.1 Analysis method

The answers were analysed by a theory-based content analysis. The theoretical background was the NBIC matrix (Table 11). In the matrix the innovative capability is divided into three sub-dimensions: openness or creativity, knowledge or expertise, and operationalization capability. The second main dimension is the components of the functioning of the regional innovation environment, including the resources, institutional setup and the internal dynamics of the innovation environment. The third dimension is the levels of social reality in play in the regional innovation environment, divided into structural, social, cultural and intellectual levels.

The purpose of the analysis was to find out about the characteristics of the co-operation network in the MTAP-programme by analysing how the answers represented the different components of regional innovation capability. The answers were placed in the cells of a three dimensional innovative capability matrix. Some answers were placed in two cells because they gave information on several components of innovation capability.

After positioning the answers to the matrix the three sub-dimensions of innovation capability were analysed.

7.1.2 Openness/creativity

Openness or creativity refers to the element of newness in innovation actions and it intends to “capture those capabilities needed to transcend the existing technological, processual, social and service solutions and search for new possibilities” [18]. The answers categorized in the openness and creativity sub-dimension of innovation capability provided information on actions in the innovation environment on social and structural levels. There were answers related to all levels of the innovation environment (resources, institutional set-up, internal dynamics). All elements of openness/creativity were not included in the questions: Some cells in the matrix are relevant only for a broader analysis of regional innovation capability. The openness and creativity related answers are presented in Table 35 on page 123.

Openness and creativity on the structural level of social reality came forward in answers A1-Q6, A2-Q6, A3-Q6, A4-Q6, A5-Q6, A6-Q6 and A3-Q11. They were also all related to the resources of the innovation environment. The university had a research-oriented role in innovation processes. It increased the heterogeneity of resources and information, which would not necessarily have been outsourced without a programme:

“Role of the research organization. If it had not been available, the knowledge would not have been supplied separately. It has increased the heterogeneity of information.” (A1-Q6)

From the university’s point of view, the nature of research inputs was mainly applied research knowledge. Gilsing *et al.* have found that major barriers in knowledge transfer processes between universities and industries are the risk of information leakage, conflicts of interests and scientific knowledge being too general [166]. This risk can also be identified in knowledge production in the MTAP programme. In some cases, it did not necessarily differ from knowledge that could perhaps be purchased from an engineering office. However, the companies felt it was clearly research oriented. This might be due to a couple of reasons: companies categorize it as research-oriented because of its source (see answer A5-Q6), or because the focus of the R&D work in the companies concentrates more on development issues than scientific research. Vice versa, the risk of scientific information being too theoretical to be useful to the companies may also be a barrier [166]. That was not brought up in the answers. The lack of heterogeneity of information calls for structures on the regional level but also generalized trust and social-level channels to communicate, as mentioned in following answer:

"...Co-operation with university in testing and research is easier when there is an organized information channel (one person)." (A6-Q6)

Table 35. Openness/creativity related answers.

	Structural level	**Social level**	**Cultural level**	**Intellectual level**
Resources	heterogeneity of resources of the innovation environment *A1-Q6, A2-Q6, A3-Q6 A4-Q6, A5-Q6, A6-Q6, A3-Q11*	generalized trust	cultural diversity	number of workers in creative jobs
Institutional setup	structures for innovative and creative initiatives and activities	innovation networks surpassing the sectoral and organizational limits *A1-Q1, A2-Q1, A3-Q1 A4-Q1, A5-Q1, A6-Q1, A1-Q12, A2-Q12 A3-Q12, A4-Q12, A6-Q12, A4-Q13*		
Internal dynamics		presence of multiple and contradictory views in innovation processes *A1-Q6, A2-Q6, A3-Q6 A4-Q6, A5-Q6, A6-Q6*	visionary capability *A1-Q7, A2-Q7, A3-Q7 A4-Q7, A5-Q7, A6-Q7*	

Heterogeneity of resources and their use can also be seen as a tool for gaining long-term competitive advantage (A3-Q11). More typical of companies was to see the long-term benefits in the growth of the companies' intellectual level than in exploiting the resources.

Social level related answers on the openness and creativity dimension of innovation capability were related to the institutional set-up and internal dynamics of the innovation environment. The answers on the organizational set-up described the functioning of the materials technology related network created under the MTAP programme (A1-Q1, A2-Q1, A3-Q1, A4-Q1, A5-Q1, A6-Q1, A2-Q12, A4-Q12, A1-Q12, A3-Q12, A6-Q12 and A4-Q13). There were two kinds of sector-crossing co-operation in the MTAP network: the new connections between research and industry but also some new connections between different industrial sectors. The co-operation link with the university came up in several answers (A1-Q1, A2-Q1, A3-Q1 A4-Q1, A5-Q1, A6-Q1, A2-Q12, A4-Q12, A4-Q13) The co-operation network with university was necessarily not created through the programme, in some cases it had already been constructed (A3-Q9, A4-Q13).

"The programme has not changed the characteristics [of the research culture] but tightened the already existing co-operation." (A4-Q13)

The creation of co-operation network with other companies, especially those participating in the programme, emerged in answers A1-Q12, A2-Q12, A3-Q12 and A4-Q12. Some new innovation processes were created between industries (A1-Q12, A3-Q12, A6-Q12). In the matrix the new processes are seen as representing the operationalization capability rather than the openness/creativity dimension. If the network does not have the capability to create new processes, its operationalization capability is low. However, even if the companies identified the MTAP network and themselves as part of it, fewer new industrial sector-crossing innovation processes were created than expected, even though it was one aim of the programme since the selection of companies for the programme. Nevertheless, promoting the new innovation processes between the companies is not the ultimate aim of the advisory professorship model, although it creates new strategic co-operation between universities and companies. Some other practice-based innovation tools are designed specifically for that purpose.

The openness/creativity dimension on the social level related to the internal dynamics of the innovation system can in the NBIC matrix be seen as the presence of multiple and contradictory views in innovation processes. The answers that can be seen as representing this category are A1-Q6, A2-Q6, A3-Q6, A4-Q6, A5-Q6 and A6-Q6. All of these answers were also related to the heterogeneity of information on the structural level and to resources of openness and creativity. As seen from this perspective, the participation of the university to the companies' innovation processes is not only about giving different, more research oriented information, but simply about increasing the amount of different views, which can be considered a reachable aim as such. Contradictions of views were not brought up in the answers. In addition to the heterogeneity of information, diversity is mentioned in two answers (A3-Q6, A5-Q6). One respondent saw that information provided by the university is some kind of "deeper" knowledge:

"Yes, diverse information on the same phenomenon from own organization and the university. The role of university as a provider of deeper/wider knowledge." (A5-Q6)

The visionary capability element of openness and creativity is located in the matrix in the cell categorized to internal dynamics and cultural level of social reality. In the context of regional development, visionary capability means the region's ability to find potential development trajectories based on its history and new techno-economic opportunities [167]. The role of a university of technology in research projects, which are partly industry-funded, is often to seek new technological opportunities for industries, based on the development paths of products and manufacturing in companies. Usually the company has set a future or at least a market vision, providing guidelines for research. Question seven aimed at getting some information on the nature and usability of the research work but also on the visionary capability of companies, in other words, whether companies are utilizing the research inputs more in creating something new or improving the existing products as part of a project portfolio. This does not exclude the idea that existing projects can also be visionary. According to the answers, in most cases the focus was on existing projects (A1-Q7, A2-Q7, A3-Q7, A5-Q7 and A6-Q7). In one company, the work was more concentrated on creating new ones (A4-Q7). This does not allow to make any conclusions about the visionary capability as such. However, some information of the companies' desire to find new technological opportunities can be gathered from the nature of research inputs and reports. Five research reports out of a total of 25 were clearly directed to the search of new technological or business opportunities with a longer timeline (5 to 10 years). As a conclusion on the visionary capability, the advisory professorship model can be used as a tool for improving the visionary capability of the innovation network, companies and even regions. The main function is to produce new information for companies, which can use it as part of their own forecasts when information on future markets is needed and the development paths have to be chosen.

7.1.3 Knowledge/expertise

The sub-dimension of knowledge or expertise in the NBIC matrix refers to the intellectual and scientific nature of innovation. They are the capabilities to acquire the knowledge needed in innovations. The knowledge/expertise related answers are presented in Table 36 on page 127.

The culture of research and lifelong learning represents the resources and cultural level of knowledge. Answers A1-Q13, A2-Q13 A3-Q13 A4-Q13 A5-Q13 A6-Q13, A1-Q2, A4-Q2 and A5-Q2 are related to this cell. It is possible to identify several mechanisms of how the model has affected the research culture. The first one consists of the issues of the use of the advisory professorship model as an external research resource. First, the research resources can be used to confirm the existing knowledge of the company (A6-Q13). The company may want to confirm this information because of a tight schedule or its own limited resources. This kind of a practice can have various effects. It may have a positive effect on the reliability of information and thus on success in launching new innovations. On the other hand, it may indicate a lack of knowledge and skills, uncertainty, or lack of resources in the organization. Another effect on research culture is learning that different sources of information and the outsourcing of information/knowledge can be used (A2-Q13). In one case, an increase of the activities of an already existing co-operation network was mentioned (A4-Q13). One answer identified a possibility that participation to the programme might have affected the research orientation of the company (A1-Q13).

The nature of the research culture in companies in the light of the type of innovation processes in which the information of research inputs was used remained quite unclear. In answers A1-Q2, A4-Q2 and A5-Q2 the companies describe their R&D or innovation model as systematic. The term was also used in the question. More detailed information would be needed to analyse the nature of innovation processes. It can only be concluded that the interviewees categorized their innovation processes to have characteristics belonging to systematic, process oriented, "traditional" innovation models rather than to other models, or without a relation to any model.

Table 36. Knowledge/expertise related answers.

	Structural level	**Social level**	**Cultural level**	**Intellectual level**
Resources	public R&D funding	participating in national and international R&D networks	culture of research and lifelong learning *A1-Q2, A4-Q2, A5-Q2, A1-Q13, A2-Q13, A3-Q13 A4-Q13, A5-Q13, A6-Q13*	level of education; scientific specialization; R&D workers A1-Q11, A5-Q11, A5-Q14, A2-Q6
Institutional setup	research and education infrastructure	structures for connecting of specialized expertise to the innovation processes *A1-Q4, A2-Q4, A3-Q4 A4-Q4, A5-Q4, A6-Q4, A1-Q1, A2-Q1, A3-Q1 A4-Q1, A5-Q1, A6-Q1, A1-Q5, A2-Q5, A6-Q5*		
Internal dynamics		processes of collective learning	absorptive capacity *A1-Q1, A3-Q1, A4-Q1 A1-Q5, A2-Q5, A3-Q5, A4-Q5, A5-Q5, A6-Q5, A1-Q8, A2-Q8, A3-Q8, A5-Q8*	

Level of education and scientific specialization of resources are the main references indicating the intellectual level of resources of the innovation environment, especially on the regional level. In this research context it is more natural to discuss the level of knowhow or knowledge in companies. This aspect came forward in answers A1-Q11, A5-Q11 and A5-Q14. Respondents to A1-Q11 and A5-Q11 saw that the long term effects of the model can be seen or are influencing through the development of knowledge or knowhow:

"The development of know-how have positive long-term effects." (A5-Q11)

The development of knowledge was also seen to have an impact on technological specialization in answer A5-Q14. Technological specialization represents operationalization capability and is discussed in more detail in the next chapter. One respondent saw that increased co-operation activities led to improvement of knowledge (A2-Q6).

Institutional setup related issues on the social level of knowledge and expertise elements of innovation capability are the structures for connecting specialized expertise to the innovation processes. The social structure of the MTAP-network is presented in Figure 10 on page 129. The main organizations were the university and the companies. An important part of the social structure of the MTAP network between the companies and the university was the local contact person (CU in Figure 10) of the university (A1-Q6, A2-Q6, A3-Q6, A4-Q6, A5-Q6, A6-Q6). There were also main contact persons (C) in companies, acting as a broker of information coming in and going out of the company. They disseminated development needs and ideas to the university and forwarded information on the model and research inputs gained from the university in their own organizations (A1-Q5). The research inputs spread, for example, through development teams (T) or from engineering departments around the organization (A1-Q5, A2-Q5, A6-Q5). The local contact person could also have direct contacts with teams and employers.

"Knowledge has spread well especially in the development team and the organization. Knowledge has been spread through one person's activity…" (A1-Q5)

At the university, the local contact person was mostly in contact with the professors. Although all the professors of the department were part of the model, most of the communication at the university was centralized through the communication link of a professor in charge of the project and co-operation.

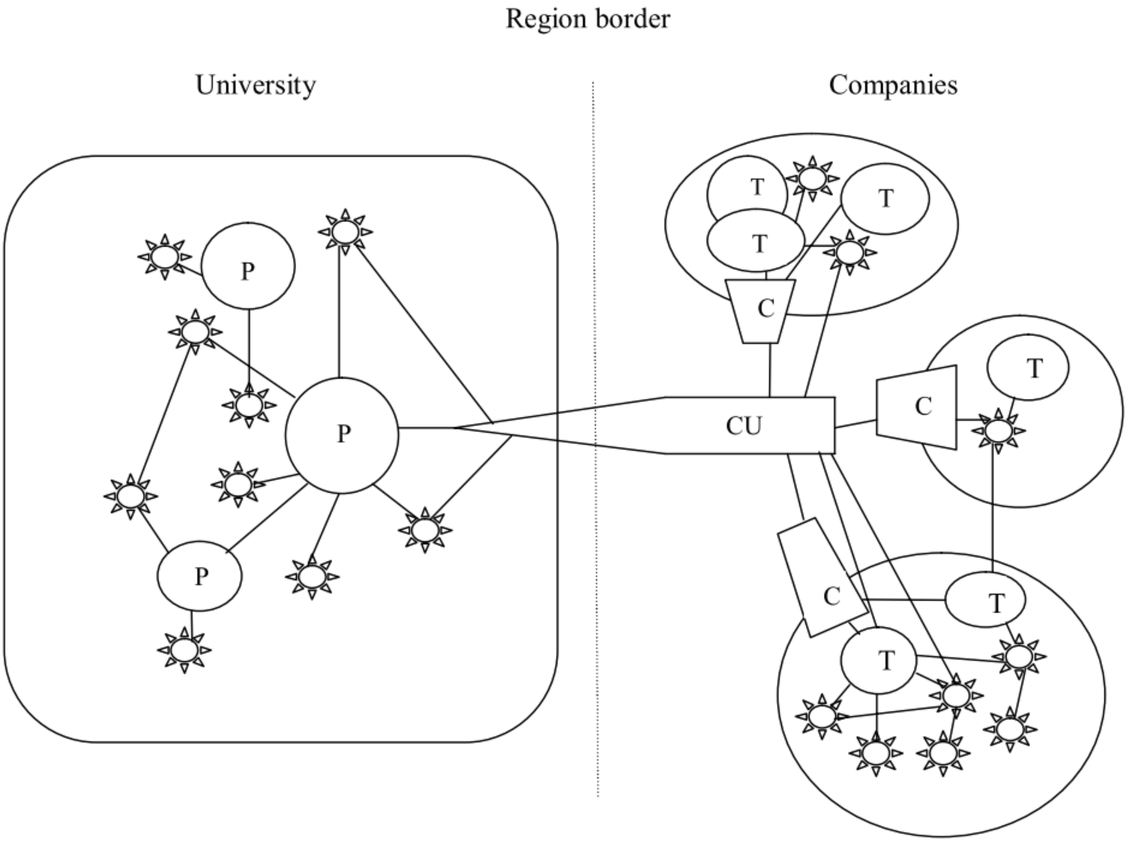


Figure 10. Schematic figure of the region-crossing social structure and connections in the MTAP network.

The interactions between the university and the companies in the programme was mostly one-to-one communication and meetings. Usually 1 to 3 persons participated from the university: the local contact person, a professor and a researcher. From the companies' side, typical participants were the contact person of the company, 1 to 2 managers or team leaders and 1 to 2 R&D staff members. With one company, regular, large co-operation meetings were arranged approximately 3 to 4 times per year with 10 to 12 participants (A2-Q4). Communication took place through meetings, e-mails and phone. One company also saw reports as one means of communication (A1-Q4).

