Technology Business Research Center
Research Reports 20

MARKET OPPORTUNITIES FOR PAPER INDUSTRY IN RADIO FREQUENCY IDENTIFICATION

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Lappeenranta 2009

ISBN 978-952-214-714-1 (paperback)
ISSN 1795-6102

ISBN 978-952-214-715-8 (PDF) (URL: http://www.lut.fi/TBRC)

Digipaino, Lappeenranta, 2009

ABSTRACT

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Research Report

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97 Pages, 31 Figures, 16 Tables, 1 Appendix

The paper industry has been experiencing remarkable structural changes since paper demand growth has ceased and some markets are declining. One reason behind the declined demand is the Internet, which has partially substituted the newspaper as a source of information. Paper products alone can no longer provide livelihood, and the paper industry has to find new business areas.

In this research, we studied radio frequency identification (RFID), and the market opportunities it could provide for paper industry. The research combined a quantitative industry analysis and qualitative interviews. RFID is a growing industry in the beginning of its life cycle, in which value chains and technologies still evolve significantly. The industry is going to concentrate on the future, and in the long term RFID-identifiers will probably be printed on paper substrate or directly onto products.

Paper industry has the chance to enter the RFID industry, but it has to obtain the required competences, for example through acquisitions. The business potential RFID offers to paper industry is inadequate, and while reviewing new strategic options, the paper industry must consider more options, for example the entire printed intelligence.

Keywords: Radio frequency identification, printed intelligence, value chain, paper industry

TIIVISTELMÄ

Matti Lehtovaara, Matti Karvonen, Kimmo Suojapelto, Tuomo Kässi

Paperiteollisuuden Mahdollisuudet Radiotaajuisessa Etätunnistuksessa

Tutkimusraportti

Lappeenranta 2009

97 Sivua, 31 kuvaa, 16 taulukkoa, 1 liite

Paperiteollisuus on suuressa rakenteellisessa muutoksessa, sillä paperin kysynnän kasvu on pysähtynyt tai jopa vähentynyt eräillä markkina-alueilla. Eräs tekijä vähentyneen kysynnän taustalla on Internet, joka on osittain korvannut perinteiset lehdet informaation välittäjänä. Paperituotteet eivät enää yksin mahdollista elinkelpoista liiketoimintaa, vaan paperiteollisuuden on löydettävä uusia liiketoiminta-alueita.

Tässä työssä tutkittiin radiotaajuista etätunnistusta (RFID) ja sen tarjoamia liiketoimintamahdollisuuksia paperiteollisuudelle. Tutkimuksessa yhdistettiin määrällinen toimiala-analyysi sekä laadullinen haastattelututkimus. RFID on elinkaarensa alkuvaiheessa oleva kasvava toimiala, jonka arvoketjut ja teknologiat edelleen kehittyvät huomattavasti. Toimiala tulee tulevaisuudessa keskittymään, ja pitkällä aikavälillä RFID-tunnisteet tullaan todennäköisesti painamaan joko paperitarralle tai suoraan lopputuotteeseen.

Paperiteollisuuden on mahdollista mennä RFID-toimialalle, mutta se edellyttää vaadittavien kyvykkyyksien hankkimista esimerkiksi yritysostoin. RFID-alan liiketoimintapotentiaali on niin ikään riittämätön paperiteollisuudelle, ja sen on tutkittava esimerkiksi koko painettua älykkyyttä strategisia vaihtoehtoja mietittäessä.

Hakusanat: Radiotaajuinen etätunnistus, painettu älykkyys, arvoketju, paperiteollisuus

FOREWORD

This research report describes the findings of master's thesis "*Market Opportunities for Paper Industry in Radio Frequency Identification"* that was carried out along with Talikko research project. The research project Talikko at Technology Business Research Center (TBRC) in Lappeenranta University of Technology (LUT) studied new business opportunities emerging in the intersections of forest-, ICT- and energy industries. During the research we realized the importance to understand the industry changes, and to draw the appropriate conclusions. We hope that this report could be of practical use both for industry representatives and academics.

We are grateful for everyone who supported to our research, and especially we like to thank the interviewees who greatly contributed to our project. Finally, we thank our researchers Matti Karvonen, Matti Lehtovaara and Kimmo Suojapelto. Many employees from TBRC and LUT also lend us a hand when needed, and we owe warm thank you to them.

In Lappeenranta, January 2009

Tuomo Kässi

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ACRONYMS

B2B	Business to business
EBIT	Earnings before interest and taxes
EPC	Electronic product code
HF	High frequency
IC	Integrated circuit
ICT	Information and communication technology
ID	Identification
IP	Intellectual property
ISO	International organization for standardization
LF	Low frequency
NPD	New product development
PPI	Pulp and paper industry
R&D	Research and development
RFID	Radio frequency identification
ROIC	Return on invested capital
R2R	Roll to roll
SBU	Strategic business unit
SCM	Supply chain management
SIC	Standard industrial classification
SME	Small and medium size enterprise
STDEV	Standard deviation
UHF	Ultra high frequency

1 INTRODUCTION

During the most part of the past century paper consumption was strongly linked to economic growth of nations and the consumption increased rather steadily. However, it seems that such direct connection between gross domestic production (GDP) and consumption is no longer valid. In fact, paper consumption began to decline in North America during 1990's and today, also the markets in Western Europe and Japan are mature. (Hetemäki & Nilsson 2005)

One of the key reasons for the declined demand is that electronic media, especially Internet, have rapidly substituted traditional media including newspapers, radio and television as a source of information and news. This has lead to an overcapacity in many paper product brands, falling end product prices and decreased profitability of pulp and paper industry (PPI). (Hetemäki & Nilsson 2005)

The paper demand still increases in Asia, particularly in China, and the paper industry has invested heavily into new manufacturing plants there, while closing production capacity in mature markets. In addition to these structural changes, the industry in Finland is facing the challenges of high input costs and shortage of raw materials. In these circumstances there is a strong likelihood that the Finnish paper industry will make its further investments in the growing markets, where raw material and labor costs are also competitive. The industry may wither away in Finland, a development that would have deep consequences for many individuals as well as the whole society.

Paper products alone can no longer offer livelihood for the entire industry, and it is of significant importance that the industry augments its efforts to generate new businesses. Printed intelligence extends new functionalities typically into paper or plastic substrate (e. g. Hakola et al. 2006; Södergård et al. 2007). Among other areas of printed intelligence, radio frequency identification (RFID), especially printed RFID, could offer new business opportunities for the paper industry.

1.1 Background

Technology Business Research Center (TBRC) was founded in 1999, and it is an internationally operating research institute at Lappeenranta University of Technology (LUT). TBRC's competences are based on the university's resources and strengths, in particular technological and business knowledge. These dual resources enable the institute to build multi-disciplinary teams, which are able to execute demanding research projects.

The Institute's research strategy is to produce high-level academic results as well as practical solutions for the industry, combining technology and business issues and taking international orientation into consideration. At present TBRC's key customer industries include forest-, ICT-, energy- and metal industries as well as the public sector. Typically the implemented research projects are funded by both national and international financiers and industries. (TBRC 2008)

Due to eroding industry boundaries and the new, evolving business environment, novel approaches are necessary in order to identify and exploit potential business opportunities at the intersection of industries. The primary objective of the Talikko research project was to identify new business opportunities emerging, particularly in the intersections of forest-, ICT- and energy industries. (Karvonen et al. 2008a)

This study was completed within a Talikko research project studying the intersection between forest and ICT-industries. The recent development of pulp and paper industry is studied, and the impacts of ICT on PPI in particular. Focus is to evaluate the new business opportunities that printed intelligence, especially radio frequency identification (RFID), could offer for the paper industry.

1.2 Objectives and limitations of the study

The main objectives of this research are: first, to study companies that operate within the RFID industry, and second, to extend the knowledge about business dynamics within the industry. Further goals are to evaluate possible future development of printed

intelligence and RFID industries, and to estimate paper industry's interest and possibilities in entering into the RFID industry. Finally, the target is to compose future visions for paper industry, especially in Finland. The objectives were formulated in the following main research question and sub-questions:

Main research question:

- *What kinds of key players and value chains exist in the RFID industry, and how might the value chains evolve?*

Sub-questions:

- *How might the printed intelligence and RFID industries and markets develop during the next decade?*
- *How could paper industry benefit from the RFID business?*

In the theoretical framework, innovations, especially the leading principles of innovations and the open innovation phenomenon are introduced. Enterprise competences are presented as well as the path dependence and dominant design phenomena.

The present situation of PPI is introduced as the background of the empirical study. The study is limited to the RFID industry, although printed intelligence in general is also dealt with, as printed RFID, in particular, forms a part of printed intelligence. The primary source of information about the companies and their activities within the RFID industry is an industry analyst and consultancy company IDTechEx. The financial data will be gathered from an international marketing information provider's Thomson ONE Banker (2008) data bank. The gathered knowledge is then complemented by interviewing Finnish specialists using a semistructured questionnaire.

1.3 Structure of the research

The overall structure of the study is as follows: In chapter 2, the present situation of forest industry, especially pulp and paper industry is shortly described. The focus is on extending the understanding of the impacts of ICT on the forest industry. Theoretical framework of the thesis is put forward in chapter 3 concentrating mainly on innovation management, enterprise competences, technology trajectories and dominant design phenomenon. Both quantitative industry analysis and qualitative interviews as research methods of the thesis are described in chapter 4. Printed intelligence and RFID industry are outlined in chapter 5. The ultimate focus is to describe RFID technology, its benefits, typical applications and markets. The RFID industry value chain and typical key players are introduced in chapter 6. The industry analysis will be complemented with industry specialists' opinions about the future evolution of the industry. Experts' views about RFID benefits for paper industry are put forward, and future visions for the industry are composed in chapter 7. Analysis of the key findings and recommendations for possible further studies are discussed in chapter 8. Chapter 9 delivers an overview of the subject. The general framework of the study is illustrated in figure 1.