Next, the procedure for launching new innovation processes is described. The communication initiatives usually originated from the university. In the meetings between the university and company contact persons, research needs were specified. Sometimes a professor and R&D staff participated to the meetings, in cases where the problem or need was specified in advance. The local contact person discussed the problem with the professor having competence in that research field. It was determined whether it is possible A) to find technological or scientific solutions to the problem, and B) to find a suitable research employee to make the study. After starting the research process, there were multi-directional information flows between the company and the university, and between the research and R&D staff. After the completion of the study, usually a common meeting for presenting and discussing its results and future actions was arranged.

Absorptive capacity of knowledge and information is a key element of the innovation capability. It belongs to the cultural level of social reality and internal dynamics of the innovation environment. In the context of this study, absorptive capacity was evaluated as the ability of companies to utilize the information and knowledge produced by the university in the MTAP programme. It means the ability to spread the received information in the organization and to utilize it in innovation processes and research and development actions.

First, the absorptive capacity can be analysed resource-based. The companies' resources on a general level were already described in the previous chapter concerning the structures of co-operation. Answers A1-Q1, A3-Q1 and A4-Q1 refer to the companies' resources and contact channels. These companies had a broader network than other companies.

Question five particularly asked about the companies' opinions on the absorptive capacity of their own organization. Five of the six respondents considered that the information was spread well in the organization and the ability to absorb information was good:

"Within the project organization, the information has moved forward well. Also the [a product named] example has been used in communication. There has been ability to absorb." (A3-Q5)

One respondent noted that absorptive capacity is also related to the nature and form of the given information. The form of university research reports may not the most optimal in tight-scheduled business processes.

"The utilizability of information is affected by the nature of the provided information and the presentation format (e.g. the form of reports). There was information on the model, but maybe it might have been even more extensive. In principal there was capacity to absorb, but the nature of information also affects it." (A4-Q5)

The same phenomenon, the usability of information, should also be taken into account if the absorptive capacity is analysed through the operationalization level of the information. Some answers provided information on the purposes information was utilized at companies. In answer A4-Q2, the respondent considers that information is utilized primarily for commercialization. The information provided had also led to new projects (A3-Q7, A4-Q7), products (A1-Q8, A3-Q8), product improvements (A2-Q8, A5-Q8) and process improvements (A1-Q8, A2-Q8).

7.1.4 Operationalization capability

In the previous chapter the structure and the functions of interaction processes for knowledge production in the MTAP network were described. In this chapter, the capability to realize new applications by exploiting the achievable knowledge base, the operationalization capability, is evaluated. Operationalization capability means the ability of commercialize inventions or implement them to existing processes and practices. It can also mean the development of inventions into new processes or practices. In addition to the network's matrix analysis, operationalization capability is evaluated on the basis of the actual innovations created in the programme. The answers related to operationalization capability are presented in Table 37 on page 132.

Supporting actions for commercialization are placed in the cell related to resources and structural level of operationalization capability. In one answer, the respondent saw that the knowledge was utilized for commercialization.

"...Most valuable commercial value for the characterization of materials and [removed] tests. Utilized mainly for commercialization..." (A4-Q2)

In the same company, new products, product improvements and process improvements were reported (A1-Q8). New product or process innovations were also identified in answers A2-Q8, A3-Q8 and A5-Q8. It seems that the resources and structure of the MTAP programme was capable to help the companies at the commercialization stage of the products and in transforming the knowledge as innovations. Possible reasons for that ability may have been the charting of market-based research needs by the companies, and the nature of the research inputs, being in the form which made them usable for companies for commercialization purposes.

Table 37. Operationalization capability related answers.

	Structural level	**Social level**	**Cultural level**	**Intellectual level**
Resources	support actions for commercialization; risk funding *A4-Q2, A1-Q8, A2-Q8, A3-Q8, A5-Q8*	participating in national and international business networks *A1-Q12, A3-Q12, A6-Q12*	attitudes towards entrepreneurship	technological specialization, business expertise *A1-Q14, A2-Q14, A3-Q14 A4-Q14, A5-Q14, A6-Q14*
Institutional setup	structure and casting of the mediator organizations	amount of the innovation related firm-level co-operation *A1-Q2, A2-Q2, A3-Q2 A4-Q2, A5-Q2, A6-Q2, A1-Q8, A2-Q8, A3-Q8, A4-Q8, A5-Q8, A6-Q8*		
Internal dynamics		leadership of the innovation networks *A1-Q3, A2-Q3, A3-Q3 A4-Q3, A5-Q3, A6-Q3, A1-Q7, A2-Q7, A3-Q7 A4-Q7, A5-Q7, A6-Q7*	change-oriented development culture	

A resource related but mainly social-level characteristic of operational capability is the participation in national and international business networks. The study did not aim at getting information on the general level of participation but on possible growth in co-operation stimulated by the programme (Q12). The business co-operation emerged in some answers (A1-Q2, A3-Q12 and A6-Q12):

"The model is utilized on the international level through the company's own activities in international co-operation. Some co-operation with [company name removed] through the MTAP-network." (A1-Q12)

Representing the dimensions of the intellectual level of social relations and resources of the innovation environment are the technological specialization and business expertise, the indicators of the operationalization capability in the NBIC matrix. Analysing the business expertise or its development in this context is quite difficult. It can be understood as know-how of the company staff to turn research inputs into new business. Question 14 asked about the possible effects of the model on technological specialization. Some effects were identified in answers A1-Q14 and A5-Q15. In A1-Q14, the effect was the result of specializing on a new business field, and in A5-Q15 the result of the development of the company's own special knowledge. In the company of respondent of A1-Q14, new production equipment was also purchased (A1-Q8). By contrast, in responses A2-Q14, A3-Q14, A4-Q14 and A6-Q14 no effects on technological specialization were recognized.

In the NBIC matrix, the operationalization capability related to the institutional set-up is categorized in structural or social level issues. In the matrix, the main social level indicator is the amount of the innovation related to company-level co-operation. In this analysis, by contrast, taking into consideration the special features of the MTAP programme, the amount and characteristics of the innovation related university-company co-operation is used. To specify the amount of co-operation numerically is difficult, because all co-operation under the MTAP programme was innovation related with several different co-operation forms. Next, the co-operation amounts which can be numerically presented are summarized based on the answers and Table 13 (p. 93) and Table 38 (p. 135). Table 38 gives a summary of the main results and activities in the Key Performance Indicator (KPI) form.

Communication was mostly focused on creating new co-operation projects and innovation processes. The main co-operation forms were project meetings, research reports, seminars and other oral and written communication. The number of pre-studies and research reports was 25, and they were related mostly to materials and process development, especially in plastics. Some studies were related to seeking new business or technological opportunities. They can be seen to be used as an external source for companies to catch weak signals and future trends in technological foresight (see e.g. [168]). Pre-studies were distributed quite evenly among five companies; one company did not use that option. 30–50 smaller investigations and research processes were realized. Three seminars were arranged and were participated by two hundred persons from the companies and universities (Table 13). 65 new innovation processes were started (Table 38). All of the companies used the research information provided by TUT as "fast inputs" to support their own R&D activities (A1-Q2, A2-Q2, A3-Q2, A4-Q2, A5-Q2 and A6-Q2). With one exception, the companies used TUT also as a provider of technological pre-studies and research reports. One company which did not use that option used TUT as a partner in the planning of new technological R&D processes (A5-Q2). At least four R&D projects of the companies were activated. New products, services or product improvements were recognized in four companies. (Table 13, A1-Q8, A2-Q8, A3-Q8, A4-Q8, A5-Q8, A6-Q8)

Question 9 asked if the results would exist without the MTAP model and in what time. Five answers, (A1-Q9, A3-Q9, A4-Q9, A5-Q9, A6-Q9), mentioned a quicker development time. The respondent of answer A2-Q9 seemed to be quite uncertain: first the respondent is convinced that all the results will surely be achieved, but at the end assumes a totally opposite opinion:

"Surely, and perhaps in the same time, but now at least more efficiently. Or maybe they might have not been realized at all." (A2-Q9)

Especially two enterprises differed interestingly by the nature of their collaboration. The first company used the model clearly as a knowledge resource. It utilized the university-level knowledge as inputs to their own innovation processes. Still, the results were good: a technological pre-study gave an idea of a new plastic material to improve the properties of an existing product, and now the new product with better properties is on the market. The other company used the model to expand and "accelerate" the activities of the existing co-operation network between the TUT DMS and the company. It was strategic co-operation, where the new development ideas and projects were discussed and planned freely together. The main result was the planning and starting of a very large new research and development project.

Table 38. Summary of the main results and activities in the Key Performance Indicator (KPI) form.

	Number	In number of companies/ companies interviewed	Budget [€]
Companies that participated in the MTAP programme	18		
Companies that funded the MTAP programme	8		
New products, services or product improvements		4/6	
Process improvements		2/6	
New know-how or expertise		6/6	
New data, information or knowledge		6/6	
New knowledge networks		6/6	
New turnover or positive effects on profits		2/6	
Positive effects on company image and other long term effects		4/6	
R&D projects started	4	4/6	1,633,420
Research projects started	8		573,420
Materials related innovation and research processes	34	6/6	
Processing technologies related innovation and research processes	14	4/6	
Other new innovation processes started	12		
New innovation processes, total (studies, investigations etc.)	65		

Concerning the innovation processes of the MTAP programme, the structures of the programme seemed to be more efficient in producing novel research information than in planning or further preparation of R&D projects. The companies' side of the operationalization capability remained quite unclear, despite the successful commercialization and innovation examples.

The leadership of innovation networks is a complex question, especially with a wide, multidimensional network like in the MTAP programme. It represents the dimension of internal dynamics and social level of operationalization capability. Leadership can be categorized in several roles. The official leadership of the MTAP programme was a responsibility of the project's steering group. It consisted of representatives of the companies and universities. Concerning the research needs, three companies identified the needs by themselves (A2-Q3, A4-Q3, A6-Q3). With one company, the identification was made in co-operation (A2-Q3). With one enterprise, research initiatives came from the company itself, from the university or were joint processes (A5-Q3). In one case, the needs came from the company, but further planning was usually done together with the university (A1-Q3). When the programme was launched, it was expected by the university that the identification of the research needs would take place mainly in the form of co-operation between industry and the university: now the research needs were largely established by the companies. An interesting social observation was that a very high share of communication initiatives originated from the university and were made by the local contact person, who had the role of an activator. Companies rarely took the first move in communication to launch new processes.

The leadership of the innovation network can also be analysed through the leadership of innovation processes. Most often the resources of the university were used as part of already existing projects of the companies (A1-Q7, A2-Q7, A3-Q7, A5-Q7, A6-Q7). In that case, the leadership of the whole innovation process remained at the company, although the management and steering of the sub-process (research process) was the university's responsibility. When research needs were specified together (A2-Q3) or in research processes focused on creating new ones (e.g. in A3-Q7, A4-Q7), the leadership and responsibility of the innovation processes were shared.

7.1.5 Summary and contributions

The novelty of the MTAP programme compared to other advisory professorships was that the operations were clearly divided into two elements: activities in the region and transferring information from the head unit of the university to the region. The innovation network of the programme also contained more companies than previous professorships and problem-setting was more based on companies' needs.

The main research contributions are in the use and networks of practice-based innovation tools, grounded on theories of practice-based innovations and systems. The main research contribution is in applicability, usability and effectiveness of a practice-based innovation tool, the advisory professorship model, and in new information concerning the internal dynamics and innovation capability of the practice-based university-industries innovation network. The perspective of analysis was on individuals and companies of the network and on technological innovations of the companies, including product, process and technology innovations.

Concerning the social network, the organizational borders between the university and companies were able to be crossed in a way that university participated actively to the solution of the companies' market-based challenges. The social network in the MTAP programme was capable to produce novel information related to actual company-based needs. The network had also operationalization capability to launch new innovations by exploiting the provided knowledge, and new innovation processes in the companies and between companies and universities. The structural holes in regional innovation systems offer possibilities for new networked innovation processes [18]. The main structural holes in the network of the MTAP programme were the links between the industries and companies. Including elements to the advisory professorship model to support the surpassing of organizational and industrial limits between companies would increase the capability to produce new innovations. The applicability of the model in moving information between companies and industries is not the most optimal without further development. To further enhance co-operation between companies and the connection of accumulated knowledge of industries, more efficient structures for systematic communication would be needed. In the MTAP programme, the operationalization capability to build new processes between the university and industries was good, but the operationalization capability between the companies was low. This was related to fact that contact persons of the companies were on management level. They have the implementation authority but not necessarily adequate, updated information of the status of their R&D projects or markets. Deepening the contact and the co-operation network to operative players of the companies may have affected the amount and quality of new innovation processes positively. However, it might include the risk that the nature of desired knowledge and information would move out from the research and core expertise fields of the university.

The development of strategic co-operation relationships between the companies and the university was more challenging than expected, even if it is one of the main aims of the advisory professorship tool. A minor contradiction can be seen in a fact that in general, the practice-based innovation tools are meant for identification and creation of new processes based on practical challenges of companies, but an important aim of the advisory professorship programme was, in addition to making the knowledge of the university available to regional practice-based innovation processes, to create new strategic alliances between the university and the region's industry. The programme was created as a result of formulation a strategic co-operation relationship between the university and the region, and the resourcing the programme aimed at the creation of strategic co-operation between the university and the companies, though the main focus was on the solution of the companies' practice-based problems.

The companies seemed to have capacity to absorb information of the research inputs in their innovation processes in creating new products or developing product and process improvements. The industry that participated to the MTAP programme can be considered mainly low-tech, mature industries. The innovation network, processes and effects of the programme, as well as the motivation to participate to the programme correspond well to the typical characteristics of technological development in low-tech companies (e.g. [154]). The products of low-tech industries are less complex and often quite easy to imitate, technological development processes are less incremental and patenting is not so commonly used option. Technological development is mainly based on transferring the knowledge created in other industries or research organizations: Companies concentrate on the exploitation of existing technological knowledge instead of exploring new knowledge. Typical of low-tech companies are that they have close relations with organizations creating knowledge: universities, polytechnics, etc. Participation to innovation networks is also quite common. Companies also need to have a good absorptive and transformative capacity of information. [154]

However, to develop research capacity to absorb the information purchased from research organizations, can be seen as a traditional strategy for university–industry co-operation. The industry-university collaboration of the MTAP programme had also characteristics of the new approach, which is more typical of high-tech-industries. It aims at stimulating a process of joint creation of more fundamental knowledge. The research contracts are seen more as rights to access to the tacit knowledge of a research organization’s network than an agreement on certain services. [104; 153]

In the companies’ answers it was clearly brought out that the characteristics of the university-level research inputs were different than in their normal internal development activities or in co-operation with subcontractors. It affected the reliability of information with possibilities to double-check and cross-check it. When using the model in confirming their own existing knowledge, it is a question of the amount of information rather than its novelty. The characteristics of the information produced in the programme were also different than what is possible to create in more typical projects and activities of university–industry co-operation. The innovation processes were based on practical problems of the companies and connected to existing and planned R&D projects, but also to the initiation phase of new strategic research openings or collaboration. However, focusing on the form of the produced information and methods to spread it in the organization would help in finding new innovations.

If the same issue is observed from the university viewpoint, it seems that the nature of the research information produced in the MTAP programme was also different than in typical projects of universities. The university–industry co-operation is mostly operated through fundamental or applied research projects of universities, R&D projects of companies and subcontracted research and testing services. In the programme there were a lot materials technological pre-studies, which were conducted in a relatively short time period and whose scope was usually quite restricted. They were based on concrete, practice-based problems in the companies’ activities, usually pertaining to the product properties, availability of materials, processing technologies or markets and research knowledge in selected fields. These facts do not indicate that the pre-studies would have been less scientific or less challenging: as a matter of fact, tight schedules and combining the business based and scientific approaches posed their special demands. There are some reasons and restrictions why this kind of information is usually not a result in typical university–industry projects. Regarding the scope, frequency of occurrence or the urgency of the issue, it is usually not possible or reasonable to start a research process of such practice-based problems with a university, comparing the inputs needed by the company with the research outputs. Getting a new research process started needs quite a lot of efforts, time and resources from the company's side. Even if the results of the research were excellent, the most restricting factor is time. Often companies need new information in tight-scheduled R&D projects and in the solution of unexpected problems. The solutions and answers are looked for simultaneously with internal and external resources. If the answers are found with other ways during the start-up process with the university, all the inputs to that process are wasted. The MTAP programme, instead, offered already existing communication channels and a co-operation model to be used immediately. Typical lengths of the pre-studies were from a few weeks to three months. Also a lot of smaller studies, with lengths of one to five days were conducted. The contents and nature of the studies varied quite a lot. There were some studies with strong applied focuses, concentrated, for example, on finding materials for certain thermal and abrasive environments. However, there were also studies with top-level national or international research knowledge related to certain research fields, aiming at new industry-university co-operation processes and the utilization of international research knowledge.