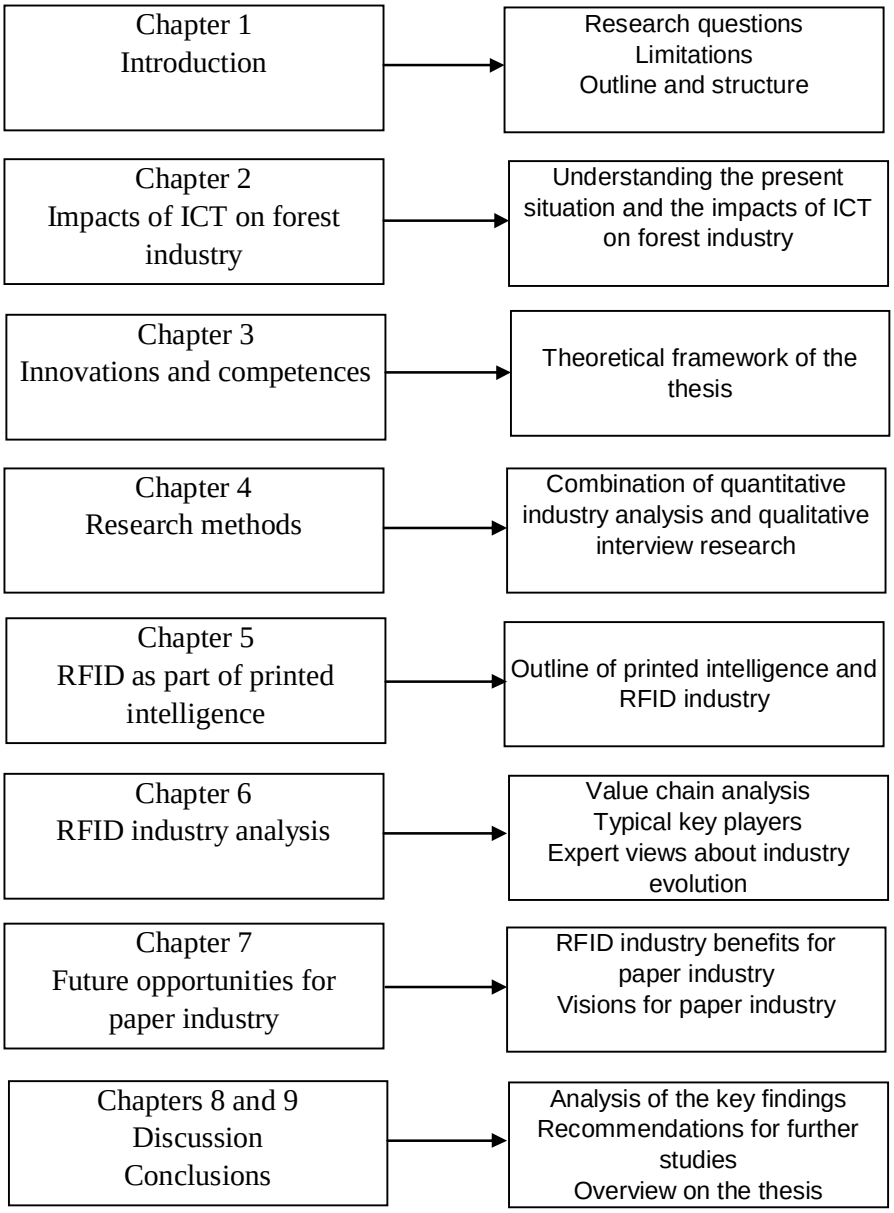

Figure 1: The general framework of the study

2 IMPACTS OF ICT ON FOREST INDUSTRY

The purpose of this chapter is to explain the present economical situation and business environment of paper industry. Special attention is given to the description of recent major impacts of the information and communication technology (ICT) and electronic media on the forest sector.

Global forest industry has traditionally based its strategies on history and a stable market environment. It seems evident that the industry has not yet faced such extensive changes worldwide, which are typically necessary to accelerate the invention of radical changes in technologies or markets. (Lamberg et al. 2006)

PPI is a mature industry, where the keys to success have been enormous investments typically in production technology and the aim to utilize the economics of scale. The industry has been highly path dependant by closing its paths for decades, for instance by technology decisions. In many cases the investments have been successful, but there are examples, when wrong investments have even led to a break up of a entire enterprise. (Lamberg et al. 2006)

As a matter of fact, pulp and paper industry has experienced remarkable structural changes over the past two decades. One of the key reasons behind the change are the impacts of the information and communication technologies on the forest sector. Taking into consideration the speed, how fast ICT-sector's innovations emerge, it can be expected that transformations in the forest sector will continue in the coming decades. (Hetemäki & Nilsson 2005)

In the past, the general assumption was that paper consumption was strongly related to gross domestic production (GDP). However, recent studies claim that paper consumption and GDP are no longer tied together this strongly. According to Diesen (2007), the correlation between consumption and GDP still exists, and consumption increases in the

lower GDP range (up to 15 000 USD), but saturation of the consumption begins at higher GDP (about 35 000 USD). Also, consumption of newsprint as well as printing and writing paper increased from 1960's to 2000 in spite of the fact that new innovations in ICT equipment and services increased significantly, as well. Nonetheless, newsprint demand on the United States market has developed interestingly during the past two decades. It seems that there was a structural break in the consumption in late 1980's and today's consumption is at the same level as in 1970's. There are several reasons behind this development, for example, more efficient use of newsprint raw materials, but the most significant reason is probably that Internet has rapidly substituted traditional media including newspapers, radio and television as a source of news and information. Projections predict further decline in the consumption. (Hetemäki & Nilsson 2005; Diesen 2007) Figure 2 shows paper consumption and GDP relation per capita.

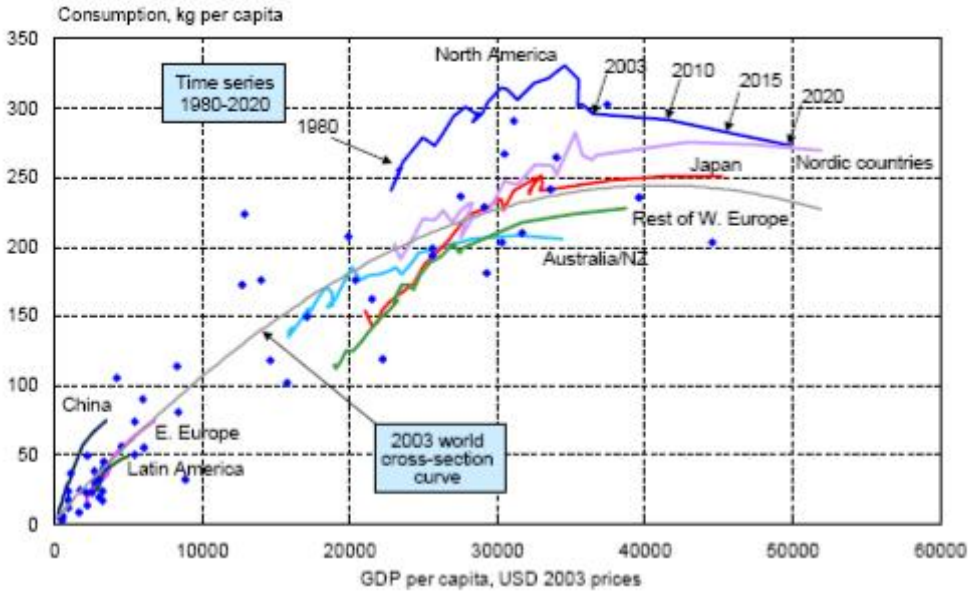

Figure 2: Paper consumption and GDP relation (Diesen 2007)

The United States market represents approximately one-quarter of world newsprint consumption and the use of information technology there is also advanced. Thus market trends in United States are important indicators of what might take place in other mar-

kets. In fact, paper demand per capita has declined in recent years in several other OECD countries as well. (Hetemäki & Nilsson 2005)

It is predicted, however, that the global demand of paper and paperboard will still increase by slightly over two per cent annually, but there are several uncertainties such as price and technological development, evolving speed of electronic media and economic growth in Asian countries, especially in China. On the whole, it seems obvious that the markets in Western Europe, North America and Japan are mature and growth will take place in particular in Asia, where new capacity will also be invested. (Suhonen 2006) Figure 3 shows regional paper and paperboard demand forecast through 2020.

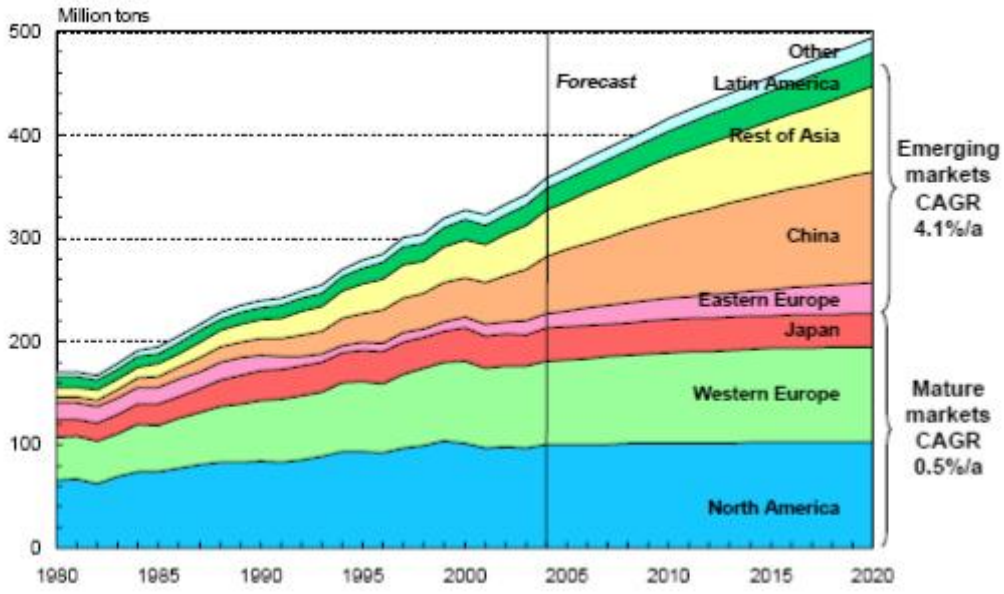

Figure 3: Paper and paperboard demand forecast through 2020 (Suhonen 2006)

Today, the pulp and paper industry is also facing other challenges than the impacts of ICT and electronic media on paper demand. One of the main concerns is that during the past few years the industry's profitability has declined remarkably. This is mainly caused by decreased end product prices and increased labor, raw material and energy costs. In order to compensate the reduced revenues, the industry has either invested into new efficient machinery and thus created overcapacity, or, what has been the case especially in North America, curbed investments leading to diminishing competitiveness.

The third key issue is paper industry's old fashioned and environmentally poor image. (Diesen 2007) In addition to the issues mentioned above, Hayhurst (2001) points out that industry fragmentation is another reason for the poor profitability. The top five forest companies represent less than 30 per cent of global market share, which is significantly lower than, for example, the equivalent in the automotive or mobile phones industries. Thus consolidation is expected to take place in the future. However, PPI is a more local industry than automotive and mobile phones, and it may remain more fragmented than the more global industries.

At present the paper industry operating in Finland is also facing the impacts of raw material shortage, which is going to be worse in case Russia increases the export duties for raw wood materials during the year 2009 as announced. Even if such duties would eventually be cancelled, the uncertainty of future raw material supply prevents PPI from investing in new production capacity in Finland. According to Kärkkäinen (2005), one probable scenario is that PPI is not investing in new capacity in Finland and in 2020 the plants are old fashioned and inefficient. On the contrary, globally operating Finnish paper companies are investing in countries where markets are growing and raw material supply is secure and price competitive. (Kärkkäinen 2005)

The Finnish forest industry employs almost 100 000 people directly and when we include other industries within the forest cluster, the indirect employment figures are much larger. The forest industry represents about one quarter of Finland's export value, which is the highest figure in the world. The influence of the forest cluster is, however, gradually declining due to other industries' expansion. (Diesen 2007)

According to Hetemäki and Nilsson (2005) Finland, Sweden and Canada are highly dependent on forest sector and in the new challenging situation these countries have an outstandingly high interest in creating new strategies. These include policies to ensure the shift from old to new technologies and business models takes place as smoothly as possible, investments in research and development (R&D), and fresh ideas about new opportunities. (Hetemäki & Nilsson 2005)

Sabel and Saxenian (2008) suggest that Finland and the Finnish forest industry, in particular, is at risk of becoming a victim of past success. The risk is that powerful developing countries with fast growing markets will learn and outdo the Finnish industry, and it will lose its technological advantage. Alongside with the rationalization of present businesses, the companies have to seek for radical innovations and transformation to novel business areas. (Sabel & Saxenian 2008)

The forest cluster located in South-East Finland is among the biggest in the world, and in 2004 the Centre of Expertise Program (OSKE) called forest industry experts to discuss the future opportunities of the cluster. Four different future scenarios were formalized, from which the scenario named "*Individualistic world*" supported by another one named "*In technology we trust*" were selected as the most promising ones. Scenarios emphasized customer-orientation, efficient technology utilization and new radical innovations in order to create new products and business concepts. (Vinaccia 2005)

As a whole, pulp and paper industry is facing a structural change mainly because of ICT and electronic media impacts on newsprint demand, falling product prices and increased input costs. Currently, the expensive Euro and a raw material shortage are additional burdens for the PPI operating in Finland. Taking the above into consideration, it is not surprising that the industry in Finland has been forced to restructure its operations and close down some of the oldest and most inefficient factories and shift more production closer to fast growing markets and better raw material resources, namely to Asia and Latin America. In case Russia is raising export duties for raw wood material to 50 Euros per cubic meter during 2009, as it has announced, more capacity closedowns in Finland can be expected. Since paper products alone no longer provide livelihood for the industry, it is essential that the Finnish paper industry accelerates its efforts to find new business opportunities. One of such prospects might be printed functionality and RFID.

3 INNOVATIONS AND COMPETENCES

In this chapter, the theoretical framework of the thesis will be introduced. To begin with, the way in which especially discontinuous innovations are supported and exploited in corporations, is presented. The open innovation model and the importance of the core competences of a company will be discussed next. Typical industry trajectories and path dependence are described, and finally, the dominant design phenomenon is put forward.

3.1 Towards open innovation

Innovations arise from a new idea generation, and the creativity to form of useful ideas can be either individual or organizational creativity. The creativity of an organization is rather complex depending on the individuals' creativity and their interaction and behaviors. Company routines, structures and incentives may amplify or thwart creativity. Innovation goes beyond idea generation; it is the implementation of ideas into practical devices and processes that have commercial value. Innovations can arise from individual inventors, firms, universities, government laboratories or non-profit organizations. One of the most important factors, however, is the linkage system between the innovators. The network leverage knowledge effectively, and acts as a powerful agent of technological advance. Today, in the competitiveness and success many industries depends on efficiently executed innovations and recently developed company products and services. (Schilling 2008)

The capability to detect various connections and opportunities and to take advantage of them is among the driving forces of innovations. New technology can often play a significant role, particularly by enabling radical innovations. However, innovation is not just about new technologies or opening up new markets, but can also be about new ways to serve existing customers and markets. Innovations are typically able to offer strategic advantages for enterprises and institutions. For example, a novelty in the company offering, process or complexity could offer advantages, which others find difficult to attain. Just to mention few other advantages, timing gives first-mover advantage,

platform design offers the platform on which to build product variations, and rewriting the rules provides completely different way of doing things. Radical changes, or in other words discontinuous innovations, can offer something entirely unequaled, or change the rules of the game and even the basis of society. (Tidd et al. 2005)

In case a firm constructs its innovations on the firm's existing knowledge, innovations can be considered as competence-enhancing ones. Thus the particular company increases value added by leveraging its existing competences. On the other hand, innovations can be regarded as competence-destroying ones, if the company's innovations are not grounded on its existent competences or they are left obsolete. (Tushman & Anderson 1986; Schilling 2008)

In order to enable innovations to evolve, they have to be actively led according to the company innovation strategy. Yet, since the competitive situations of companies, organization cultures, products and processes differ from one to another, innovation processes have to be adjusted accordingly. However, innovation process should be seen as one of the company's key processes along with management , customer relations and supply chain processes. The leadership of innovation belongs to the top management, but the process covers the whole organization. Effective innovation leadership includes leading both people and subjects, and the ability to sensitively alternate between creative and process management. (Apilo et al. 2007)

Carefully planned roadmap from idea generation until new product launch to market is essential for a successful innovation process. The innovation process can be divided into the search, selection and implementation phases, and special emphasize is put on learning and re-innovation throughout the whole process. (Tidd et al. 2005)

Formerly internal R&D used to be a valuable strategic asset for companies, and development was typically executed within the company boundaries and intellectual properties (IP) were carefully controlled so that competitors could not benefit from the company's own ideas. The foundation of this closed innovation has, however, eroded during the recent years because the mobility of knowledge workers has risen significantly, thus

making it much more difficult for companies to control their expertise and ideas. The other key factor behind the change has been the increased availability of venture capital enabling the establishing of new enterprises and the commercialization of emerged ideas. In the new open innovation model, companies utilize both own ideas and ideas from other organizations in order to commercialize them. Company should also profit from its own IP by selling the rights to other companies in case it cannot itself directly benefit from its own IP. (Chesbrough 2003) The open innovation model is illustrated in figure 4.

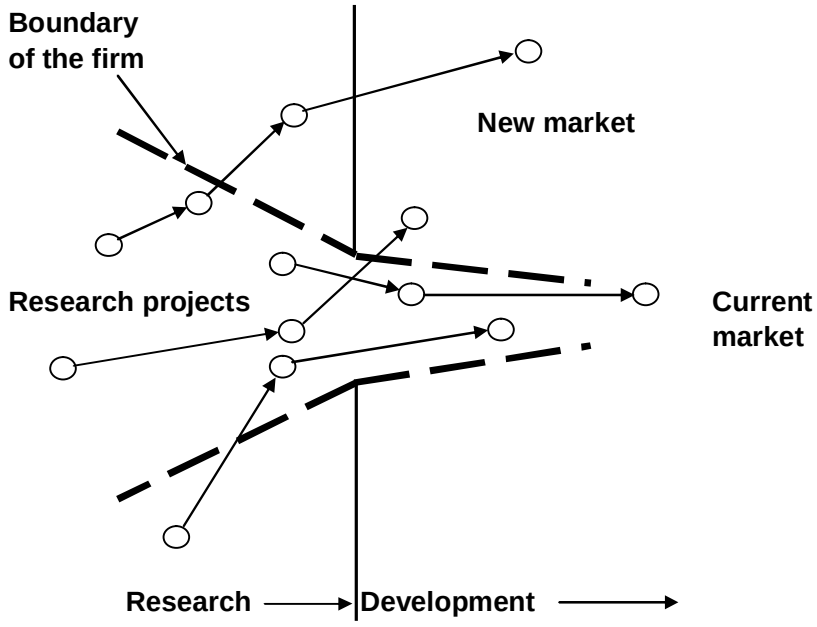

Figure 4: The open innovation model (Chesbrough 2003)