Concerning the effectiveness of the tool, a major part of the companies had new products or services and product and process improvements created in the programme. All of the companies saw that the programme had created new know-how, expertise, data, information, knowledge and knowledge networks. They saw that model increased the heterogeneity, availability and reliability of the information to the companies. It is quite impossible to estimate the indirect financial outputs of the actions in the MTAP network, for example, the definitive value of new information. On the other hand, in the case of a new commercial product the direct financial outputs can quite easily to be calculated. Nevertheless, it should be remembered that the development of a new product and its entrance to the market are influenced by several factors. In two cases, which the companies reported to be created through the model or by the influence of the programme, the connection between the products and the programme was very clear. In the first case, it was a question of a technical improvement to an existing product, which improved the usability and functionality of the product. In the other case, new research information of the properties of a unique material was produced, which was a critical factor in succeeding to manufacture a new product. The processing of this material was extremely challenging and it was not changeable because of the company's strategy and internal motives.

One key issue to the positive results might be the interdisciplinary nature of materials research at the DMS of TUT. Because R&D groups of industries often concentrate on solving technological challenges of products, they often need knowledge and information of several fields of science. These interdisciplinary research groups may have problems to communicate with research teams of universities, which typically represent only one discipline [157]. In this case, the interdisciplinary nature of the research groups both at the university and in industry, might have helped in the communication.

One question was: is it possible to separate the effects of the programme from other factors. In question 9 it was asked if the results would been created without the model/in what timeline. Because the questionnaire and interviews were made in a way that all respondents were clearly aware that they were asked particularly about the results of this very programme, they analysed their answers through that framework, which decreased the risk of identifying irrelevant results. Another question was, would some other tools or models of co-operation been equal or more efficient than the MTAP model. In this case there would have been more concrete results, or the same results would have been achieved with less resources, the companies' or the universities' own resources. In retrospect, it would have been beneficial for the further development of the tool to have a question about suggestions on how the co-operation would have functioned better, and in what parts of the model there was something to be improved. It is also quite difficult to imagine any internal project of an organization or a joint project without the creation of know-how, expertise, data, information, knowledge and knowledge networks at least at some level.

The main practical contribution is that practice-based innovation tools and their applications may be used successfully in regional development and in university–industry co-operation. The delivery of and access to knowledge of the universities outside of the region can be offered by the combined structure of regional and head unit activities and resources. The regular university–industry communication during the programme was based on the definite contact persons of both sides. In general, companies consider the difficult accessibility of university staff as great factor limiting, restraining and even preventing the co-operation with universities. This fact is creating barriers to the knowledge transfer between companies and universities and for starting of new joint research and development processes. The companies saw that the practice of a specific university contact person was a functional solution, which is worth taking into consideration when the advisory professorship models are developed further. Nevertheless, it is also important to recognize the fact that the development of models and practices to stimulate the formulation of multi-level, direct contacts and networks between the research staff of the universities and the R&D groups of the companies would be beneficial. In the MTAP programme the number of the direct contacts and the width of the network could have been larger. A communication network based on certain main players increases the risks of discontinuity in the information flows and polarization of information, causing failure risks in innovation processes.

As a summary, the MTAP programme managed to formulate new practice-based innovation processes, concentrated on practice-based problems and development targets in the companies' products, operational environment or markets. The role of the university was mainly in producing information especially in the front-end phases of the innovation processes, related mostly to properties and processing knowledge of materials, the feasibility of development ideas and the search of new R&D opportunities. The nature of university based inputs was typically fast, short-termed, but scientific. Some of the innovation processes ended up in the market. New know-how, expertise, data, information, knowledge and knowledge networks were also created. Because there are no comparative studies or information, the possibility cannot be excluded that some other tools might be equally or more usable, functional and effective so that the same or better results would had been achieved with less resources of the companies and universities.

7.2 Developing the regional innovation system in materials technology

The other research problem was: what are the most important materials, technologies and fields of materials science for the materials processing industry in the Lahti region and how to develop the materials-technical expertise and innovation system in the region? This problem was approached with several sub-questions. Information was gathered of the region's materials technology related to a) industry and industrial needs b) expertise and knowledge of universities and other research and education-giving organizations c) infrastructure d) public policies and strategies, and e) innovation system and capability.

First, the answers of the research part described in Chapter 6 provided information of the importance of different materials and materials technology to industries. The need and demand for materials research were also determined. Second, the competences of main universities in materials research in the Lahti region in contributing to these industrial needs was analysed in Chapter 5. Third, Chapter 5 also described the activities of MTAP programme in regional development work, including the expertise related to materials technology and material efficiency in Lahti in a national framework, and the infrastructure in the Lahti region related to materials technology and efficiency. Fourth, the effects, results and the activities of the MTAP programme are used future in Chapter 8 for concluding how the materials technology related regional network should be developed in the.

The aim of the analysis in this chapter is to get information on what materials research fields are important for the regions' industries and thus which research fields, activities and co-operation should be developed and resourced in the context of regional development. The companies operate globally but their regional significance is remarkable, for instance, through the value of gross production and employment. The above notwithstanding, the companies' interests in regional development might be low because their key activities are directed to customer and supply interfaces beyond the regional point of view.

7.2.1 Analysis methods

In the regional development context the results are analysed with two different methods. In thematic analysis, the theme "challenges and opportunities of materials technology" was catalogued to sub-themes according the three focus areas of regional development. The competitiveness and economic development strategy for the Lahti region for years 2009–2015 defines three main focus areas of regional development and "spearheads" of know-how in the region. They are 1) environment, 2) design and 3) practical innovations. Regionally this choice is seen representing the strategies of smart specialization, based on strong fields of regional know-how, breaking the boarders of industrial clusters [169]. The answers in Table 33 on page 119 are classified under these sub-themes.

The other analysis is based on the theory of regional effectiveness of universities, according to Storper [16] and Tura [17]. Out of the traded mechanisms of the regional effectiveness of universities, two mechanisms were selected: delivery (efficient transfer of knowledge, experts and education) and accessibility: easily and efficiently reachable contacts to university. Untraded mechanisms include all activities and resources already existing in the region. The feature evaluated was the level of the functioning of the mechanism. The features were:

1. Level of un-traded knowledge
2. Level of knowledge delivery: efficient transfer of knowledge, experts and education in materials technology
3. Level of knowledge accessibility: easily and efficiently reachable contacts to universities

First, the results concerning the main materials, technologies and research fields to the industries are discussed and summarized. Then the key issues and knowledge sectors in materials technology are placed in the matrix with the effectiveness mechanisms of the universities. The levels of regional knowledge, access and availability of the sectors are marked with three grades: - (no/poor), + (some/tolerable) and ++ (a lot/good).

7.2.2 Thematic analysis

Answers concerning the recycling of materials, the use of renewable resources and ecological sustainability were classified to the environmental sector. Answers concerning the properties and selection of materials, processing of materials, and structure, composition and properties of the products were classified to design-related issues. Answers based on some novelty element were classified under the practical innovations sector, where the solution of the problem would need a combination of both theoretical, practical and business knowledge, or the issue could be approached with the practice-based innovation tools.

Environment

Recycling was emphasized in answers A2, A10-3, A11-2, A13-1 and A15-2 (Table 39). In general, recycling is a wide term including, for example, materials and processing technical issues, financial and marketing perspectives and product properties. In the answers, more detailed descriptions of the challenges were not brought up except in A15-2, where purity, availability and feeding were mentioned. The use of renewable, bio-based, natural or non-oil based materials was mentioned in answers A11-1, A11-2 and A13-2. Besides wood-based materials, industries are not using significant amounts of renewable materials in product manufacturing in the Lahti region. Eco-friendliness came forward in answer A10 (A10-1 and A10-3).

Table 39. Environment related challenges and possibilities.

Environment	
A2	Recycling
A10-1	Eco-friendliness, free of emissions
A4-2	Environmental aspects
A10-3	In general: recyclability, eco-friendliness
A11-1	Enhancing the use of renewable materials in products (sustainable development)
A11-2	Biobased, natural and recyclable materials
A13-1	Recycling possibilities of materials
A13-2	Non oil-based plastic raw materials
A15-2	Materials recycling related issues: purity; availability, feeding

It is good to recognize that recycling, bio-based materials and eco-friendliness can be in contradiction to each other. The use of bio-based materials can restrict the opportunities of recycling. For example, the use of biodegradable polymers in product manufacturing may cause errors, difficulties and extra costs in recycling systems, which are usually based on legislation and regulation of product responsibility, like recycling systems of bottles and other packages. The existing systems are not designed to receive or process other materials than currently used. The ultimate cause of the malfunctions in the system is the different properties of the materials. Bio-based polymers have typically different thermal properties (lower melting or glass transition temperatures than volume plastics), high absorption of water and moisture, different transparency and other differences in chemical and mechanical properties when compared to plastics more common in packages (PE, PET, PP, PA). Preventing the non-suitable materials from passing in the system would need new collection and separation equipment, new practices and education, and new instructions for consumers. There is no causal relationship between the use of biomaterials and eco-friendliness. Environmental effects of materials and products can be estimated and analysed with life cycle assessment (LCA). In case of biopolymers, the benefits are that the processing temperatures of typical biopolymers are lower than those of traditional plastics, decreasing the energy consumption of production. The main benefit of biodegradable biopolymers is that littering is less harmful than with normal plastics because of the degradation in nature. The main disadvantages are that the production processes of biopolymers are usually less efficient than volume plastics with a long industrial history. There can be great differences in product properties affecting durability and usability. [39] For example, in a LCA on shopping bags in Finland, the bags made from bioplastics were more harmful to the environment than bags manufactured from virgin PE, recycled PE or paper [170].

Design

Most of the answers categorized in the design sector were related to properties of materials (A1, A7-1, A3-2, A7-5, A7-6, A14-2, A7-4, A13-3, A14-1) (Table 40, p. 147). The characteristics of materials have a strong effect on the design, structure and functioning of the product. Such issues include thermal properties and heat resistance (A7-1, A7-5, A3-2), antibacterial properties (A14-2, A14-1), chemical structure (A7-4), functional and active materials (A13-3), moulding properties (A7-5) and durability (A7-6). Some of the material properties can also be categorized to properties of final product (A14-1, A14-2, A7-5, A3-2, A7-1). However, design and structure also affect the functioning of goods. For example, low thermal properties of plastics do not necessarily limit their use in high temperature applications if thermal absorption is prevented with other materials or structural choices. Other product properties were functionality (A9-3), antifriction surfaces (A7-3) and abrasion resistance (A7-2).

The selection of materials and search for alternative materials was emphasized in several answers (A12, A14-3, A5, A1, A7-4). For manufacturing companies, the critical factors are material prices and ensuring the desired product quality. A change of material in the manufacturing process contains a lot of risks, which is why the companies are highly reliant on raw materials suppliers. The amounts of raw materials used are usually small in the companies of the region, which makes the tailoring of materials by raw material manufactures almost impossible. Small supplied amounts also affect the willingness of suppliers to price negotiations.

Table 40. Design related challenges and possibilities.

Design	
A1	Increasing the knowledge of material properties and especially the possibilities of new materials.
A3-1	3D modelling to make dimensional accuracy as good as possible.
A14-4	Continuous problem: products have to carry bigger stresses but their weights cannot increase.
A3-4	Joining of metal and plastic parts
A3-3	Manufacturing of big-sized plastic parts cost-effectively
A10-2	Structural strength
A14-3	Alternative materials, metals to plastics
A12	Selection of materials and alternative materials
A5	The selection of materials is challenging: Several suppliers, several materials suppliers with standard *[material name removed]* which are different, because standards allow certain tolerances. With *[removed]* suppliers, the batches are big, they have their own product development.
A9-2	Research, design
A9-3	Testing of functionality
A7-1	Thermal properties of metals and alloys
A3-2	Cost effective heat resistant materials in *[removed]*
A7-2	Erosion-corrosion, abrasive wear
A7-3	Antifriction surfaces
A7-4	Additives, catalysts
A7-5	Moulding properties and thermal resistance of plastics
A7-6	Durability of sealing materials
A13-3	Intelligent and active materials
A14-1	Aseptic safety of materials
A4-1	Surface treatment

Structure and design related answers included 3D modelling (A3-1) and structural strength (A14-4, A10-2). A change of material in a product is not just a material concern but also a structural problem (A14-3). The same applies to joining of different materials (A3-4): a joint can be made with bonding or welding, but also with different structures, such as clip joints.

Concerning manufacturing, the production of large plastics parts cost-efficiently was important in one company (A3-3) Different additives are used in plastics. They do not just affect the properties of materials but also processing (A7-4). Moulding properties (A7-5) are important in companies using injection moulding or other moulding technologies. Surface treatment (A4-1) is related to material properties, but also to product design and the retreating machinery needed.

Practical innovations

Answers based on some novelty element in technology, markets or business models, or where the solution of the problem would need a combination of both theoretical and practical knowledge or technological and business knowledge were classified in the practical innovations sector (Table 41). It also includes some matters, which would have been suitable to be approached with the practice-based innovation tools in the context of regional development.

Table 41. Challenges and possibilities related to practical innovations.

Practical innovations	
A6	Development of new competitive materials
A15-1	Optimization of supply chain
A15-3	Optimization of development and manufacturing processes of plastic products
A3-3	Manufacturing of large-sized plastic parts cost-effectively
A4-3	Development of materials, process development
A9-5	Industrial activities in *[removed]* have moved out from Finland and are not coming back. Product testing is a possibility where research is still needed and developed.
A9-1	Globalization of research and development

Some of the challenges would need both materials technological and industrial economy/management related knowledge or their combination (A6, A15-3, A3-3, A4-3). Two of the answers expressed concerns about the globalization of the R&D work and industrial activities (A9-5, A9-1), being matters which are also important in the regional development work and give reasons to regional innovation policies, tools and strategies.

7.2.3 Availability, access and delivery of the research knowledge

For the industries of the region, the plastics and metals were the most used material groups, followed by wood. The most used individual materials were steel and thermoplastics. In a priority analysis, the differences between plastics, metals and wood were quite small and the precise priority order of these materials cannot eventually be concluded. Concerning the priorities inside the material groups, it can be said that the priority order of metals was steel and aluminium, and that thermoplastics were the most important plastics if the standard deviations are taken into account. These results are quite expected considering the industrial sectors represented in the study. The usage and importance of plastics was slightly higher than predicted. There were just two companies in the study representing the plastics industries. Large amounts of plastics in product manufacturing and in packaging purposes are also used in other industrial sectors. Plastics, metals and wood were selected to the analysis.

The most important research areas of materials technology for companies were fundamental research and materials development, recycling and recovery of materials, characterization and testing, process development and material efficiency. The most important research service for companies was quite clearly the testing services. The research services related to plastics and metals were almost equal in comparison between different material groups. The research related to plastics was quite clearly identified as the most important. That may indicate that the companies see plastics as a challenging material to process and handle. In general, there are some typical difficulties connected especially to plastic materials. The very large amount of commercial raw materials with their specific characteristics makes material selection complicated in many cases. In addition to the material properties, the processing method has to be taken into consideration in the selection phase, because raw materials are tailored for certain technologies. Injection mouldable, extrusion and rotation mouldable grades differ, for example, by their melt viscosity, additives and particle size. The processing method and parameters also have a strong impact on the properties of the final product. The melt processing of plastics needs special knowledge because of their viscoelastic nature. Machining of the semi-finished products can be problematic because of the heat sensitiveness and related phenomena (relaxation of residual stresses, melting, crystallization, etc.).