Open innovation influences how R&D should be managed within companies. Early stage development projects typically have uncertainties about their commercial and technical potential, and increased external sources of knowledge due to open innovation tend to complicate the evaluation of projects. Companies have to fit their projects, as usual, into their current business models, but on the other hand, they also have to create

options for extended future business models, and manage projects that at first look unpromising, but which might later on turn out to be valuable ones. (Chesbrough 2004)

3.2 Enterprise competences

A company's competences are based on its various resources, which can be regarded as building blocks of enterprise capabilities and competencies. Resources can be categorized into three groups: physical resources such as land, buildings and machinery; human resources as manpower, training and experience; and organizational ones such as enterprise culture and reputation. Next in the hierarchy are capabilities, which are located in different department functions of the firm and related to the company's ability to exploit its resources. Competences form the third level of the hierarchy, and can be defined as cross-functional integration and co-ordination of capabilities. In diversified companies competencies are built up from skills and know-how within different strategic business units (SBU). Core competencies are a unique collection of competencies that cross SBU boundaries, and are widespread in the corporation. Higher-level competency has more value added and is more difficult to accomplish than the ones lower in the hierarchy. (Javidan 1998)

Core competences are formed from the collective learning of the organization. In particular, they are related to the abilities to integrate sophisticated technologies and coordinate diverse production skills. Core competences provide access to a variety of potential markets, they contribute significantly to customer satisfaction and the company's end products, and they are difficult for others to recognize and imitate. Core competences are also rare, and typically even diversified corporations have only few fundamental core competences. In the short run, a company's competitiveness can be grounded for instance on relative price and performance of end products, but the long term competitiveness derives from systematically built core competences. (Prahalad & Hamel 1990)

Company strategies and competences are also strongly interrelated. Corporate mission and strategy determine long-term objectives and success by defining business portfolios, where company intends to be. Furthermore, the top management has to define what the required competences and core competences are in order for the company to be competitive in the future. Thus corporate strategy and mission are firmly related to core competences. On the other hand, the aim of business strategy is to formulate the competitive position of the SBU in relation to its competitors. Functional strategies of different departments aim to ensure that business unit's strategies are executed in practice. (Javidan 1998) Competencies and strategic hierarchies, and their interrelations, are illustrated in figure 5.

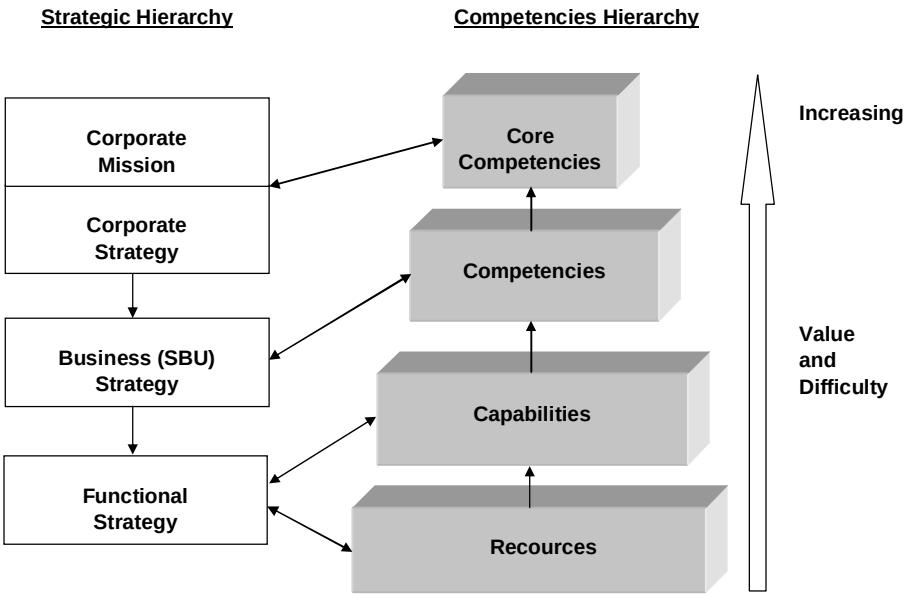

Figure 5: The interrelation between strategies and competences (Adapted from Javidan 1998)

It is vital for companies to integrate both company strategies and core competences. In addition to that, firms have to identify the right technology and market fit, since the adequate technology selection could create remarkable competitive advantage for the company. Companies can further build their competences and eventually core competences by taking their core competences and business strategies carefully into account,

while making technology selections. In other words, companies should efficiently integrate their overall business strategy, core competences and key technologies. (Torkkeli & Tuominen 2002)

3.3 Industry trajectories

Companies are path-dependent, because they have constraints of technological knowledge and corporate competence. Firms' present and likely future knowledge tends to channel company innovation strategy, and so do corporate competences, since they limit what the company is capable of learning and exploiting. As a consequence of the fact that learning is typically incremental, the learning processes tend to be path-dependent and moving from one path of learning to another one is usually very difficult and sometimes impossible. As a result, companies have difficulties moving into other paths, though this may be possible, for example through acquisitions, especially in case firms belong to related industries. (Tidd et al. 2005)

There are abiding differences among industrial sectors as far as the sources and directions of innovations are concerned. The size of firms varies and so does the type of products made. Also the objectives, sources and locus of innovation differ. For example, chemicals and electronics firms are typically big, whereas instruments and software firms are small. Bulk materials are typically price sensitive and machinery products performance sensitive. Product innovations are common in ethical drugs and process innovations in steel firms. Agriculture relies on suppliers as the source of innovation and machinery on customers. Chemicals and electronics firms execute in-house innovation and ethical drugs basic research. Electronics firms' own innovation is typically located in R&D laboratories, automobiles' in production engineering, machine manufacturers' in design offices and banks' in system departments. Companies can be categorized into five major technological trajectories: supplier-dominated, scale-intensive, science-based, information-intensive and specialized suppliers. (Tidd et al. 2005) Table 1 illustrates typical core sectors, major sources of technological accumulation and main strategic tasks of each trajectory.

Table 1: Five major technological trajectories (Tidd et al. 2005)

	Supplier-dominated	**Scale-intensive**	**Science-based**	**Information-intensive**	**Specialized suppliers**
Typical core products	Agriculture Services Traditional manufacture	Bulk materials Consumer durables Automobiles Civil engineering	Electronics Chemicals	Finance Retailing Publishing Travel	Machinery Instruments Software
Main sources of technology	Suppliers Production learning	Production engineering Production learning Suppliers Design offices	R&D Basic research	Software and systems departments Suppliers	Design Advanced users
Main tasks of innovation strategy					
Positions	Based on non-technological advantages	Cost-effective and safe complex products and processes	Develop technically related products	New products and services	Monitor and respond to user needs
Paths	Use of IT in finance and distribution	Incremental integration of new knowledge	Exploit basic science	Design and operation of information systems	Matching changing technologies to users' needs
Processes	Flexible response to user	Diffusion of best practice in design, production and distribution	Obtain complementary assets. Redefine divisional boundaries	To match IT-based opportunities with user needs	Strong links with lead users

When comparing a typical capital-intensive (low tech) process industry, such as the pulp and paper industry, and a high tech industry, such as the electronics industry, many differences in innovation activities can be evidenced. For instance, PPI tends to base its competition on the price and quality ratio, whereas electronics industry's competition is

based on new innovations. PPI's R&D expenses are typically below one per cent of annual sales, whereas electronics R&D expenditure is usually over four, sometimes close to ten per cent of annual sales. PPI's patenting activity is usually low, and innovations incremental process innovations. Electronics industry's patenting activity is high, and innovations tend to be fundamental product innovations. (Ebeling 2008) Table 2 illustrates the innovation activities of process and electronics industries.

Table 2: Innovation activities in PPI and electronics industry (Ebeling 2008)

	Pulp and paper industry	**Electronics industry**
Competition criteria	Price / quality ratio	Innovation
R&D intensity	Low	High
Innovation focus	Process	Product
Scale of innovation	Incremental	Fundamental
Innovation source	Knowledge from other sciences and industries	Self made or co-operatively developed new information
Patenting	Low	High
Skills and competences	Practical knowledge and skills	Theoretical knowledge and cognitive skills
Co-operation	Customer - producer	University - producer

When firms are thus categorized, there is a danger of over-simplification. On the other hand, when companies are categorized diverged, their similarities are easily ignored. However, supplier-dominated companies' innovations tend to come mainly from suppliers, therefore their main task of innovation strategy is to use others' technology to reinforce their own competitive advantages. Scale-intensive firms' innovation strategy is based on incremental product and production improvements, and diffusion of best design and production practices throughout the organization. Science-based firms rely on monitoring and exploiting the results from basic research, they focus on high-tech products and acquire necessary assets. Information-intensive companies focus their strategy on developing complex information processing systems and often also radically new services. Specialized supplier firms are usually rather small, and thus they tend to rely on lead users, adopt the needed technologies from others and fit these to customer

requirements. As a conclusion, trajectories can improve the understanding of companies' technology strategies by clarifying the reasoning of the sources of company technologies, their contribution to competitive advantage, the tasks of innovation strategy and the most probable opportunities and threats. (Tidd et al. 2005)

3.4 Technology cycles

Technologies seem to undergo repeated cycles, and understanding the evolution of these cycles helps companies to predict the time of radical changes. The cycle begins with an era of ferment, technological discontinuity, while the majority of the technological progress takes place. The technological discontinuity then generally leads to a single industry standard, a dominant design, which is then followed by a peak in sales and cease in innovation activity. Discontinuities never become dominant designs and on other hand dominant designs are always behind the cutting edge of the industry technology. The new product undergoes incremental changes and architectural innovations during the dominant design period. Incremental innovations are followed by process innovations, while production methods and value chain activities are improved. Dominant design will eventually be followed by a new technological discontinuity and a new dominant design cycle. (Anderson & Tushman 1990; Tushman 1997) Technology cycles and dominant design are illustrated in figure 6.