The possibilities and challenges of futures materials technologies were mostly related to the improvement of the properties of existing materials and to the development of the processing technologies of materials. As a strategic point of view, 14 of the 15 companies were going to make internal investments in materials technology related R&D in the next two years. Six of the companies considered the investments as remarkable. Thirteen of the companies were going to invest in external R&D services and ten companies in the research services of universities. Naturally, it is impossible to find an industrial product which had no concrete, solid form constructed from materials, excluding the service business. R&D in industrial companies is in most cases related to materials technology at some level and volume. However, the answers indicate that materials technology related development issues are recognized in the companies, and are considered worth of investments by some internal logics.

Materials technological research expertise of Finnish universities are part of the state of art discussed in Chapter 3. The materials technological research expertise and knowledge in the region is viewed in Chapter 5. The regional status and the activities of the Aalto University and TUT have changed in the region since these descriptions. TUT diverged from the Lahti University Consortium in 1.3.2011, but the regional projects and their activities remained. The Lahti Unit of Aalto University was administratively integrated to the Department of Civil and Environmental Engineering on the main campus in Espoo 1.2.2012. Some development projects and their personnel were moved to LUAS. These changes meant the decrease of regional influence and authority in public development of both universities, and in the regional availability of the resources and knowledge of the universities. The expertise fields of the research organizations have not changed substantially since 2007. The study related to infrastructure in materials technology and efficiency was conducted in 2009. There have been no major changes in locations, equipment or facilities. In addition to the knowledge of the universities, the expertise of a local university of applied sciences (LUAS) is taken into account in the analysis.

In materials knowledge, the delivery of knowledge, experts and education are based on projects and education co-operation or formal, strategic co-operation relationships, like advisory professorships. Contacts and access to universities of technology are well established and remained the same because of the long history of co-operation with TUT and Aalto. Untraded research knowledge is found at LUAS. The knowledge of HU is focused on environmental sciences. The university level local technological research resources are based on the projects of TUT and Aalto University (Table 42).

Table 42. The availability, access and delivery of materials technological knowledge.

		Resources	Delivery	Access
Materials	Plastics	+	++	++
	Metals	+	+	+
	Wood	+	+	+
Research fields	Fundamental research and materials development	-	+	+
	Recycling and recovery of materials	+	++	++
	Characterization and testing	++	+	+
	Process development	+	+	+
	Material efficiency	+	+	+
Research services	Testing services	+	+	++
Possibilities	Properties of materials	++	+	++
	Product properties	+	+	+
	Recycling	+	+	+

Concerning the research fields, there are currently no resources for technological basic research of materials in the region. Some applied knowledge concerning the development of materials is found in LUAS. HU has fundamental materials related knowledge based on environmental research. Delivery and access options to TUT are still available, especially in plastics. Recycling and recovery of materials and material efficiency were the key expert fields of Aalto. TUT has also university level knowledge with access and some delivery options. Some expertise in such research fields is also found in LUAS, especially in plastics. LUAS has also some facilities for the characterization and testing of materials and process development. Some testing services of materials are offered by LUAS and HU in the region. LUAS has some product testing in furniture. The possibilities in materials technology were most related to properties of materials and products and to recycling. Regional resources are offered by LUAS with its activities and education in materials technology and design. Delivery and access to Aalto HUT and TUT still exist on some level.

7.2.4 Summary and contributions

The main regional strengths in materials research are the multilevel applied materials knowledge and knowledge in environmental use of materials on the basic and applied level. Facilities for testing and analysis services of materials and products used in quality control and product development are also rather conveniently placed in several locations. Good delivery and access options are found for the research of plastic materials and for recycling research. The main lacks are the deficiency of the basic knowledge of the properties and processing of engineering materials and of university level environmental technology. Especially the development of such research fields in materials technology and their access and delivery options capable to boost the environment and design business sectors should be promoted. Recycling and properties of materials were considered the main challenges and possibilities. When applying the MTAP programme, many of the new innovation processes launched and all new innovations realized through the programme were related to plastics. It seems that the regions' resources and knowledge especially in this field of materials technology have innovation potential in the region, which is in accordance with the results of the application process of the regional development platform method in the Lahti region [120; 129]

The practical contributions to this research part are related to the regional development in the Lahti region. New information was generated concerning the use of materials and the needs of the manufacturing industries for materials research. The main part of materials technological possibilities and challenges in the companies pertain to the focus areas of public development, especially to design and environment. When focusing on certain sectors in regional development, cross-sectional, horizontal research fields are easily forgotten. In addition to the practical innovation sector, "hard" cross-sectional technical sciences, based especially to industrial history of the region, should also be promoted. Renewing of industries is not possible without a combination of old and new technologies.

A practical contribution is also made in the analysis of development of materials technological knowledge in the Lahti region. The region has multilevel materials technology important for industry, with good delivery and access options. However, this knowledge is located in several places, which makes communication and effective utilization difficult if the aim is to promote the development of design and cleantech sectors. The companies consider the materials technology related research and development actions important and worth of investments. The main lack in regional materials technological knowledge is the lack of basic research and knowledge concerning the selection of materials.

7.3 Reliability and validity

In qualitative research the reliability and the credibility of the research refers to the question if independent researchers would end up with similar results and conclusions as the original researcher. Internal reliability of research means if other researchers would analyse and match the existing constructs to the data and observations similarly to the original researcher. External reliability is corresponding to the issue if independent researchers would find the same truth and come up with similar conclusions by replicating the study. [171-173]

Before analysing the internal and external validity of this research in detail, the other criteria for reliable scientific research are viewed. According to Airila & Pekkanen [174], scientific research is public, critical and autonomous. Further, the evaluation of scientific research should be based on the novelty, publicity, truthfulness and generality of the information and knowledge, and on the publicity, criticality and autonomy of the research [174].

In addition, the reliability of science can be analysed by the objectivity and the reproducibility of the research, adequacy of the research material, and independence of the research results. The scope of the analysis should be based all of the research materials, and the stages of the analysis should be documented and visible to the reader. The relevance of the research can also be evaluated. The confirmation of the results means that the results are supported by the results of other studies. [14; 175]

Concerning the criticality, autonomy and objectivity of the scientific research, it should be independent from the opinions and prejudices of the researcher. However, all qualitative research requires the active role of the researcher in the environment he/she is observing. In case studies, a researcher and a research object can interact constantly with each other as part of the research process. At the same time, the researcher should be neutral and objective. These were also principles in this study. The author was participating to regional activities and development of materials technology as regional research manager of TUT DMS. Without this role in regional materials technology related network, the evaluation of the functions and activities would had been difficult or impossible. The evaluation study and process was conducted in a way that attempted to maintain the objectivity and neutrality in every stage of the research, including the analysis of the results and conclusions.

The independence of the opinions and prejudices of the outsiders is a more difficult question. Because the research material was mainly based on the interviews of the representatives of the companies, the research material and data cannot be independent on the opinions of other people. However, they were part of the research, not outsiders, but still their opinions and answers are naturally affected by their living and working environments. The research is located in a regional environment, where the practice-based innovation policy is highlighted in regional development policies and strategies, and the materials technology and knowledge has clearly been important part of the industrial activities. The positive public and private atmosphere related to the research topic, might have affected answers of the interviewed persons.

The internal validity of the research can also be discussed. The field of the study was in between the materials science and practice-based innovation theories. In the theory part, the materials science and innovation theories were viewed in generally. In the study, the regional characteristics of these issues were also presented. The case study was regional and had limits in the generalization of the research results. In qualitative research the generalizability of the results is typically low, compared to quantitative research [15].

The main aim of this study was to give information of the usability of the advisory professorship tool in university–industry co-operation, outside technology and regional contexts. Nevertheless, the network-based innovation tools and innovation processes are naturally tied with the network and its partners where they are applied. It is not possible to measure the effects outside this network. The network has to be connected to certain regional or industrial areas. The effectiveness of a tool would be different in other regions, with other industries, persons and communication skills. The network analysed in this study is unique. The results of the research indicated that the advisory professorship program in materials technology was able to create a reasonable number of new practice-based innovative processes and other outputs in the Lahti region. In other regions, with other participants in the network, the results might be different – the generalizability of the results is low.

Furthermore, concerning the internal validity of the research, the research was made by structured face-to-face interviews. Structured interviews are a widely used quantitative research method, but they can also be used in qualitative research. In the interviews, the interviewer and the interviewee both had the structured form with the questions. The interviewer presented the questions, and wrote down the answer of the interviewee. If it was an open question, the interviewer repeated the written answer so that the interviewed was able to check it. It is natural and obvious that the interviewees understood different materials and research fields through their own knowledge and experience, which can affect their answers. All information in the research interviews is information given by individual people in companies. It may present more individual ideas and opinions than the “official” thoughts of the companies. It still can be seen as best available information, in the framework of the time and research resources available. The same applies to how the innovation environment and capability related to the advisory professorship-model was evaluated. It can be discussed how well the selected indicators represent the truth, and how reliable the answers are. Another question is how the effect of the model can be separated of other factors. There is the risk that effects of other phenomena, like changes in the market situation or competitors, implementation of new production methods etc., are measured. One issue affecting reliability was that the interviews were not recorded. The decision was based on the use of the structured interview method. Because of that, there was no possibility to check the original answers or their semantics, stresses and word-by-word forms. The answers existed only in written form. The answers were not written down in their strict form word by word, but by making notes on their essential contents.

The conceptual framework used in the case study, the NBIC matrix, is meant for measuring the innovation capability of a region. As described in Chapter 4.7, in this study the matrix was used to evaluate the innovation environment in the network generated through the MTAP programme, and how the changes in available regional resources (inputs) and public steering work of materials technology through the MTAP programme affected the innovation capability and the network. The matrix was not used to analyse how the TUT as an organization succeeded in the Lahti region.

The objectivity of the research can be attempted to be secured using two or more supportive research methods or information produced by different observers from the same phenomena [14]. In this study, the approach of the last research problem (how to develop and arrange the materials-technical expertise and innovation system in the Lahti region so that it would serve the region and its needs best?) was approached by several research methods: by interviews, questionnaires, literature studies etc. While the adequacy of the research materials is one of the criteria of the reliability of the research, the multiple approaches increased the amount of the research materials and thus the reliability of the results.

The reproducibility of the research is more typical of quantitative research than qualitative research. In quantitative research the research material should represent statistically the fundamental set, while in qualitative research the research materials should represent the relevant characteristics of the research subject and to be theoretically considerable [15]. In the qualitative research it is important that the deduction chain of the researcher can be followed. In this research, all the research stages and results are presented, documented and able to be followed by the reader.

In this study, the companies were selected by the author to represent the industries in the region processing the main material groups comprehensively, which was evaluated to fulfil the requirements of reliable qualitative results. However, the companies which participated in the research were quite big industrial companies. The nature of innovation processes may differ in big, small, medium-sized and micro companies. A major part of the companies had a large existing product portfolio with processing methods needed. If there had been recently founded companies, in the middle of the creation process of totally new products and businesses, the results might have been different. New companies might seek new technologies and materials more freely, because they have no existing infrastructure, resources, markets or products. In big, low-tech industrial companies the material and processing costs might be relatively higher than in new companies, where R&D cost may represent a majority. However, these major companies and their needs are crucial for the regional innovative system for many reasons. They generally have both the resources and the interest to participate to regional development, even if this interest has decreased through globalization. They are creating income and well-being to the region. A minor positive and negative effect in their activities can have major regional influence.

In the next chapters, the reliability and validity of the actual results and their conclusions are discussed and summarized in more detail. The materials and the fields of the R2 were pre-selected by the author on the basis of the existing knowledge and experience and on the basis of literature. In the question form, all the main materials used in companies were included and fourteen fields of material research were selected. It is possible and even probable that some other researcher would select different materials research fields or categorize them differently, relating also to the external validity of the research.

The companies represented the major part of the materials processing industry in region. The interviewed persons were the main persons in charge of materials technology and development issues. The research questions were formulated on the basis of literature and theoretical and practical knowledge in engineering materials, their applications, materials research and technologies. The research interviews were made using a structured questionnaire form. It was estimated that the research data was adequate for analysis and giving conclusions. All of the research data was transformed from the questionnaire form to electronic format. There were no difficulties in the process or ambiguities in the original research data. Summary tables and figures were made from each question and they are all presented in this thesis. Mean values and their standard deviations were calculated concerning the numerical data. Concerning the usage of materials, it was only asked if the material was used in the company or not. If actual amounts had been asked, the results might have been different. Weight or volume based analyses would have been quite difficult to conduct. The data concerning the actual amounts is hard to collect, and companies usually do not want to disclose it to outsiders. The analysis of the results would have been difficult, because the weights and volumes of the materials are not comparable, for example, because of their different specific densities.

Concerning the demand for materials research services, the aim of Question 2 was to give a picture of what the main sources of research services utilized by the companies are. The services were divided into six categories. The reliability of the answers depends how well the respondents are aware of the outsourced research services in their companies. In Question 4 the answers were based on the respondents’ expectations and estimations of the research services utilized in the next two years. The actual realization of the research services can naturally be different. The reliability of the answers of most important materials research fields is also related to how well the respondents’ opinions are in correlation with the companies' actual needs. Question 6 concerning the internal and external R&D investments related to materials technology in the future was also a strategic question, and maybe the respondents were not the best persons in the companies to answer such questions. It should also be kept in mind that most R&D activities in industrial companies are connected to materials technology at some level.

The aim of the R1 was to give a satisfactorily wide and detailed picture of the innovation network formulated through the MTAP programme, and to observe and measure the inputs (resources, information) to this innovation system, and the results and effects of the system, which were affected by the programme. The aim was also to evaluate the functions and mechanisms of the innovation system, and by analysing the inputs, outputs, functions and results to get a picture of the innovation capability of the network. The author played an active role in the MTAP network but tried to maintain the neutrality and objectivity in every stage of the research. The reliability of this research part also depends on the reliability of answers. Because social connections were formed in the programme, the answers might give a too positive or negative picture of the network, related to social and economic relationships and experiences during the programme and inside the network. There might be some other theoretical frameworks with possibilities to be used, but these were specifically formed for the analysis of the network and practice-based innovation processes on the regional level. In this study the frameworks were used in the analysis of certain sub-network in a regional context.

Internal dynamics were addressed especially by Question 5, but also by Questions 1–4 and 6–7. The reliability of these answers and results also depends on how well the respondents were aware of their organization's functions. To get more detailed information of the internal dynamics especially inside the companies, the other employees participating to the network should also have been interviewed, e.g. the R&D team members. The actual results and effects of the network were clarified with Questions 8–14. The respondents of the companies seemed to be even very well aware of the direct results of the programme; the products or their improvements, knowledge, information, etc. asked in Question 8. Almost all companies answered to Question 9 that the results might have been attained at least partly without the programme, but certainly it would have taken a longer time. The answers give an opportunity to use them for drawing the conclusion that the programme accelerated the innovation processes, but some other questions would also have been necessary to compare the effectiveness of the programme to other possible development paths. Similarly to the proper results, the respondents were quite aware of the direct financial effects caused by the manufactured products. However, they could not give any exact financial numbers. Other influences, like image and competitiveness effects, were quite challenging to answer, and the validity of the answers can also be considered low.

The answers and results to the question of possible impacts to research culture and absorptive capacity of information were versatile and interesting. The answers were based on the respondents' own individual experiences. It was quite interesting that different characteristics and effects of the university-level information were emphasized. The benefits and effects of an extra source of information, which was different, more scientific than in their own processes or with subcontractors seemed to be well analysed. In the answers the respondents seemed to value especially the scientific, reliable information produced by the university as part of their own, existing innovation processes. The answers were more concentrated on the nature and benefits of the information than on the actual impacts of their own research culture. Some clear impacts were mentioned: the increase of systematic processes, confirmation of their own knowledge and increase of the activities of existing industry-university network. By interviews of the internal organization members, more reliable and detailed information of the effects on the research culture could have been reached.

Concerning research question 2, a comprehensive evaluation of the regional innovation policy and capability consists of two main elements: a) Evaluation of the functioning of the regional innovation environment by examining the inputs, as well as internal organization and dynamics of the innovation environment and b) Evaluation of the short-term results and long-term effects of the innovation activity [18]. In the conceptual framework for the evaluation of the regional innovation capability, the components of innovation environment are the resources, institutional setup and internal dynamics. The resources of the innovation environment in the MTAP programme were not just the TUT and companies participating to the programme, but also the other universities, companies and development organizations in the region, which were directly or indirectly part of the network for materials technology. In addition to the research interviews, also the study of regional infrastructure in materials technology and analysis of the materials research supply in the region gave information of the resources and the institutional setup when giving conclusion in research question 2. In the R1, this kind of information was obtained with Questions 1-7. The reliability of the results depends on how well the respondents were aware of their organizations resources involved in the programme. The infrastructure and research supply studies were based on literature and questionnaires and they gave reasonably detailed information.

There is also an evaluation of the second grade effects in the conceptual framework of the regional innovation capability: possible effects on the competitiveness and well-being of the region. This is a level which was not directly studied or measured in the thesis, but the suggestions in conclusions concerning the development of regional materials technology related network are aimed at improving the competitiveness of the region. All other components of the evaluation process of innovation capability in the regional context are viewed or studied in the thesis. Public policies and strategies related to materials technology were mainly analysed through public documents, policies and strategies. The timeline of this information was mainly 2000–2015. To get a wider perspective, it would have been beneficial to extend the timeline to strategies of the 20th century, though the analysis was more concentrated on the recent and future role of materials technology in the Lahti region.

The materials technology related innovation system was observed through the activities of the MTAP programme. No other public steered university–industry innovation networks in the region is focused on the development in materials technology. There are some networks connected to materials technology at some level: the Lahti Mechatronics Network, the Cleantech Cluster and the network created around the CleanDesign activities. Most of the companies participating to the MTAP programme are also members of at least one of these networks. There was an exchange of information, communication and other co-operation between these networks during the years 2008–2012.

8 Conclusions

In this chapter, the final conclusions concerning the research questions are given. There are also some recommendations and suggestions for further studies.

8.1 The advisory professorship model as an innovation tool

In the thesis the usability and effectiveness of a practice-based innovation tool for university–industry co-operation, the advisory professorship model, was evaluated. The research material was collected by applying the tool with a materials technological emphasis in the regional co-operation network in 2008–2012. The inputs, functions and internal dynamics of the innovation environment, as well as the results and effects of innovation activities in the materials technology advisory professorship programme (MTAP) network, were analysed qualitatively using a conceptual framework for the evaluation of regional innovative capability and the Network-Based Innovative Capability (NBIC) matrix. Three sub-dimensions of innovation capability: openness/creativity, knowledge/expertise and operationalization capability of the MTAP network were analysed.

The main research contribution was in the applicability, usability and effectiveness of a practice-based innovation tool, the advisory professorship model, and in new information concerning the internal dynamics and innovation capability of the practice-based university-industries innovation network, grounded on theories of practice-based innovations and systems. The perspective of analysis was on individuals and companies of the network and on technological innovations of the companies, including product, process and technology innovations. It is claimed that the advisory professorship model is a useful practice-based innovation tool for regional university–industry co-operation with some limitations.

In the network of the MTAP programme, new practice-based innovation processes, concentrated in practice-based problems and development targets in companies products, operational environment or markets were created. The organizational borders between the university and companies could be crossed in a way that the university participated actively to the solution of companies' market-based challenges. The social network had also operationalization capability to launch new innovations by exploiting the provided knowledge and new innovation processes in the companies and between companies and the university. The role of the university was especially in producing of information in the front-end phases of innovation processes, related mostly to properties and processing knowledge of materials, the feasibility of development ideas and in searching of new R&D opportunities. The nature of university based research inputs was typically fast and short-termed. The companies seemed to have capacity to absorb information of the research inputs in their innovation processes in creating new products, or in developing product and process improvements: Some innovation processes ended up as new products or product improvements. New knowledge, information and knowledge networks were created. The main structural holes in the network of the MTAP programme were the links between the industries and companies. Including elements to the advisory professorship model that support the surpassing of organizational and industrial limits would increase the capability to produce new innovations. The development of strategic co-operation relationships between the companies and the university was more challenging than expected.

It is claimed that regarding successful application processes of the advisory professorship model there exist at least the next five limitations and critical conditions. There has to be 1) sufficient involvement and interest of the companies 2) sufficiency of interdisciplinary university-level knowhow 2) workable operation model and practices 4) enough technological knowledge in brokerage actions to connect the weak links in the industry-university network to find new innovation potential and 5) adequate absorptive and transformative capacity of information by the companies utilizing the model. In general, the capacities of small-sized companies are limited. They might have difficulties to notice the structural holes with possible benefits. On the contrary, the absorptive capacity of the low-tech companies can in many cases be considered good, because they typically seek existing technological solutions to exploit. Focusing on the form of the produced information and methods to spread it in the organization would probably help in finding new innovation pathways.

In regional university–industry co-operation, structures should be developed for promoting the openness and creativity of the innovation networks, offering multi-level knowledge. That is one of the fundamental aims of open innovation networks. The university could join as an integral part to networks where problem-solving is based on the needs of companies, as long as there is mutual trust and common rules. An important feature in the operations of universities in regions lacking of their own university is to act inside the region and also to have efficient mechanisms to deliver knowledge to the region. Regional activities offer an accessible contact interface to companies and other players. The university does not need to compromise its role of a research organization or the scientific level of the research inputs too much, though there is the risk of the scientific knowledge being too general for the main aims of the university when using the advisory professorship model. In the creation of new, industrial border crossing innovation processes between companies, some other practice-based innovation tools may be more effective and advanced for such purposes. The combination or uniting the advisory professorship model with some other model may be more efficient in creating multi-dimensional networks between the companies and universities.

In this study, the regional innovation system was mainly viewed from the regional and industrial points of view. In this conclusion chapter, the relation of the results to the more traditional activities and strategies of the universities can also be shortly discussed. In addition to the teaching and research purposes of the universities, the societal service function is one role of higher education. The general trend is that the co-operation between universities and their environment is increasing and finding new combined ways to interact. Universities are starting to play more important roles in national and also in regional innovation systems. In regional university-region policies, a university can either develop more efficient practices to transfer knowledge between the university and the region, or to strengthen the continuous forms of regional interactions. The MTAP programme has characteristics of both of these policies. The development of regional interactions was operated through the work of regional contact person. The technological knowledge was mostly transferred from the head unit of the university to fulfil the regional needs. The results and the effects of the model can be considered good and beneficial from the point of region and industry.

From the point of the university, it is more complicated. The main aim of the programme, settled by the university, was to create and activate new contract research projects and to find new external funding for the research groups. This was meant to be achieved by the activation of the regional co-operation network, which partly already existed, especially with the plastics industry. The purpose was to find especially joint projects with the materials processing industry, but also with public players. This relates to the general trend in Finland that universities increasingly develop contacts with external, non-university actors and raise external funding. In Europe, the general trend has been in recent decades to cut the financing from the basic research. In Finland, the funding level of the basic research is still better. However, contract research is becoming more important, and research units are increasingly heading towards the business sector and public services by developing cooperative linkages [157].

While the universities are under pressure to find new contract research projects, there is increasing demand for academic results and international co-operation. Contract research projects are typically short-termed and mainly concentrated on applied research. They are more difficult for achieving continuous knowledge accumulation for researchers and academic results than basic research projects funded by Tekes or Akademi. The nature of the contract research projects is typically less international for universities. The international dimension and contacts of the international co-operation are provided more often by the client than the university in contract research projects. In regional networks the scope can be even more restricted.

These issues are also relevant when analysing the projects activated by the MTAP programme. The biggest activated projects were the research and development projects of the industry. These projects included subcontracted research from universities, but typically the research was contracted from several universities, and the research part of each university was quite small. There were also quite a lot of small projects, focused mainly on testing and analysing of materials and products. The activated research projects were mostly funded by the public funding instruments, like EU, Tekes and regional development programmes. Three long-term, larger research and education projects were activated. One was a three-year Tekes-funded research project, which gave an opportunity for scientific results with publications and a dissertation. There was also one bigger education project. However, there was a lot of short term, smaller research projects with public, cost-based funding.

If the motives of the stakeholders to participate to the MTAP programme are analysed, some differences can be seen. For the region the main motives were to make the operational preconditions better for the region's industry, to improve the attractiveness of the region, and to increase the activities and the accessibility of the university in the region. The main motives for the companies were to gain access to one extra source of knowledge and knowledge network to improve the availability of knowledge-based resources, to speed up innovation processes, and to increase the reliability of information to be used in product development and manufacturing processes. The main motives of the university were to find new sources of external funding for research and to find new scientific opportunities in collaboration with large international companies.

Traditionally, innovation systems in Finland have been technologically oriented. The advisory professorship model uses social, technological and economical knowledge. The results can be utilized by natural and social sciences. For universities it can be a useful, flexible and cost-efficient tool for regional co-operation, without heavy organizational structures. In addition to social actions, expertise of the research field, technologies and industries is needed in regional activities. It is also important to have knowledge of the universities and their operation models and expertise of the practice-based innovation processes. The research areas and the research groups of the universities should be interdisciplinary by nature, to communicate better with the R&D groups of the companies. Because the interdisciplinary research groups are quite rare at the universities, they should lower the boundaries and increase the communication between the departments and faculties of the universities.

8.2 Developing the regional innovation system in materials technology

In the thesis the materials technology related regional resources, infrastructure and needs from both private and public sectors were studied. In the regional development context the results were analysed with two different methods. In a thematic analysis, the challenges and opportunities of materials technology for companies were analysed through the focus areas of regional development. In the other analysis, the levels of regional availability, access and delivery options for materials technological research were analysed.

The industry in the Lahti region uses a wide range of different materials. Important material groups for industries in the region are plastics and metals, but also wood-based materials and other industrial materials are used. Because the research and development work in companies is mostly product-based, there is a need for multi-material knowledge. The main regional strengths in materials research are the multilevel applied materials knowledge and knowledge on the environmental use of materials on the basic and applied level. Facilities for testing and analysis services of materials and products are also rather conveniently placed in several locations. The main drawbacks are the deficiency of the basic knowledge of the properties and processing of engineering materials and of university level environmental technology. Especially the development of such research fields in materials technology and their access and delivery options capable to boost the environment and design business sectors should be promoted. Innovation potential is found especially in knowledge and resources of plastic materials.

For low-tech industries, customer-orientation, design, networking and continuous process development are the main competition tools. In regional public development work, it is important to continue the development of design and cleantech sectors and to improve discussion and co-operation between material experts and materials processing industries. The special characteristics of the industry using materials should be taken into consideration.

Further, public policies and strategies should support activities which ensure the availability of multi-material scientific and practical knowledge, infrastructure and resources. There should be activities to create models to promote the networking and knowledge transfer between industrial sectors and activities to create more efficient practices to transfer knowledge between universities and the region, especially in the research fields lacking delivery and access options. In addition to knowledge transfer, the creation of strategic co-operation relationships between research groups of universities and companies should also be promoted. There are still some cluster-based networks in the region, like mechatronics and grain clusters. The networking between the clusters should be supported or the cluster-based approach replaced by modern innovation systems and network policies. The regional interactions on social, cultural and organizational levels between universities, industries, research and educational organizations in materials technology and in general should be developed. The development of processing techniques of different materials, especially the continuous processes, where the amounts of used materials and energy are at a high level, for example the extrusion process of plastics, is recommended.

To create new social networks, knowledge transfer, and new combinations of knowledge between different material processing industries, universities, educational organizations and companies, the regional scientific and practical knowledge and infrastructure of materials and technologies should be centralized. Today the resources of materials technology are located in several places in the Lahti region, without synergy creation. The potential of existing and cumulated knowhow is dismissed. There is a need for research of materials and their properties, process development and characterization and testing services. There should be common research, testing, education, learning facilities and meeting places. Communication and co-operation between materials research and design sectors should be developed. The main part of materials technological possibilities and challenges in the companies are related to the focus areas of public development, especially to design and the environment. Because of the strong manufacturing industry in the region, the problem setting should be product-based with interdisciplinary university co-operation. To promote the development of more resource efficient products, the discussion between materials science and environmental sciences should be developed, for example, focusing on enhancing recycling and alternative renewal/recycled materials, keeping in mind the total picture of the product lifecycle's environmental effects. Because of the ability of the advisory professorship tool in the creation of new practice-based innovation processes and knowledge transfer from universities to industries, the development of new advisory professorship programmes should be actively promoted, also in materials technology.

The practical contributions to this research part were related to regional development in the Lahti region. When focusing on certain sectors in regional development, cross-sectional, horizontal research fields are easily forgotten. In addition to practical innovation sector, “hard” cross-sectional technical sciences, especially those based on the industrial history of the region, should also be promoted. Renewing of industries is not possible without a combination of old and new technologies.

8.3 Recommendations for further research

In this study, the usefulness of advisory professorship tool as a practice-based innovation tool for university–industry co-operation was mainly approached from the regional and industrial viewpoint. In the conclusion part its relation to the more traditional activities and strategies of the university was shortly discussed. One recommendation for future research is to analyse the relations and possibilities of the practice-based innovation processes and tools through universities’ strategies and normal activities. Even if there is evidence that the tools are useful and beneficial from the industrial and regional viewpoints, is the situation the same when observed from the universities' viewpoint? If the tools are further developed, the logics and motives should be analysed through modern science policies and recent development of national and international research strategies. The role and motives of the universities are changing in a way which in the future might not favour the development of regional co-operation, especially in the regions where operations of the universities have been mainly based on sub-units. This change can be seen in recent strategies of several Finnish universities.

To understand the effects of the advisory professorships on regional innovation network better, the other regional advisory professorship programmes applied in the Lahti region should also be analysed. The MTAP programme was one of the applications of the advisory professorship-tool, being larger and longer than the programmes in general, which typically have focused on the work of an individual professor and his/her research group. Comparing the tool and its results and effects with other practice-based innovation tools applied in the Lahti region would help in planning of future policies and strategies.

From the materials technological point of view, one recommendation of the research is a study pertaining to new applicable materials and materials technologies for the needs of the regional industry, including cleantech solutions. It should be prepared with the help of the industries using relevant tools in preparation and applying processes. The presence of both business and research experts, complemented with other specialists in early stages of innovation processes is needed.

In the conclusion part it was suggested that to create new social networks, knowledge transfer, and new combinations of knowledge between different material processing industries, companies, universities and educational organizations, the regional scientific and practical knowledge and infrastructure of materials and technologies should be centralized. To realize such an innovation centre with a materials technological focus, the logics, activities and operations of corresponding international centres should be evaluated and studied.

9 Bibliography

1. Allwood, J.M., Ashby, M.F., Gotowski, T.G. & Worrell, E. Material efficiency: A white paper. 2011, Resources, Conservation and Recyling 55 (2011), pp. 362-381.

2. Dobrzański, L., A. Significance of materials science for the future development of socities. Journal of Materials Processing Technology 175 (2006), pp. 133-148.

3. Manoharan, M. Research on the frontiers of materials science: The impact of nanotechnology on new material development. Technology in Society 30 (2008), pp. 401-404.

4. Work programme 2013 cooperation theme 4 nanosciences, nanotechnologies, materials and new production technologies – NMP. European Commission, 2012.

5. Verkkotietokeskus. [Online] [Cited: 15 5 2012.] http://www.verkkotietokeskus.fi/.

6. Lahden alueen elinkeinostrategia 2005-2008. 20 p. (in Finnish)

7. Lahden seudun kilpailukyky- ja elinkeinostrategia 2009-2015. 24 p. (in Finnish)

8. Päijät-Hämeen maakuntastrategia. Päijät-Hämeen liitto, 2009. 32 p. (in Finnish)

9. Harmaakorpi, V., Melkas, H. & Tura, T. Regional Innovation Platforms, in Boschma R., Cooke, P., Toedtling, F. & Martin. R. (eds). Handbook on Regional Innovation and Growth, 2011. Edward Elgar Publications. 629 p.