The emergence of a dominant design is often the result of a combination of technological, economical and organizational factors, and thus it is not necessarily simply the most promising technological invention. However, when dominant design becomes the industry standard, it opens new possibilities to accelerate the adoption of a new design as dominant, for example: industry regulation and government intervention, strategic moves of firms, networking in the industry and possession of collateral assets. (Suarez & Utterback 1995)

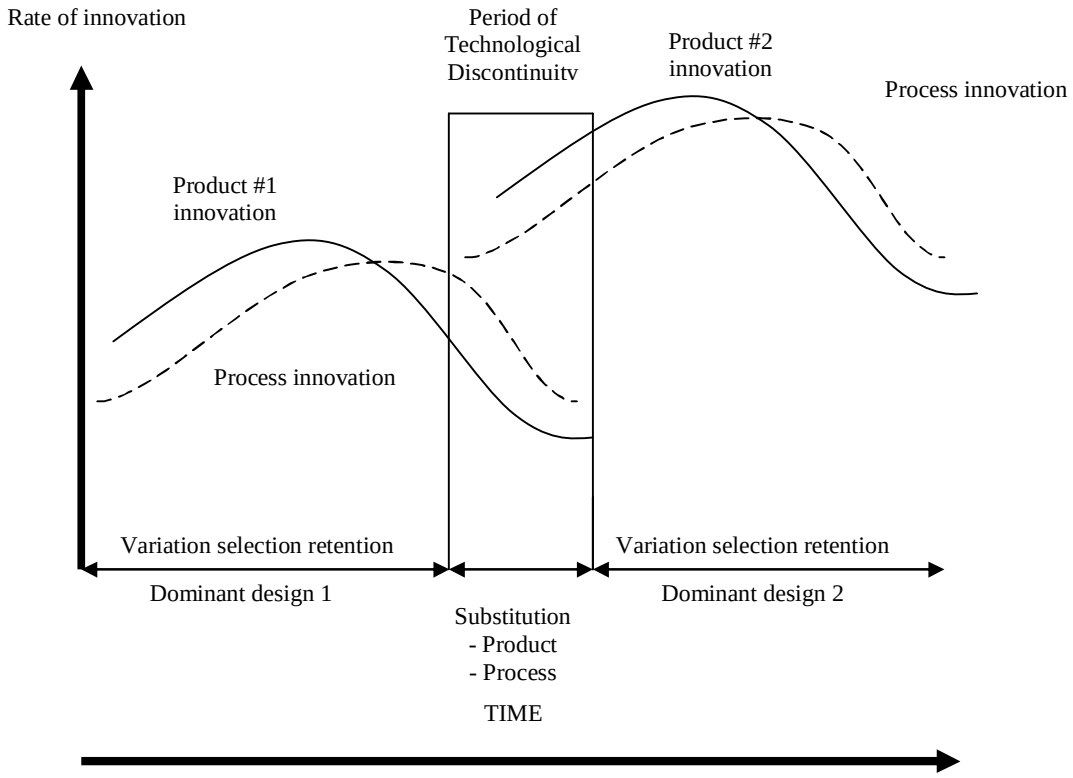

Figure 6: Technology cycles (Tushman 1997)

All in all, the transformation in the paper industry seems to be fundamental. Paper industry has industry competences and innovation activities typical to the scale-intensive technological trajectory. The industry is likely to need novel competences, while possibly entering into new businesses that differ from conventional paper making. Competent innovation management and efficient utilization of the open innovation paradigm are of consequence, while firms aim to achieve especially discontinuous innovations. In the empirical study of the thesis the aim is to extend the knowledge about the lifecycle of RFID industry and the typical enterprise competences within the industry. Furthermore, the aim is to understand, what type of transformation the paper industry has to undergo in case it desires to enter into RFID industry.

4 RESEARCH METHODS

This section contains the description of the research flow. Firstly, the selection criteria for the studied companies and interviewed persons are introduced, and secondly the data collection and analyzing methods are put forward. Finally, the overall purposes of the analyses are described. The purpose was to combine a quantitative industry analysis and a qualitative interview research in order to obtain a holistic view of the RFID industry.

4.1 Industry analysis

As a starting point the researcher group of three people used the industry analyst IDTechEx's data bank on RFID solution providers. The preliminary collection of firms was then studied using their Internet home pages, which revealed a significant number of their suppliers, partners, competitors and customers within the industry value chain. In order to ascertain the accuracy of the manually gathered data, it was independently collated and then crosschecked by other researchers. The final sample of companies was then formed from the Thomson One Banker (2008) data source. The gathered data included financial factors such as company revenue, return on invested capital (ROIC), earnings before interest and taxes (EBIT) and R&D expenditure. Non-financial data consisted of the number of employees, company age and areas of business activity. Companies were categorized by using Standard Industrial Classification (SIC) codes using the three-digit level in analysis, available for example at the U.S. department of labor (2008). SIC codes were originally created by the U. S. Department of Commerce, and they categorize all business activities that cover five per cent or more of a company's total net sales. The primary code indicates the main line of company business.

In further analyses, the companies were categorized into four groups: value chain's upstream focused players, downstream focused players, vertically integrated firms, and PPI labels and printing companies. A firm was defined as an upstream operator in case it operated at the beginning of the value chain, and its RFID business was related to identifiers such as chips, tags, antennas and labels, or devices such as interrogators and printers. Downstream focused firms operated at the end of the value chain and concen-

trated in software and integration. Firms operating in the whole value chain had varying activities at both ends of the business value chain. Companies were selected into PPI labels and printing group, if their primary SIC codes were 262 (paper mills), 267 (converted paper and paperboard products), 271 (publishing and printing newspapers), 275 (commercial printing) or 279 (service industries for the printing trade).

Furthermore, a number of focal firms were examined more specifically. A company was selected as a typical key player if it had significant RFID activity, was operating broadly in the value chain or was evaluated to possess remarkable market share in some specific business segment. A typical key player could also occupy extensive partner and customer network, operate globally and perform active marketing.

4.2 Interviews of Finnish RFID specialists

RFID Lab Finland is a non-profit undertaking founded in 2005 that aims to support the Finnish RFID industry and other related actors in evolving their RFID business and especially the export activities. Over 40 globally operating Finnish firms, research institutes and universities are partners in this undertaking. (RFID Lab Finland 2008) The Lab was asked for potential company representatives and RFID specialists for the interviews and the officials recommended a group of professionals in the field.

Part of the contacted interviewees also recommended other specialists within their organization or in other firms to be interviewed, and thus extended the potential knowledge base. The interview invitation was sent to 23 specialists, and 12 (52 %) of them accepted the invitation: seven industry representatives and five from academic or research institutes. The enquiry was composed of semistructured questions concentrated on three main issues: how printed functionality and RFID-business is going to develop during the next ten years, how RFID value chain will evolve during that period, and how could paper industry possibly benefit from RFID. The interviews took place between 22nd of September and 17th of October in situ and they were recorded. The inter-

views lasted from 41 to 78 minutes, with the mean of 59 minutes. Table 3 illustrates the interview duration, and interviewee position and organization type.

Table 3: Interviewee information

Interview duration (min)	Interviewee position	Organization type
62	D. Sc., Project Manager	Academic
78	M. Sc., Marketing Director	Industry
44	D. Sc., Professor	Academic
65	Director	Industry
56	Research Director	Research institute
42	D. Sc., Manager	Industry
68	Vice President	Industry
49	Entrepreneur	Industry
50	Project Manager	Research institute
66	Director	Industry
62	Technology Manager	Industry
41	D. Sc., Team Leader	Research institute

4.3 Research flow

While analyzing the companies in the value chain, the development of company revenue and the number of employees are essential factors in order to understand the growth of the individual companies as well as the development of the whole business sector. Return on invested capital (ROIC) and earnings before interest and taxes (EBIT) reveal the profitability of an enterprise, and R&D expenditure express how extensively a company invests into new product development (NPD), thus making potential innovations possible. Company ages may indicate for example that mature firms have entered the industry, or new enterprises have been established. The overall view of the research is shown in figure 7.

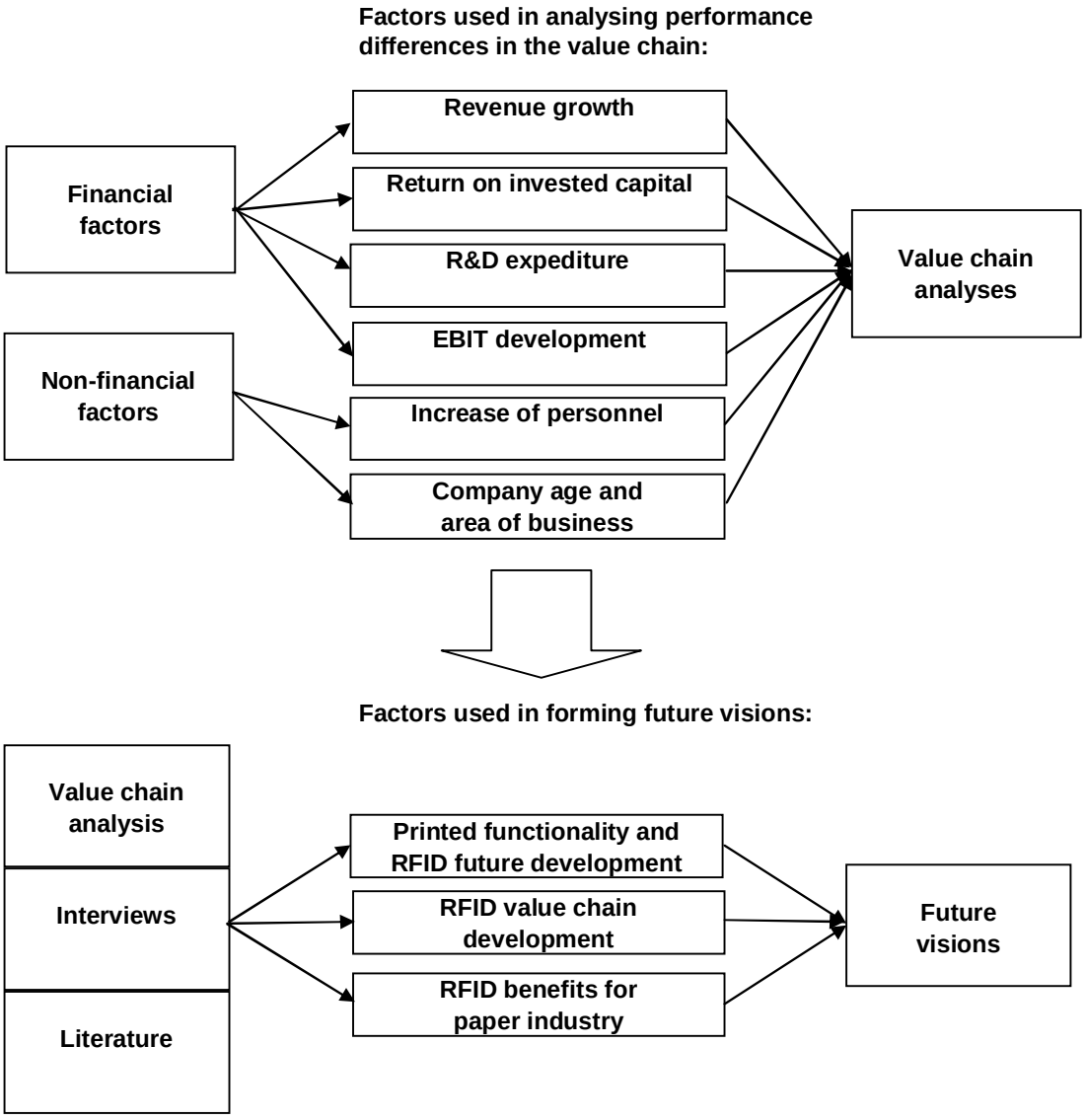

Figure 7: Research flow

The future visions formed for the paper industry were based on the executed industry analysis and the interviews of Finnish specialists in the RFID branch. The presented visions are a synthesis from value chain analyses, interviews and literature, and not the ones of the interviewees alone. Interviews also covered printed functionality, since it is a broader entirety, from which RFID, especially printed RFID forms a section. However, the ultimate focus of the research was on RFID; the players within the value chain, and the future development of the industry.

5 RFID AS PART OF PRINTED INTELLIGENCE

This chapter presents printed intelligence and especially radio frequency identification as part of printed intelligence. The results of the RFID industry analysis are described as well as the outcomes from the interviews of the RFID-specialists and industry representatives. In addition to the general industry value chain analysis, some of the typical key players are examined more specifically.

5.1 Printed intelligence

Printed intelligence, or in other words, printed functionality, offers new business possibilities for paper and board manufacturers. Printed intelligence should, however, not be mixed up with printed electronics, although this is commonly done even with professionals. Printed intelligence extends the functions for printed matter whereas printed electronics' aim is the production of electronic devices. (Södergård et al. 2007) According to Hakola et al. (2006) printed functionality adds new functionalities usually into paper or plastic substrate and functionality could be on the substrate's surface or within it or possibly both. Printed functionality consists for example of such areas as optical and electronic codes, embedded codes, electronics, optics, displays and sensors. Different areas of printed functionality are described closely on table 4.

Table 4: Different areas of printed functionality (Hakola et al. 2006)

Main areas	Sub-areas
Optical codes	• Linear bar codes (1D bar codes) • Two-dimensional bar codes • Reactive codes
Hidden or embedded codes	• Invisible codes • Digital watermarks • Microtext • Magnetic codes
Electronic codes	• RFID (Radio Frequency Identification) tags
Visual effects	• Holograms, kinegrams
Electronics	• Passive components • Conductors • Circuit boards
Optics	• Light guides • Micro lenses
Displays	• OLED (Organic light-emitting diode) • LCD (Liquid Crystal Display) • Thermo chromic
Sensors and indicators	• Temperature, moisture, oxygen, chemical compounds

Hybrid media is related to printed intelligence and it can be defined as the integration of different functionalities, media and contents. Convergence between digital media and fiber-based products is essential. Printed barcodes linked to digital media and electronic papers are examples of hybrid media. (Hakola et al. 2006; Karvonen et al. 2008b)

According to Pöyry (2004), hybrid media can be defined as all means that extend ordinary media's content, interactivity, distribution and devices. However, the definition of hybrid media varies and is not well established and the term is not very widely used overseas but is very Finnish expression. In fact, Finland has favorable opportunities to

evolve hybrid media, because of its strong paper-, media- and electronics industries. (Pöyry 2004)

Nevertheless, several research and development (R&D) projects related to hybrid media have been conducted abroad. For example, one of them is connecting paper, electronic and mobile media. The case in point is connected to radio frequency identification (RFID) reader, which could be integrated into a mobile phone. Users could then read RFID codes simply by setting the mobile phone close to the code. (Pöyry 2004) Figure 8 shows the framework of hybrid media, and overseas R&D projects, such as mobile RFID reader.

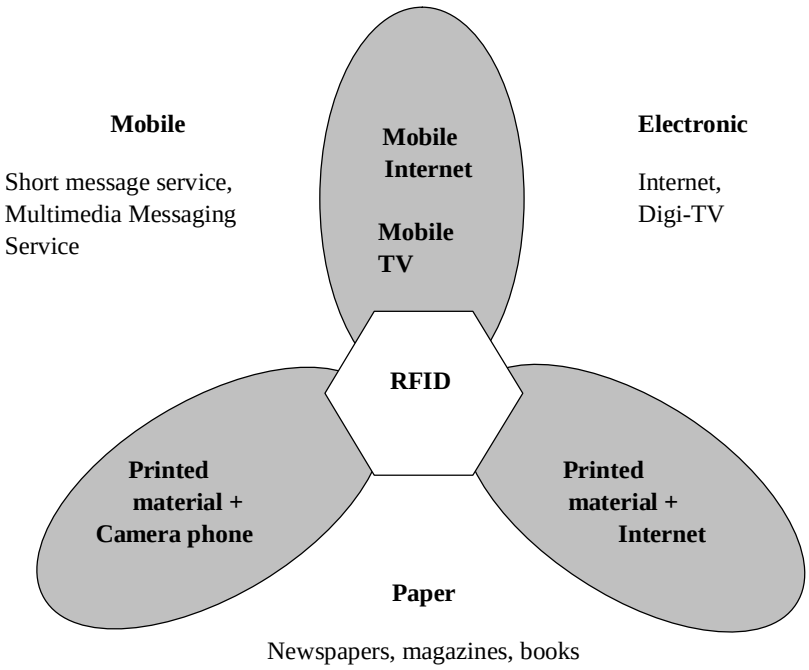

Figure 8: Hybrid media triangle and overseas R&D projects (adapted from Pöyry 2004)

Harrop and Das (2008) predict that printed intelligence market has the potential to become a 300 billion USD business in about 20 years, meaning that it will be bigger than the silicon semiconductor industry today. Similarly, Hakola et al. (2006) estimate considerable growth potential for printed functionality with forecasted global sales of 70 billion Euros already in 2015. Printed intelligence offers new functionalities and better

performance, such as robustness, lighter weight, thinness and fault tolerance compared to conventional electronics. Furthermore, printed intelligence is often lower in cost, and these characteristics open the way to the possible future success. Printed intelligence will have a significant impact on electronic industry as well as packaging-, silicon chip- and display business. (Harrop & Das 2008)

The interviewed Finnish specialists were more cautious in their estimates of the future development of the printed intelligence markets. Optical and electronic codes have evolved and, for example, the display and sensor markets are emerging, but on the other hand, the present recession in the world economy might hinder the positive development. The academic and research specialists were slightly more optimistic about the future development than the industry representatives.

The roll to roll (R2R) printing process is one of the manufacturing methods with most potential, while printing, packaging and electronic industries are seeking new ways to serve their customers by new cost effective large scale production methods. Although it is difficult to predict the future success of this technology, sensors, bar codes, printed RFID, digital watermarks, holograms, electronic paper and flexible batteries and solar cells, for example, have already been successfully manufactured by using the roll to roll method. The emergence of the new technology depends not only on the maturity of the technology itself, but on the resources available in order to bring it to market. (Kesola 2007)

The Finnish experts also agreed that R2R is an efficient production method and one of the key competences of paper industry. However, the production method has to be adjusted according to the demanded volumes of the manufactured product brand in order to optimize the cost-efficiency factors.

In order for the predicted future of the printed intelligence to come true, many industries need to collaborate more intensively than today to exploit each other's competences. Among those industries, printing, chemicals and electronics are included. For example, printing industry has to provide its low cost, high-speed reel to reel (R2R) competences,

chemicals industry new chemicals and electronics industry thin films-, multilayer- and precision patterning technologies as well as clean room and testing capabilities. (Harrop & Das 2008) Figure 9 illustrates the industries, which are seeking to collaborate.