10. Harmaakorpi, V. & Melkas, H. (eds). Innovaatiopolitiikkaa järjestelmien välimaastossa. Helsinki 2008, Kuntaliitto. 251 p. (in Finnish)

11. Lahden kaupunkiseudun innovaatioympäristön kehittämisstrategia. 2005. 28 p. (in Finnish)

12. Eerola, S. Akateemisen ja soveltavan materiaalitutkimuksen tarpeet ja tarjonta Päijät-Hämeessä. Nastola 2007, Muovipoli. 20 p. (in Finnish)

13. Miller, R.L. & Brewer, J.D. (eds). The A-Z of Social Research. Cornwall 2003, SAGE Publications. 345 p.

14. Eskola, J. & Suoranta, J. Johdatus laadulliseen tutkimukseen, 7. painos. Jyväskylä 2005, Vastapaino. 266 p. (in Finnish)

15. Uusitalo, H. Tiede, tutkimus ja tutkielma, 1.-7. painos. Juva 2001, WSOY. 121 p. (in Finnish)

16. Storper, M. The Regional World. Territorial Development in a Global Economy. New York 1997, Guilford Press. 338 p.

17. Tura, T. Proximity and the Regional Effectiveness of Universities - A Mechanism-based Approach. Paper presented at the Fifth Proximity Congress. 28-30 June 2006 Bordeaux, France. 22 p.

18. Tura, T., Harmaakorpi, V. & Pekkola, S. Breaking Inside the Black Box: towards a dynamic evaluation framework of regional innovative capability. Sciency and Public Policy 35(2008)10, pp. 733-744.

19. Eerola, S., Laaksonen, H., Tiainen, T. & Tura, T. Materiaalitehokkuuteen ja materiaalitekniikkaan liittyvän osaamiskeskittymän rakentaminen Lahteen. Lahti 2009, Finnish Regional Centre Programme. 35 p. (in Finnish)

20. Eerola, S. & Neva, T. Päijät-Hämeen muovivirrat. 2009, Tampere University of Technology. 17 p. (in Finnish)

21. Parjanen, S. Creating Possibilities for Collective Creativity: Brokerage Functions in Practice-Based Innovation. Dissertation. Lappeenranta 2012, Lappeenranta University of Technology. 166 p.

22. Parjanen S. Innovation sessions as sources of new ideas, International Journal of Innovation and Learning 11(2012)4, pp. 352-368.

23. Eerola, S., Tura, T., Harmaakorpi, V. & Järvelä, P. Advisory Professorship Model as a Tool for University–Industry Co-operation. European Planning Studies, 15.1.2014, DOI: 101080/09654313.2013.869558

24. Cohen, W. & Levinthal, L. Absorptive capacity: a new perspective on learning and innovation. Administrative Science Quarterly 35(1990)1, pp. 128-152.

25. Marshall, M.N. Sampling for qualitative research, Family Practice 13(1996)6, pp. 522-525.

26. Statistics Finland; Suomen virallinen tilasto (SVT): Teollisuuden alue- ja toimialatilasto [Online]. ISSN=1797-4747. Helsinki, Tilastokeskus [Cited: 6 1 2014.] http://www.stat.fi/til/atoi/tau.html

27. Chung, D.D.L. Applied Materials Science, Applications of Engineering Material in Structural, Electronics, Thermal and Other Industries. Boca Raton 2001, CRC Press. 256 p.

28. Pfeifer, M. Materials Enabled Design. Burlington 2009, Butterworth-Heinemann. 306 p.

29. Ashby, M.F. Materials Selection in Mechanical Design, 2nd ed. Oxford 1999, Butterworth Heineman. 495 p.

30. Crawford, R.J. Plastics Engineering, 3nd ed. Oxford 1999, Butterworth-Heinemann. 434 p.

31. Harper, C.A. Handbook of Materials for Product Design. New York 2001, McCraw-Hill. 1000 p.

32. Van der Vegt, A.K. From Polymers to Plastics. Delft 2002, DUP Blue Print. 237 p.

33. Åström, B.T. Manufacturing of Polymer Composites. Cheltenham, UK 1997, Nelson Thornes Ltd. 469 p.

34. Wypych, G. Handbook of Fillers. Toronto 2000, ChemTec Publishing. 831 p.

35. Duncan, T.V. Applications of nanotechnology in food packaging and food safety: Barrier materials, antimicrobials and sensors. Journal of Colloid and Interface Science, 363(2011)1, pp. 1-24.

36. Arora, A. & Padua, G. W. Review: Nanocomposites in Food Packaging. Journal of Food Science, 75(2010)1, pp. 43-49.

37. Whitaker, J.C. Microelectronics 2nd Edition. Boca Raton 2005, CRC Press. 464 p.

38. Cahn, R.W. Materials Science: Past, Present and Future. Materials Today, 2(1999)3, pp. 8-11.

39. Lundqvist, L., Leterrier, Y., Sunderland, P., Månson, J-A.E. Life Cycle Engineering of Plastics: Technology, Economy and the Environment. Eastbourne 2000, Elsevier. 206 p.

40. Ashammakhi, N., Peltoniemi, H., Waris, E., Suuronen, R., Serlo, W., Kellomäki, M., Törmälä, P. & Waris, T. Developments in Craniomaxillofacial Surgery: Use of Self-Reinforced Bioabsorbable Osteofixation Devices. Plastic and Reconstructive Surgery, 108(2001)1, pp. 167-180.

41. Ashammakhi, N., Suuronen, R., Tiainen, J., Törmälä, P. & Waris, T. Spotlight on Naturally Absorbable Osteofixation Devices. The Journal of Craniofacial Surgery 14(2003)2, pp. 247-259.

42. Kricheldorf, H.R. Syntheses and application of polylactides. Chemosphere 43 (2001), pp. 49-54.

43. Kellomäki, M. Bioabsorbable and Bioactive Polymers and Composites for Tissue Engineering Applications. Dissertation. Tampere, 2000, Tampere University of Technology. 246 p.

44. Global Trends 2015: A Dialogue About the Future With Nongovernment Experts. 2000, National Intelligence Council.

45. Harmaakorpi, V. Building a competitive regional innovation environment – The regional development platform method as a tool for regional innovation policy. Dissertation. Helsinki 2004, Helsinki University of Technology. 235 p.

46. Energy technology perspectives 2008: scenarios & strategies to 2050. Paris 2008, International Energy Agency. 642 p.

47. Laakso, J. & Roschier, S. Toiminnalliset materiaalit –teknologiaohjelman toimintasuunnitelma. Helsinki 2007, Tekes. 23 p. (in Finnish)

48. Naumanen, M. Materiaalitekniikoiden kehityskohteita. Helsinki 2005, Teknologiateollisuus ry. 84 p. (in Finnish)

49. Westwood, A.R.C. Materials and Society – Impacts and Responsibilities. Metallurgical and Materials Transactions, 27B(1996), pp. 337-350.

50. Roco, M.C. The emergence and policy implications of converging new technologies, pp. 9-22 in Bainbridge, W.S. & Roco, M.C. (eds). Managing Nano-Bio-Info-Cogni Innovations: Converging Technologies in Society. 2006, Springer.

51. Schwartz, M. New Materials, Processes and Methods Technology. Boca Raton 2006, CRC Press. 694 p.

52. Hannula, S-P., Turunen, E., Koskinen, J. & Söderberg, O. Processing of hybrid materials for components with improved life-time. Current Applied Physics 9(2009), pp. 160-166.

53. Pezzella, A., Capelli, L., Costantini, A., Luciani, G., Tescione, F., Silvestri, B., Vitiello, G. & Branda, F. Towards the development of a novel bioinspired functional material: Synthesis and charcaterization of hybrid Ti02/DHICA-melanin nanoparticles. Materials Science and Engineering C 33(2013)1, pp. 347-355.

54. El Achaby, M. & Qaiss, A. Processing and properties of polyethylene reinforced by graphene nanosheets and carbon nanotubes. Materials and Design 44(2013), pp. 81-89.

55. Patole, A.S., Patole, S.P., Young, S-Y. & Yoo, J-B. Self assembled graphene/carbon nanotube/polystyrene hybrid nanocomposite by in situ microemulsion polymerization. European Polymer Journal 48(2012), pp. 252-259.

56. Inagaki, M. Carbon coating for enhancing the functionalization of materials. Carbon 50 (2012), pp. 3247-3266.

57. Roco, M.C. The long view of nanotechnology development: the National Nanotechnology Initiative at 10 years. J Nanopart Res 13 (2011), pp. 427-445.

58. Maine, E., Garnsey, E. Commercializing generic technology: The case of advanced materials ventures, Research Policy 35 (2006), pp. 375-393.

59. Lendlein, A., Langer, R. Biodegradable, Elastic Shape Memory Polymers for Potential Biomedical Applications, Science 296 (2002), pp. 1673-1676.

60. Wache, H.M., Tartakowska, D.J., Hentrich, A. & Wagner, M.H. Development of a polymers stent with shape memory effects as a drug delivery system, Journal of Materials Science: Materials in Medicine 14 (2003), pp. 109-112.

61. Salo, J., Tulikoura, I., Konttinen, Y.Y., Santavirta, S. Luufiksaatioon käytetyt biomateriaalit. Lääkelaitoksen biomateriaalijulkaisut: Ortopediassa ja traumatologiassa käytetyt biomateriaalit. Kommentointiversio, 1999, pp. 105-118.

62. Wei, Z.G., Sandström, R. Shape-memory materials and hybrid composites for smart systems. Journal of Materials Science 33 (1998), pp. 3743-3762.

63. Kapanen, A., Ryhänen, J., Danilov, A. & Tuukkanen, J. Effect of nickel-titanium shape memory metal alloy on bone formation. Biomaterials 22 (2001), pp. 2475-2480.

64. Kujala, S., Ryhänen, J., Jämsä, T., Danilov, A., Saaranen, J., Pramila, A. & Tuukkanen, J. Bone modeling controlled by a nickel-titanium shape memory alloy intramedullary nail. Biomaterials 23 (2002), pp. 2535-2543.

65. Monkman, G.J. Advances in shape memory polymer actuation. Mechatroncis 10 (2000), pp. 489-498.

66. Liu, Y., Gall, K., Dunn, M.L. & McCluskey, P. Thermomechanical couplings of shape memory polymers in flexure. Smart Materials and Structures 12(2003)6, pp. 947-954.

67. Gall, K., Dunn, M.L., Liu, Y., Finch, D., Lake, M. & Munshi, N.A. Shape memory polymer nanocomposites. Acta Materialia 50 (2002), pp. 5115-5126.

68. Poilane, C., Delobelle, P., Lexcellent, C., Hayashi, S. & Tobushi, H. Analysis of the mechanical behavior of shape memory polymer membranes by nanoindentation, bulging and point membrane deflection tests. Thin Solid Films 379 (2000), pp. 156-165.

69. Harmaakorpi, V., Hermans, R. & Uotila, T. Suomalaisen innovaatiojärjestelmän mosaiikki. Helsinki 2010, Taloustieto Oy. 204 p. (in Finnish)

70. Teknologiateollisuus ry. [Online] [Cited: 4 12 2012.] www.teknologiateollisuus.fi.

71. Tampere University of Technology. [Online] [Cited: 12 2 2013.] www.tut.fi.

72. Aalto University. [Online] [Cited: 12 2 2013.] www.aalto.fi.

73. University of Oulu [Online] [Cited: 14 2 2013.] www.oulu.fi/yliopisto/.

74. Lappeenranta University of Technology [Online] [Cited: 14 2 2013.] www.lut.fi.

75. University of Turku [Online] [Cited: 14 2 2013.] www.utu.fi.

76. Åbo Akademi University [Online] [Cited: 14 2 2013.] www.abo.fi.

77. University of Jyväskylä [Online] [Cited: 14 2 2013.] www.jyu.fi.

78. VTT Technical Research Centre of Finland [Online] [Cited: 14 2 2013.] www.vtt.fi.

79. Giacone, E. & Mancò, S. Energy efficiency measurement in industrial processes, Energy 38(2012)1, pp. 331-345.

80. Measuring eco-efficiency. A guide to reporting company performance. Geneva, 2000, World Business Council for Sustainable Development.

81. Müller, K. & Sturm, A. Standardized eco-efficiency indicators-report 1: concept paper. Revision 1.05/January 2001. Basel 2001, Ellipson AG.

82. Erkko, S., Melanen, M. & Mickwitz, P. Eco-efficiency in the Finnish EMAS reports-a buzz word? Journal of Cleaner Production 13 (2005), pp. 799-813.

83. Reference Document on Best Available Techniques for Energy Efficiency. 2009, European Union. 430 p.

84. Heikkilä, I., Huumo, M, Siitonen, S., Seitsalo, P. & Hyytiä H. Paras käytettävissä oleva tekniikka (BAT), Teollisuuden energiatehokkuus. Helsinki 2008, Suomen Ympäristökeskus. 91 p. (in Finnish)

85. Materiaalitehokas toiminta säästää luontoa ja rahaa. Helsinki 20008, Elinkeinoelämän keskusliitto EK. 28 p. (in Finnish)

86. Communication from the commissions to the Council and the European Parlament, Integrated Product Policy, Building on Environmental Life-Cycle Thinking. 2003, European Commission. 30 p.

87. EU Website. [Online] [Cited: 20 4 2012.] http://europa.eu/index_fi.htm.

88. Directive 2009/125/EC of the European Parliament and of the Council establishing a framework for the setting of ecodesign requirements for energy-related products. 2009, European Union.

89. Vähemmästä enemmän ja paremmin, Kestävän kulutuksen ja tuotannon toimikunnan (KULTU) ehdotus kansalliseksi ohjelmaksi. Helsinki 2005, Ympäristöministeriö ja kauppa- ja teollisuusministeriö. 168 p. (in Finnish)

90. Kohti kierrätysyhteiskuntaa – Valtakunnallinen jätesuunnitelma vuoteen 2016. Helsinki 2008, Ympäristöministeriö. 54 p. (in Finnish)

91. Hallitusohjelman toimeenpanon arviointi hallituskauden puolivälissä – Hallituksen strategia-asiakirjan seuranta. Helsinki 2009, Valtioneuvoston kanslian julkaisusarja 14/2009. 287 p. (in Finnish)

92. Kansallinen luonnonvarastrategia, älykkäästi luonnon voimin. Helsinki 2009, Suomen itsenäisyyden juhlarahasto Sitra. 12 p. (in Finnish)

93. Kansallisen luonnonvarastrategian taustaraportti, luonnonvaroissa muutoksen mahdollisuus. Helsinki 2009, Suomen itsenäisyyden juhlarahasto Sitra. 56 p. (in Finnish)

94. Blinnikka., P. Materiaalitehokkuuden palvelukeskus, esiselvitys, alueelliset ympäristöjulkaisut nro 364. Tampere 2004, Pirkanmaan ympäristökeskus. (in Finnish)

95. Kaila, J. Materiaalitehokkuuden palvelukeskuksen liiketoiminta- ja toimintasuunnitelmat sekä käynnistysohjelma. 2005, Kasui Oy. (in Finnish)

96. Roco, M.C., Coherence and divergence of megatrends in science and Engineering. Journal of Nanoparticle Research 4 (2002), pp. 9-19.

97. Mickwitz, P., Melanen, M., Rosenström, U. & Seppälä, J. Regional eco-efficiency indicators-a participatory approach. Journal of Cleaner Production 14 (2006), pp. 1603-1611.

98. Muoviteollisuus ry. [Online] [Cited: 16 4 2013.] www.plastics.fi.

99. Eerola, S. & Halkola, H. RePlast FinEst-hanke vaihe III -raportti. Nastola 2006, Muovipoli Oy. 45 p. (in Finnish)

100. Ignatius, S.-M., Myllymaa, T. & Dahlbo, H. Sähkö- ja elektroniikkaromun käsittely Suomessa. Helsinki 2009, Suomen ympäristökeskus. 54 p. (in Finnish)

101. Suomen autokierrätys. [Online] [Cited: 16 4 2013.] www.autokierratys.fi.

102. Kline, S. & Rosenberg, N. An overview on innovation, pp. 275-306 in Landau R. & Rosenberg, N (eds). The Positive Sum Effect. Washington D.C., USA. 1986, National Academy Press. 640 p.

103. Lundvall, B.-Å. Innovation as an Interactive Process: From User-Producer Interaction to the National System of Innovation, in Dosi, G., Freeman, G., Nelson, R., Silverberg, G. & Soete, L. (eds). Technical Change and Economic Theory. London 1988, Pinter.

104. Schienstock, G. & Hämäläinen, T. Transformation of the Finnish innovation system. A network approach. Sitra Reports series 7. Helsinki 2001, Sitra. 247 p.

105. Linton, J.D. De-babelizing the language of innovation. Technovation 29 (2009), pp. 729-737.

106. Sainio, L.-M., Ritala, P. & Hurmelinna-Laukkanen, P. Constituents of radical innovation-exploring the role of strategic orientations and market uncertainty. Technovation 32 (2012), pp. 591-599.

107. Tura, T. & Harmaakorpi, V. Science Parks as Brokers of the Network-facilitating Innovation Policy. Paper presented at XXIII IASP World Conference on Science and Technology Parks. Helsinki, Finland 6 - 9 June 2006. 13 p.

108. Porter, M. E. Clusters and the New Economics of Competition. Harvard Business Review, 10-11(1998), pp. 77-90.

109. Uotila, T., Harmaakorpi, V. & Hermans, R. Finnish mosaic of Regional innovation Systems - Assessment of Thematic Regional Innovation Platforms based on Related Variety. European Planning Studies 20(2012)1, pp 1583-1602.

110. Porter, M.E. Location, Competition and Economic Development: Local Clusters in a Global Economy. Economic Development Quarterly, 14(2000)1, pp. 15-34.

111. Cooke, P., Uranga, M. & Etxebarria, G. Regional Innovation Systems: Institutional and Organisational Dimensions. Research Policy 26(1997), pp. 475-491.

112. Braczyk, H.-J., Cooke, P. & Heidenreich, M.(eds.). Regional Innovation Systems. London, UK 1998, Routledge.

113. de la Mothe, J. & Paquet, G. (eds). Local and Regional Systems of Innovation. Norwell, USA 1998, Kluwer Academic Publishers. 341 p.

114. Doloreux, D. What should we know about regional systems of innovation. Technology in Society 24(2002), pp. 243-263.

115. Kostiainen, J. Urban Economic Development Policy in the Network Society. Tampere 2002, Tekniikan akateemisten liitto TEK. 65 p.

116. Cooke, P. Regional innovation systems, clusters, and the knowledge economy. Industrial and Corporate Change 10(2001)4, pp. 945-974.

117. Cooke, P. Regionally asymmetric knowledge capabilities and open innovation Exploring 'Globalisation 2'-A new model of industry organisation. Research Policy 34(2005), pp. 1128-1149.

118. National innovation systems. Paris 1999, OECD. 48 p.

119. Boschma, R.A. Proximity and Innovation: A Critical Assessment, Regional Studies, 39(2005)1, pp. 61-74.

120. Harmaakorpi, V. The Regional Development Platform Method as a Tool for Regional Innovation Policy. European Planning Studies 14(2006)8, pp. 1085-1104.

121. Harmaakorpi, V. & Mutanen, A. Knowledge Production in Networked Practice-based Innovation Processes - Interrogative Model as a Methodological Approach.

Interdiscplinary Journal of Information, Knowledge, and Management 3(2008), pp. 87-101.

122. Aula, P. & Harmaakorpi, V. Innovative Milieu - a View on Regional Reputation Building: A Case Study of the Lahti Urban Region. Regional Studies 42(2008)4, pp. 523-538.

123. Pekkarinen, S. & Harmaakorpi, V. Building regional innovation networks: definition of age business core process in a regional innovation system. Regional Studies 40(2006)4, pp. 1-13.

124. Uotila, T., Harmaakorpi, V. & Melkas, H. A method for assessing absorptive capacity of a regional innovation system. Fennia 184(2006)1, pp. 49-58.

125. Etzkowitz, H. Innovation in Innovation: The Triple Helix of University–Industry-Government Relations. Social Science Information 42(2003)3, pp. 293-337.

126. Sotarauta, M. & Kosonen, K. Strategic adaptation to the knowledge economy in less favoured regions: a South-Ostrobothnian university network as a case in point, in Cooke, P. & Piccaluga, A. (eds). Regional Economies as Knowledge Laboratories. Cheltenham 2004, Edward Elgar Publications.

127. Krogh von, G., Nonaka, I. & Ichijio, K. Knowledge Activists! European Management Journal, 15(1997)5, pp. 475-483.

128. Sotarauta, M., Kautonen, M. & Lähteenmäki, T. Tulevaisuustiedosta kilpailuetua: ennakointikonsepti Pirkanmaalla. SENTE-julkaisu 14/2002. Tampere 2002, Tampereen yliopisto. 83 p. (in Finnish)

129. Harmaakorpi, V., Artima, E., Kuukasjärvi, L., Pekkarinen, S. & Kokko, H. Perinteisestä teollisuusalueesta innovatiiviseksi miljööksi. Lahden malli –oppivan alueen innovaatiojärjestelmä. Lahti 2003, Päijät-Hämeen osaamiskeskuksen julkaisusarja. 69 p. (in Finnish)

130. Dosi, G., Freeman, C., Nelson, R., Silverberg, G. & Soete, L. (eds). Technical Change and Economic Theory. London 1988, Pinter.

131. Camagni, R. Local “milieu”, uncertainty and innovation networks: Towards a new dynamic theory of economic space, in Camagni, R. (ed.): Innovation networks: Spatial Perspectives. London 1991, Belhaven Press. 224 p.

132. Florida, R. Toward the Learning Region. Futures 27(1995)5, pp. 527-536.

133. Edquist, C. & McKelvey, M. (eds). Systems of Innovation: Growth, Competitiveness and Employment Vol. I-II. Cheltenham 2000, Edward Elgar.

134. Cooke, P., Heidenreich, M. & Braczyk H-J. (eds). Regional Innovation Systems: the Role of Governance in a Globalized World. London 2004, Routledge.

135. Clark, B. R. Creating Entrepreneurial Universities. Organizational Pathways of Creating Entrepreneurial Universities Transformation. Guilford 1998, Pergamon.

136. Etzkowitz, H. & Leydesdorff, L. The Triple Helix – University–Industry–Government Relations: A Laboratory for Knowledge-Based Economic Development. EASST Review 14(1995)1, pp. 14-19.

137. Slaughter, S. & Leslie, L. L. Academic Capitalism: Politics, Policies, and the Entrepreneurial University. Baltimore 1997, The Johns Hopkins University Press.

138. Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott P. & Trow, M. The New Production of Knowledge: the Dynamics of Science and Research in Contemporary Societies. London 1994, Sage. 179 p.

139. Marginson, S. & Considine, M. The Enterprise University: Power, Governance and Reinvention in Australia. Cambridge 2000, University Press. 288 p.

140. Nowotny, H., Scott, P. & Gibbons, M. Re-thinking science: Knowledge and the Public in an Age of Uncertainty. Cambridge 2001, Polity Press. 278 p.

141. Cooke, P. & Leydesdorff, L. Regional Development in the Knowledge-Based Economy: The Construction of Advantage. Journal of Technology Transfer 31 (2006), pp. 5-15.

142. Dahllöf, U., Goddard, J., Huttunen, J., O'Brien, C., Román, O. & Virtanen, I. Towards the Responsive University: The Regional Role of Eastern Finland Universities. Helsinki 1998, Edita. 76 p.

143. Goddard, J., Moses, I., Teichler, U., Virtanen, I. & West, P. External Engagement and Institutional Adjustment: An Evaluation of the University of Turku. Helsinki 2000, Edita.

144. Kinnunen, J. Korkeakoulujen alueellisen vaikuttavuuden arviointi. Kriteerejä vuorovaikutteisuuden arvottamiselle. Korkeakoulujen arviointineuvoston julkaisuja 5:2001. Helsinki 2001, Edita. 26 p.

145. Nieminen, M. Lähtökohtia yliopistojen kolmannen tehtävän tarkastelulle, in Kankaala, K., Kaukonen, E., Kutinlahti, P., Lemola, T., Nieminen, M. & Välimaa, J. Yliopistojen kolmas tehtävä. Helsinki 2004, Edita.

146. Lemola, T. Yliopistojen kolmannen tehtävän alueelliset ulottuvuudet, in Kankaala, K., Kaukonen, E., Kutinlahti, P., Lemola, T., Nieminen, M. & Välimaa, J. Yliopistojen kolmas tehtävä. Helsinki 2004, Edita.

147. Virtanen, I. Yliopistojen kolmas tehtävä. Kunnallisalan kehittämissäätiön Polemia-sarjan julkaisu nro 44. Vammala 2002, Kunnallisalan kehittämissäätiö. 82 p.

148. Maskell, P. (ed.). Innovation and learning for competitiveness and regional growth. Stockholm 2001, Nordregio R2001:4.

149. Varga, A. Universities in Local Innovation Systems, in Acs, Z. J. (ed.). Regional Innovation, Knowledge and Global Change. London 2000, Pinter.

150. Andersson, R, Quigley, J. M. & Wilhelmson, M. University decentralization as regional policy: the Swedish experiment. Journal of Economic Geography 4 (2004)4, pp. 371-388.

151. OECD Science, Technology and Industry Scoreboard 2011: Innovation and Growth in Knowledge Economies. 2011, OECD Publishing. 204 p.

152. Technology intensity definition: Classification of manufacturing industries into categories based on R&D intensities, OECD Directorate for Science, Technology and Industry, Economic Analysis and Statistics Division. ISIC REV. 3, 2011.

153. Archibugi, D. & Lundvall, B.Å. (eds). The globalizing learning economy. Oxford 2001, Oxford University Press. 307 p.

154. Palmberg, C. Sectoral patterns of innovation and competence requirements — A closer look at low-tech industries. Sitra Reports series 8. Helsinki 2001, Sitra. 101 p.

155. Bekkers, R. & Freitas, I.M.B. Analysing knowledge transfer channels between universities and industry: To what degree do sector also matter? Research policy 37(2008), pp. 1837-1853.

156. Nieminen, M. & Kaukonen, E. Universities and R&D networking in a knowledge-based economy. A glance at Finnish developments. Sitra Reports series 11. Helsinki 2001, Sitra. 139 p.

157. Meyer-Kramer, F. Science-based technologies and interdisciplinarity: Challenges for firms and policy, in Edquist C. Systems of Innovation: Technologies, Institutions and Organisations. London 1997, Pinter. 408 p.

158. Pavitt, K., Robson M. & Townsend, J. The size distribution of innovating firms in the UK: 1945–1983. Journal of Industrial Economics, Volume 35(1987)3, pp. 297-316.

159. Seppä, E. Innovation performance of firms in manufacturing industry: Evidence from Belgium, Finland and Germany in 1998-2000. Helsinki 2007, Valtion taloudellinen tutkimuskeskus. 44 p.

160. OECD Oslo Manual. Guidelines for collecting and interpreting innovation data, 3rd edition. Luxembourg 2005, OECD Statistical Office of the European Communities. 162 p.

161. Eurostat. Science, technology and innovation in Europe. 2008, European Comission.

162. Romijn, H. & Albaladejo, M. Determinants of innovation capability in small electronics and software firms in southeast England. Research Policy 31(2002), pp. 1053-1067.

163. Bellandi, M. & Caloffi, A. An Analysis of Regional Policies Promoting Networks for Innovation. European Planning Studies 18(2010)1, pp. 67-82.

164. Kallio, A., Harmaakorpi, V. & Pihkala, T. Absorptive Capacity and Social Capital in Regional Innovation Systems: The Case of the Lahti Region in Finland, Urban Studies 47(2010)2, pp. 303-319.

165. Motiva. [Online] [Cited: 8 1 2012.] www.motiva.fi.

166. Gilsing V., Bekkers, R., Freitas, I.M.B. & van der Steen, M. Differences in technology transfer between science-based and development-based industries: Transfer mechanism and barriers, Technovation 31 (2011), pp. 638-647.

167. Harmaakorpi, V. & Uotila, T. Building regional visionary capability. Futures research in resource-based regional development. Technological Forecasting & Social Change 73 (2006), pp. 778–792.

168. Battistella, C. & De Toni, A.F. A Methodology of technological foresight: A proposal and field study. Technological Forecasting & Social Change 78 (2011), pp. 1029-1048.

169. Kolmen kärjen älykkään erikoistumisen hyökkäystaktiikka-Päijät-Hämeen EAKR-hanketoiminnan arviointi. Loppuraportti, 23.9.2011. Päijät-Hämeen liitto, 2011.

170. Mattila, T., Kujanpää, M., Myllymaa, T., Korhonen, M.-R., Soukka, R. & Dahlbo, H. Ostoskassien ilmastovaikutusten vähentäminen (Mitigation of the climate effects of shopping bags). Finnish Environment Institute (SYKE), The Finnish Environment 2009. 66 p. (in Finnish)

171. Kirk, J. & Miller, M.L. Reliability and validity in qualitative research. Beverly Hills 1986, SAGE Publications.

172. Holosko, M.J. Reliability and Validity in Qualitative Research, in Thyer, B.A. (ed.) The Handbook of Social Work Research Methods. Thousand Oaks 2001, SAGE Publications.

173. LeCompte, M.D. & Goetzt, J.P. Problems of reliability and validity in ethnographic research. Journal of Educational Research 52 (1982), pp. 31-60.

174. Airila, M. & Pekkanen, M. Tekniikan alan väitöskirjaopas. Helsinki 2002, Teknillinen korkeakoulu. 72 p.

175. Silverman, D. Doing Qualitative Research, A Practical Handbook, 2nd Edition. Trowbridge Wiltshire 2005, SAGE Publications. 395 p.

176. Tilastokeskus. [Online] [Cited: 16 4 2013.] www.stat.fi.

Appendix 1.

Akateemisen ja soveltavan materiaalitutkimuksen tarve Päijät-Hämeen yrityksissä

Selvityksen tilaaja: Lahden tiede- ja yrityspuisto Oy

Selvityksen tekijä: Sauli Eerola, Muovipoli Oy

TYÖN SUORITUS JA LUOTTAMUKSELLISUUS:

Selvityksessä käydään läpi merkittävimmät päijäthämäläiset teollisuusyritykset, joiden toimintaan liittyvät olennaisesti materiaalit. Yrityskohtaiset vastaukset jäävät luottamuksellisesti ainoastaan selvityksen tekijän ja tilaajan käyttöön. Vastauksista koostetaan julkinen raportti, jossa ei esitetä yrityskohtaisia vastauksia eivätkä vastaukset ole jäljitettävissä yksittäisiin yrityksiin. Raportissa on luettelo kyselyyn vastanneista yrityksistä. Vastaukset voidaan antaa myös nimettöminä.