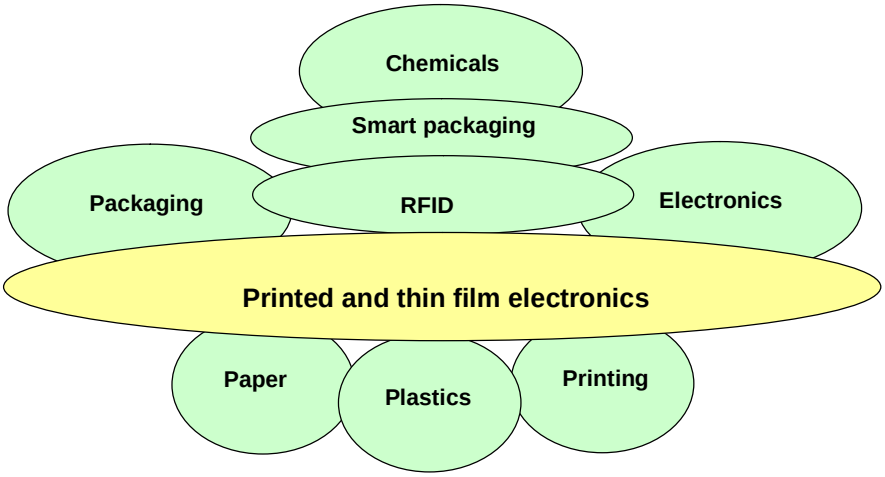

Figure 9: Industries that need to collaborate (Harrop & Das 2008)

In conclusion, printed functionality has significant growth potential and it could become a major industry within the next two decades. The potential future success lies behind the new end product and service characteristics, which the cost efficient reel to reel printing technology is able to open up. However, bandwagon depends not just on the new technologies, but in particular on the collaboration of different industries to bring in their special know-how and the capabilities to commercialize the emerging innovations.

5.2 Radio frequency identification

Automatic identification procedures have been widely used during the past decades, and are becoming more successful especially in logistics, supply chain management and manufacturing. Radio frequency identification is one of the automatic identification systems; other important ones include bar codes, smart cards, optical character recogni-

tion and biometrics, which can be divided into voice identification and fingerprint procedure. (Finkenzeller 2003)

RFID was first used in the air war during the Second World War, when German and British planes were identified as friends or foes. Just like today's RFID systems, the early systems already contained important components such as interrogators and transponders. RFID has been in commercial use by various businesses and governmental entities since the end of 1940's. It has been utilized to track items and animals and provide access control to facilities. Improved technology and drop for instance in semiconductor prices as well as broadband networking have lately increased the general use of RFID solutions. (Glover & Bhatt 2006)

However, the use of RFID, especially in logistics and manufacturing, did not evolve rapidly until retail giants, such as Wall-Mart, Metro and Tesco as well as the US Defense department began to mandate that their key suppliers implement pallet level RFID tagging. Wall-Mart was even obliged to speed up the process by putting sanctions to suppliers, who fail to tag their shipments. The most vital reason for the implementation of the new system has been the aim to improve the efficiency of the supply chain. Retailers' distribution centers' accuracy and thus their profits have been improved, whereas initial costs for suppliers have increased significantly. (Ngai et al. 2008; Blanchard 2008)

5.2.1 RFID technology and security issues

Technology and standards

RFID system typically consists of a tag, a reader and data processing equipment such as application software, computer hardware and middleware. RFID transponders, which are placed on the items intended to be tracked, consist of a memory containing integrated circuit. Tags may or may not have a silicon chip, where the necessary data is stored. In chipless tags the data can be employed in electromagnetic or acoustomagnetic

materials, for example. Tags can be active or passive: Active tags have a battery, whereas the passive tags use energy from the reader's signal to power-up the integrated circuit and transmit stored data back. The transponder has an identity, which is broadcasted to the reader using the same radio frequency and protocol in order to communicate together. (Lynn 2005; Ngai et al. 2008; Das & Harrop 2008)

The communication infrastructure consists of either wired or wireless network communications that transfers the data from transponders to readers. The RFID middleware is necessary to filter and encapsulate the raw data into exploitable form at enterprise information systems. (Glover & Bhatt 2006; Ngai et al. 2008)

The system uses radio frequencies (RF) between 3 Hz and 30 GHz, but the practical frequencies can be divided into four RF channels; low frequency (LF – 125 kHz range), high frequency (HF – 13.56 MHz), ultra high frequency (UHF – 900 MHz range) and microwave (2.45 GHz or 5.8 GHz). RFID systems generate electromagnetic waves and because the system should in no circumstances disrupt other radio services, such as radio, television or mobile phone services, the used channels for RFID are regulated. Within the most commonly used RF channels some of the actual operated frequencies differ from each other to some extend depending on whether they are operated in Europe, USA or Far East. For instance, frequency range 869 MHz is in use in Europe and 915 MHz in USA and Australia. (Finkenzeller 2003; Lynn 2005)

The frequencies have different qualities; LF penetrates most obstacles, but it requires bigger antennas and the data-transmission capability is limited. Typical reading distance between reader and tag is below 0.5 meter. HF, UHF and microwave provide higher data-carrying capacity and greater reading distance, but are more sensitive and can easier be blocked, for example by metal objects. Active tags using UHF and microwave frequencies can be used up 100 meters reading distance. (Ahola et al. 2007; Lynn 2005)

Today, there are two major standardization bodies for RFID: International Organization for Standardization (ISO) and EPCglobal (Electronic Product Code). ISO began its operations in 1947, and of the network currently comprises of 157 national standards or-

ganizations, which makes it the world's largest generator of International Standards. ISO has a strategic partnership with the World Trade Organization (WTO), the purpose being that political decisions made in WTO will be supported by technical expertise of ISO. (ISO 2008) The advancement of industry standards, in particular, for EPC to support RFID is guided today by EPCglobal (EPCglobal 2008).

There are several standards for different RFID applications and furthermore, the standards are updated periodically. For item management, for example, there are the ISO 18 000 series and the EPCglobal Class 0 and Class 1 Generation 1 and Generation 2 standards. Uniform official standards could accelerate the development of RFID market considerably and ensure an adequate competitive environment. Nonetheless, it seems that there has lately been convergence between ISO and EPCglobal organizations in order to create unified standards. (Finkenzeller 2003; Glover & Bhatt 2006; Ngai et al. 2008; Spacecode 2008)

Privacy and security issues

According to Ahola et al. (2007), privacy and security issues are frequently mentioned as central problems in RFID technology. Privacy issues are related to the possible abuse of authorized data leading to violations of personal privacy. People define privacy differently and it is simple to forget that even without RFID, societies are able to utilize various data on their citizens. However, for instance, limiting the read range of the tags and adding into them so a called kill functionality, which disables their functions after initial use, could prevent illegal use of personal information. RFID systems, like other wireless communication systems, are vulnerable for illegal use of confidential data. This adds new complexity to enterprise and government information technology (IT) safety issues. (Glover & Bhatt 2006; Ngai et al. 2008)

5.2.2 RFID benefits, applications and markets

Benefits

Probably one of the most familiar optical codes used in the past decades has been the bar code. It provides a very cost effective system for tracking items, especially today, when the codes are mostly printed directly onto items. However, bar codes also have some disadvantages, and one of them is that there has to be a line of sight between the bar code tag and the reader, whereas RFID does not require direct line of sight between tags and readers. Other benefits of RFID include for instance high inventory speed, meaning that multiple items can be scanned simultaneously. RFID tags also vary from tiny passive ones to large tags, equipped with batteries and with significant information capacity. Furthermore, some type of tags can not only be read, but can also be written and rewritten several times. (Glover & Bhatt 2006) A comparison of the characteristics barcodes and RFID are shown in table 5.

Table 5: The characteristics bar code versus RFID (Spacecode 2008)

Bar code	RFID
Read individually	Read simultaneously
Line of sight required	No line of sight required
Read manually	Automated
Read only	Read and write if required
Limited information capacity	Large information capacity
Low durability	High durability
Easy to replicate	Difficult to replicate
Inconsistent accuracy	Consistent accuracy
Lower cost	Higher cost (currently)

Applications

RFID systems have been applied, in particular, in supply chain management and manufacturing, but the potential application areas are much broader. Enterprises and entities today utilize RFID successfully in their every day operations for a wide variety of application areas, and have also started up new pilot schemes. (Ngai et al. 2008)

According to the IDTechEx RFID Knowledgebase, most cases in the beginning of 2008 occurred in retail and consumer goods category, mainly because of mandates by major retailers and military organizations. Passenger transport represented the second biggest application area, and besides high proportion of these applications were rollouts from previous years. On the contrary, many executed projects in the leisure application area came from one time events. Finance, security and safety sectors were also steadily growing and driven for example by counterfeiting and terrorism. Land and sea logistics is another steadily growing area. (Das & Harrop 2008) Typical application categories are classified in table 6.

Table 6: Typical RFID application areas (Das & Harrop 2008; Ngai et al. 2008)

• Animal detection • Aviation • Building management • Construction • Enterprise feedback control • Fabric and clothing • Financial • Food safety warranties • Health • Laundry • Leisure	• Library services • Logistics • Military • Mining • Municipal solid waste management • Museums • Passenger transport • Postal • Retailing • Security, safety • Supply chain management

Markets

The total RFID market was worth a little less than five billion US dollars in 2007, and according to Das & Harrop (2008), the market is expected to grow by nearly eight per cent in 2008 and it is forecasted to reach 27 billion US dollars in 2018, biggest potential being in East Asia, followed by North America and Europe. The growth in 2008 is expected to take place in spite of the fact that the enormous Chinese ID card project, creating a peak in demand last year, is now basically completed. At present, both China and USA stand for about one quarter of the market, and the next biggest markets in 2008 are Japan, United Kingdom, Korea and Germany. (Das & Harrop 2008; IDTechEx 2008) Currently, transponders represent 43 per cent of the five billion USD markets, interrogators including cell phone readers 29 per cent, and the rest comes from software and integration. Majority of tags today are passive, that is without battery, and future forecasts predict the trend to continue. (Das & Harrop 2008) Total RFID market projections are shown in figure 10.