Perustiedot

Yrityksen nimi: ____

Vastaaja: ____

Yrityksen liikevaihto ja henkilömäärä: ____________________________

Yrityksen toimiala:

☐ Elintarviketeollisuus

☐ Puutuoteteollisuus

☐ Kone- ja laiteteollisuus

☐ Muovi- ja kumiteollisuus

☐ Perusmetalliteollisuus

☐ Huonekaluteollisuus

☐ Rakennusteollisuus

☐ Tekstiili- ja vaatetusteollisuus

☐ Kemianteollisuus

☐ Ympäristöteollisuus

☐ Pakkausteollisuus

☐ Paperi- ja kartonkiteollisuus

☐ Muu toimiala:_________________________________

1. **Mitä materiaaleja yrityksenne käyttää? Numeroikaa käyttämänne materiaalit tärkeysjärjestykseen.**

__Metallit

- __Teräs
- __Alumiini
- __Metalliseokset
- __Muu____________________________________

__Muovit

- __Kestomuovit
- __Kertamuovit
- __Tekniset muovit
- __Lujitemuovit
- __Kumit ja termoelastit
- __Muu____________________________________

__Puu

- __Sahatavara
- __Puuliimalevyt, vaneri
  - __Paperi/kartonki
  - __Kuitulevyt
  - __Kyllästetty puu, lämpökuivattu puu
  - __Muu____________________________________

__Tekstiilit/kuidut

- __Luonnonkuidut
- __Synteettiset kuidut

__Lasikuitu, hiilikuitu

__Keraamikuidut

__Muu___________________________________

__Keraamit

__Tekniset keraamit

__Rakennusmateriaalit

__Kivi

__Keraamiset pinnoitteet

__Muu___________________________________

2. Mitä materiaalitekniikkaan liittyviä tutkimuspalveluja yrityksenne on hyödyntänyt viimeisen kahden vuoden aikana?

	Yliopistot	AMK:t	Kaupalliset tutkimuspalvelut (esim. VTT)
☐ Opinnäytetyöt	☐	☐	☐
☐ Muu tutkimus	☐	☐	☐
☐ Materiaalitestaus ja analyysipalvelut	☐	☐	☐
☐ Prosessointi	☐	☐	☐
☐ Tuotetestaukset	☐	☐	☐
☐ Muu______________________	☐	☐	☐

3. Mitkä materiaalitekniikan osa-alueet ovat tärkeitä yrityksellenne? (Me=metallit, Mu=muovit, P=puu, Ku=kuidut, Ke=keraamit)

		Me	Mu	P	Ku	Ke
☐	Materiaalien perustutkimus, materiaalikehitys	☐	☐	☐	☐	☐
☐	Tuotanto- ja valmistusmenetelmät ja niiden kehitys	☐	☐	☐	☐	☐
☐	Materiaalien kierrätys ja uusiokäyttö	☐	☐	☐	☐	☐
☐	Materiaalivirtojen hallinta	☐	☐	☐	☐	☐
☐	Materiaalitehokkuus tuotesuunnittelussa	☐	☐	☐	☐	☐
☐	Tuotteen elinkaaren hallinta	☐	☐	☐	☐	☐
☐	Materiaalien karakterisointi ja testaus	☐	☐	☐	☐	☐
☐	Materiaalien saatavuus ja vaihtoehtoiset materiaalit	☐	☐	☐	☐	☐
☐	Materiaaleihin liittyvä ympäristötutkimus	☐	☐	☐	☐	☐
☐	Liittämismenetelmät	☐	☐	☐	☐	☐
☐	Yhdistelmämateriaalit ml. komposiitit	☐	☐	☐	☐	☐
☐	Materiaalikemia	☐	☐	☐	☐	☐
☐	Pinnoitusmenetelmät	☐	☐	☐	☐	☐
☐	Pintakäsittely	☐	☐	☐	☐	☐

Tarkennuksia:

4. Mitä materiaaliteknistä tutkimusosaamista arvioitte yrityksenne hyödyntävän seuraavan kahden vuoden aikana?

		Me	Mu	P	Ku	Ke
☐	Materiaalien perustutkimus, materiaalikehitys	☐	☐	☐	☐	☐
☐	Tuotanto- ja valmistusmenetelmät	☐	☐	☐	☐	☐
☐	Materiaalien kierrätys ja uusiokäyttö	☐	☐	☐	☐	☐
☐	Materiaalitehokkuus tuotesuunnittelussa	☐	☐	☐	☐	☐
☐	Tuotteen elinkaaren hallinta	☐	☐	☐	☐	☐
☐	Testauspalvelut	☐	☐	☐	☐	☐
☐	Koeajopalvelut, prototyypit	☐	☐	☐	☐	☐
☐	Materiaalien saatavuus ja vaihtoehtoiset materiaalit	☐	☐	☐	☐	☐
☐	Materiaaleihin liittyvä ympäristötutkimus	☐	☐	☐	☐	☐
☐	Liittämismenetelmät	☐	☐	☐	☐	☐
☐	Yhdistelmämateriaalit ml. komposiitit	☐	☐	☐	☐	☐
☐	Materiaalikemia	☐	☐	☐	☐	☐
☐	Pinnoitusmenetelmät	☐	☐	☐	☐	☐
☐	Pintakäsittely	☐	☐	☐	☐	☐

Tarkennuksia:

5. Mitkä ovat mielestänne tärkeimmät tulevaisuuden suuntaviivat ja haasteet liittyen materiaalitekniikkaan ja -tutkimukseen?

6. Kuinka paljon arvioitte yrityksenne panostavan materiaalien tutkimus- ja kehitystoimintaan seuraavien vuosien aikana?

	Ei ollenkaan	Jonkin verran	Merkittävästi
Oma t&tk-toiminta	☐	☐	☐
Muilta yrityksiltä ostettu t&tk	☐	☐	☐
Akateeminen tai soveltava ostotutkimus	☐	☐	☐

7. Millä summalla yrityksenne voisi osallistua yrityksellenne tärkeän akateemisen tai soveltavan materiaalitutkimuksen rahoitukseen vuosittain?

Yliopisto	AMK
☐ 0 €/v	☐ 0 €/v
☐ 1-2 500 €/v	☐ 1-2 500 €/v
☐ 2 500-5 000 €/v	☐ 2 500-5 000 €/v
☐ 5 000-10 000 €/v	☐ 5 000-10 000 €/v
☐ 10 000 – €/v	☐ 10 000 – €/v

Appendix 2.

TAMPEREEN TEKNILLINEN YLIOPISTO

Tutkimuslomake

Materiaalitekniikan kehittyminen ja materiaalitekniikan kummilaitosmallin vaikutukset Päijät-Hämeen yrityksissä 2008-2012

Sauli Eerola, tutkimuspäällikkö, DI
Tampereen teknillinen yliopisto, materiaaliopin laitos
Muovi- ja elastomeeritekniikka
Niemenkatu 73
15140 Lahti, Finland
Puh. +358 50 587 6161
Fax +358 3 811 4333
sauli.eerola@tut.fi
www.tut.fi/mol

Johdanto

Tämä tutkimus on seuranta- ja jatkotutkimus vuonna 2007 toteutetulle työlle, jossa selvitettiin alueen teollisuudelle tärkeimmät materiaalitekniikan osa-alueet sekä materiaaliteknisen tutkimuksen yhteistyö- ja osaamistarpeet.

Tutkimus sisältää myös osion, jonka avulla pyritään mittaamaan Tampereen teknillisen yliopiston (TTY:n) materiaalitekniikan kummilaitosmallin vaikutusta alueen yrityksiin. Kummilaitosmalli koostuu TTY:n alueellisesta tutkimusjohtajasta sekä materiaaliopin laitoksen kummiprofessuurista. Se käynnistettiin vuoden 2007 selvityksen perusteella vuonna 2008 ja päättyy vuoden 2013 lopussa.

Aineiston hyödyntäminen ja luottamuksellisuus

Saatuja vastauksia käsitellään luottamuksellisena tietona. Yrityskohtaiset vastaukset jäävät ainoastaan tutkimuksen tekijän käyttöön. Vastauksista tehdään kysymyskohtaiset koosteet, jotka eivät ole johdettavissa yksittäisiin yrityksiin. Saatua, koostettua tietoa hyödynnetään tutkimuksellisesti Sauli Eerolan väitöskirjan tutkimusaineistona. Muuta mahdollista tutkimuksellista hyödyntämistä ovat koosteaineiston käyttäminen tieteellisissä julkaisuissa koskien innovaatiojärjestelmiä tai materiaalitekniikan kehittymistä.

Vastauksista koostettua aineistoa voidaan myös käyttää lähdeaineistona erilaisissa alueen kehittämisskenaarioissa, -strategioissa ja –suunnitelmissa Lahden alueen yliopisto-, korkeakoulu- ja elinkeinotoiminnan kehittämiseksi.

Vastaukset voidaan antaa myös nimettöminä.

Vastaajan perustiedot

Yrityksen nimi: ____

Vastaaja: ____

Yrityksen liikevaihto ja henkilömäärä: _________________________________

Yrityksen toimiala:

☐ Elintarviketeollisuus

☐ Puutuoteteollisuus

☐ Kone- ja laiteteollisuus

☐ Muovi- ja kumiteollisuus

☐ Perusmetalliteollisuus

☐ Huonekaluteollisuus

☐ Rakennusteollisuus

☐ Tekstiili- ja vaatetusteollisuus

☐ Kemianteollisuus

☐ Ympäristöteollisuus

☐ Pakkausteollisuus

☐ Paperi- ja kartonkiteollisuus

☐ Muu toimiala:_________________________________

OSIO 1. Materiaalit ja materiaalitekniikka

Kysymys 1.1. Mitä materiaaleja yrityksenne käyttää? Numeroikaa käyttämänne materiaalit tärkeysjärjestykseen.

__Metallit
    __Teräs
    __Alumiini
    __Metalliseokset
    __Muu________________________________

__Muovit
    __Kestomuovit
    __Kertamuovit
    __Tekniset muovit
    __Lujitemuovit
    __Kumit ja termoelastit
    __Muu________________________________

__Puu
    __Sahatavara
    __Puuliimalevyt, vaneri
        __Paperi/kartonki
        __Kuitulevyt
        __Kyllästetty puu, lämpökuivattu puu
        __Muu________________________________

__Tekstiilit/kuidut
    __Luonnonkuidut
    __Synteettiset kuidut
    __Lasikuitu, hiilikuitu
    __Keraamikuidut
    __Muu________________________________
__Keraamit
    __Tekniset keraamit
    __Rakennusmateriaalit
    __Kivi
    __Keraamiset pinnoitteet
    __Muu________________________________

Kysymys 1.2. Mitä materiaalitekniikkaan liittyviä tutkimuspalveluja yrityksenne on hyödyntänyt viimeisen kahden vuoden aikana?

	Yliopistot	AMK:t	Kaupal. tutkimuspalvelut (esim. VTT)
☐ Opinnäytetyöt	☐	☐	☐
☐ Muu tutkimus	☐	☐	☐
☐ Materiaalitestaus ja analyysipalvelut	☐	☐	☐
☐ Prosessointi	☐	☐	☐
☐ Tuotetestaukset	☐	☐	☐
☐ Muu__________________________	☐	☐	☐

Kysymys 1.3. Mitkä materiaalitekniikan osa-alueet ovat tärkeitä yrityksellenne? (Me=metallit, Mu=muovit, P=puu, Ku=kuidut, Ke=keraamit)

		Me	Mu	P	Ku	Ke
☐	Materiaalien perustutkimus, materiaalikehitys	☐	☐	☐	☐	☐
☐	Tuotanto- ja valmistusmenetelmät ja niiden kehitys	☐	☐	☐	☐	☐
☐	Materiaalien kierrätys ja uusiokäyttö	☐	☐	☐	☐	☐
☐	Materiaalivirtojen hallinta	☐	☐	☐	☐	☐
☐	Materiaalitehokkuus tuotesuunnittelussa	☐	☐	☐	☐	☐
☐	Tuotteen elinkaaren hallinta	☐	☐	☐	☐	☐
☐	Materiaalien karakterisointi ja testaus	☐	☐	☐	☐	☐
☐	Materiaalien saatavuus ja vaihtoehtoiset materiaalit	☐	☐	☐	☐	☐
☐	Materiaaleihin liittyvä ympäristötutkimus	☐	☐	☐	☐	☐
☐	Liittämismenetelmät	☐	☐	☐	☐	☐
☐	Yhdistelmämateriaalit ml. komposiitit	☐	☐	☐	☐	☐
☐	Materiaalikemia	☐	☐	☐	☐	☐
☐	Pinnoitusmenetelmät	☐	☐	☐	☐	☐
☐	Pintakäsittely	☐	☐	☐	☐	☐

Tarkennuksia:

Kysymys 1.4. Mitä materiaaliteknistä tutkimusosaamista arvioitte yrityksenne hyödyntävän seuraavan kahden vuoden aikana?

		Me	Mu	P	Ku	Ke
☐	Materiaalien perustutkimus, materiaalikehitys	☐	☐	☐	☐	☐
☐	Tuotanto- ja valmistusmenetelmät	☐	☐	☐	☐	☐
☐	Materiaalien kierrätys ja uusiokäyttö	☐	☐	☐	☐	☐
☐	Materiaalitehokkuus tuotesuunnittelussa	☐	☐	☐	☐	☐
☐	Tuotteen elinkaaren hallinta	☐	☐	☐	☐	☐
☐	Testauspalvelut	☐	☐	☐	☐	☐
☐	Koeajopalvelut, prototyypit	☐	☐	☐	☐	☐
☐	Materiaalien saatavuus ja vaihtoehtoiset materiaalit	☐	☐	☐	☐	☐
☐	Materiaaleihin liittyvä ympäristötutkimus	☐	☐	☐	☐	☐
☐	Liittämismenetelmät	☐	☐	☐	☐	☐
☐	Yhdistelmämateriaalit ml. komposiitit	☐	☐	☐	☐	☐
☐	Materiaalikemia	☐	☐	☐	☐	☐
☐	Pinnoitusmenetelmät	☐	☐	☐	☐	☐
☐	Pintakäsittely	☐	☐	☐	☐	☐

Tarkennuksia:

Kysymys 1.5. Mitkä ovat mielestänne tärkeimmät tulevaisuuden suuntaviivat ja haasteet liittyen materiaalitekniikkaan ja -tutkimukseen?

Kysymys 1.6. Kuinka paljon arvioitte yrityksenne panostavan materiaalien tutkimus- ja kehitystoimintaan seuraavien vuosien aikana?

	Ei ollenkaan	Jonkin verran	Merkittävästi
Oma t&tk-toiminta	☐	☐	☐
Muilta yrityksiltä ostettu t&tk	☐	☐	☐
Akateeminen tai soveltava ostotutkimus	☐	☐	☐

OSIO 2. Materiaalitekniikan kummiprofessuurimallin vaikutukset v. 2008-2012

Vaikutukset yrityksen innovaatio- ja suorituskykyyn

2.1. Kuvaus yhteistyöverkostosta. Millainen verkosto on ollut, kenen kanssa yhteistyötä on tehty (kummilaitoksen professorit, tutkimusjohtaja, tutkijat jne.) ?

2.2. Miten kummiprofessuurimallia on hyödynnetty (esim. nopeat syötteet, tutkimukset/selvitykset, tk-prosessien suunnittelu ja valmistelu)? Minkälaisen tuotekehitysmallin osana saatua tietoa on hyödynnetty (esim. kokeellinen tai systemaattinen innovaatiomalli)?

2.3. Miten tutkimuksen tarvemäärittely on tapahtunut – yrityksessä, yliopistossa, yhdessä?

2.4. Miten vuorovaikutus on käytännössä tapahtunut – tehokkaimmat vuorovaikutuskanavat?

2.5. Miten yhteistyö kummilaitoksen kanssa yrityksen sisällä on organisoitu – miten tieto mallista ja sen tulokset ovat liikkuneet organisaatiossa eteenpäin (johtajuus, kopinottajat?) Onko organisaatiossa ollut kyky absorboida mallin kautta saatua tietoa?

2.6. Mikä kummilaitosmallin rooli on suhteessa muun ulkopuolisen/sisäisen asiantuntemuksen hyödyntämiseen? Onko saatu tieto lisännyt käytettävissä olevan tiedon heterogeenisyyttä?

2.7. Ovatko kummilaitosmallin kautta syntyneet projektit olleet osa laajempaa prosessia – ovatko johtaneet uusiin vai olleet linkitettynä jo olemassa oleviin prosesseihin?

Yhteistyön tuotokset ja vaikutukset

2.8. Mihin projektit ovat päätyneet: onko syntynyt

- uusia IPR:iä (tai IPR:iä, joihin projektilla on ollut vaikutuksia)?
- uusia tuotteita/palveluja/tuoteparannuksia?
- tuotantoprosessien uudistumista?
- uutta osaamista?
- tietomäärän kasvua /tiedon hallinnan tehostumista?
- tiedon hankkimiskanavien laajentumista/tehostumista?

2.9. Olisivatko nämä tulokset syntyneet ilman mallia/missä ajassa?

2.10. Vaikutukset liikevaihtoon/tuottavuuteen?

2.11. Muut vaikutukset (esim. imago, pidempiaikaiset kilpailukykyvaikutukset)

2.12. Osallistuminen kansallisiin/kv. verkostoihin. Onko malli tuonut/luonut uusia verkostoja tai organisaatiorajat ylittäviä innovaatioprosesseja?

2.13. Onko mallilla ollut vaikutuksia yrityksen omaan tutkimuskulttuuriin tai tutkimustoiminnan luonteeseen? Onko malli parantanut tiedon absorbointikykyä?

2.14. Onko mallilla ollut vaikutusta teknologiseen erikoistumiseen?

Tampereen teknillinen yliopisto
PL 527
33101 Tampere

Tampere University of Technology
P.O.B. 527
FI-33101 Tampere, Finland

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