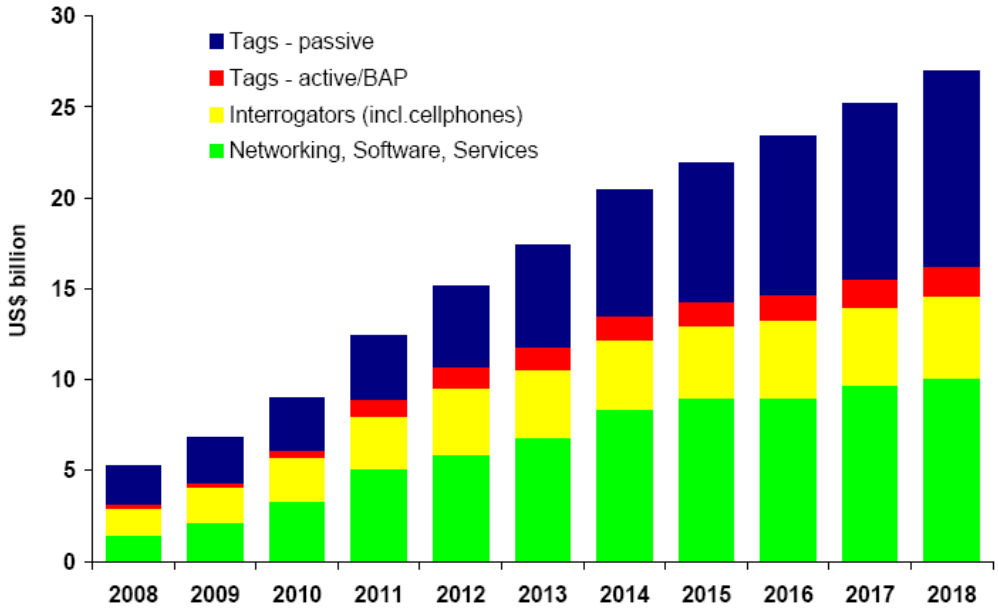

Figure 10: Total RFID market projections 2008-2018 (Das & Harrop 2008)

Among other things, the remarkably declining cost of tags is essential for successful market penetration. Passive chipless tags are predicted to cost only few USD cents at the most within ten years. Increased annual demand of tens of billions of tags and new printed RFID technologies are behind the forecasted price reduction. Also, the unit prices of active tags as well as interrogators are expected to drop significantly during the next decade. (Das & Harrop 2008)

In spite of the promising future prospects, successful adoption of RFID faces several challenges, which might hinder the fast commercialization of this industry. The key challenges can be divided into following groups; technology, standards, patents, expenses, infrastructure, profitability and substitutes. (Wu et al. 2006)

In the RFID system, hundreds of tags can be read simultaneously, but simultaneous radio signals may cause collision interface to the reader devices. Likewise, the orientation of the tag antenna has significant effects on the reading accuracy. Besides, used radio waves could be refracted by liquid or metal materials undermining the accuracy. These technology issues have still to be solved in order to reach full system reliability. Government and standardization organizations have also to work out to define unified RFID standards and frequency spectrum allocations. Procedures to handle intellectual property rights (IP) also have to be agreed upon in order for the vendors to know, whether the technology they use is royalty-free or not. The manufacturing costs of the devices, especially the tag costs, have to be reduced to make certain that the exploitation of the system evolves sustainable, and thus becomes feasible for all parties of the supply chain. RFID is far from mature yet and it can be predicted that bar codes and RFID will coexist in parallel for a long time still. (Wu et al. 2006)

A part of the interviewed Finnish specialists, especially academic and research professionals, predicted that RFID market could evolve as expeditiously as IDTechEx had estimated. Logistics provide the biggest business potential, and large-scale wholesalers insisting pallet-level identification are the drivers of market penetration. However, most of the interviewees shared the opinion that the market expansion will be slower than predicted. Inadequate infrastructure, such as still developing standards and devices

might for instance be hindering factors, and the present world economy contains considerable threats to potential market growth. RFID market penetration is also pricing sensitive, meaning that, for example, the system costs including tag costs have to be significantly reduced in order to ensure fast commercialization of the industry. Collaboration between different players and supporting industries is required, and the benefits of RFID adoption have to be transparent for the customers. (Table 7)

Table 7: RFID market development

Interviewees	Issue areas Market development, drivers and hindering factors
Person 1 Project manager, academic	**RFID could emerge.** "Various printed intelligence applications become general during next decades. Large-scale wholesalers requiring pallet-level tagging are industry drivers. Infrastructure and standardization not yet mature."
Person 2 Marketing director, ICT company	**RFID on its early lifecycle phase.** "Applications within logistics strongly developing. Tag costs have to be reduced in order to extend the use of RFID."
Person 3 Professor, academic	**Markets develop slower than predicted.** "Intelligent packaging is emerging fast. Wholesalers and logistics are the drivers of RFID development. Inadequate infrastructure hinders the development."
Person 4 Director, forest company	**RFID on its early lifecycle phase.** "Development of printed intelligence and RFID slower than predicted. Wholesalers lead the development. High tag costs, insufficient standards and infrastructure and technical unreliability delay the evolution."
Person 5 Research director, academic	**RFID on its early lifecycle phase.** "Printed intelligence and RFID evolve. However, lacks in infrastructure and security issues delay the progress."
Person 6 Manager, forest company	**Markets develop slower than predicted.** "RFID do not emerge as fast as predicted. However, logistics is the fastest developing application area. Lack of standardization delays the development."
Person 7 Vice president, forest company	**Markets develop slower than predicted.** "Large-scale players are important industry drivers. Open loop system, such as RFID needs collaboration and standardization in order to develop."
Person 8 Entrepreneur, ICT company	**Markets develop slower than predicted.** "Customers' cost savings and efficiency increase are industry drivers. HF and UHF frequencies already have dominant design standards."
Person 9 Project manager, academic	**RFID could emerge.** "Wholesalers are industry drivers. World economy and lacks in infrastructure may delay the development. Investments are required from many parties."
Person 10 Director, ICT company	**RFID could emerge.** "Standardization already mature enough. One of the key issues in implementing RFID is customer awareness of the benefits and the will to re-engineer its processes radically."
Person 11 Technology manager, ICT company	**Markets develop slower than predicted.** "Commercial benefits have to be transparent to customers. RFID still quite tiny business. The costs of RFID systems and the present world economy may hinder the development."
Person 12 Team leader, academic	**RFID could emerge.** "Wholesalers are important drivers, while implementing RFID. Challenging world economy and lack in standardization may delay the evolution."

For now, the industry value chain is very fragmented, consisting of over one thousand companies, most of them small players. Some of the silicon semiconductor manufacturers are globally operating giants just as some of the software, system integrator and – operator companies. On the other hand, some manufacturers act in niche markets, and increase just tiny value added into the value chain. Fragmented value chain cannot deliver the best efficiency and competitiveness and thus it can be expected that acquisitions and consolidation will take place in the future. (Das & Harrop 2008) Current RFID value chain is presented on figure 11.

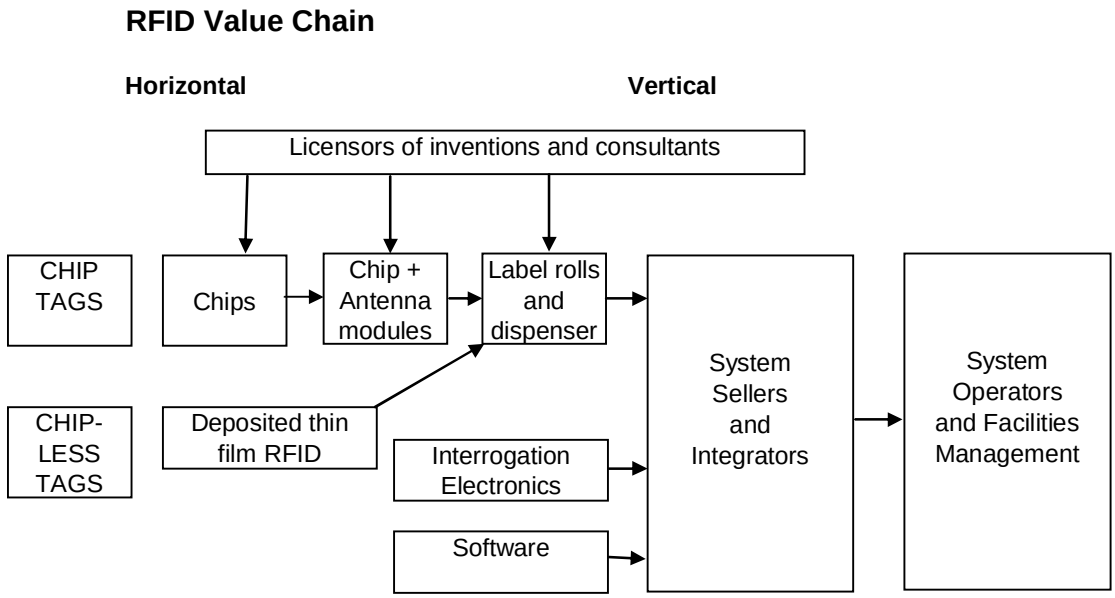

Figure 11: RFID value chain (Das & Harrop 2008)

Printed RFID

Today, most RFID tags contain a silicon chip and copper-etched circuit boards. This traditional technology sets limitations to production speed and capacity, and furthermore, the method is environmentally unfriendly. New reel-to-reel printing technology allows the use of a rotary-screen, lithographic, gravure or flexography press at a much higher production speed. Digital inkjet technology could also be used as an alternative

method. At first, the antenna is printed and then the integrated circuit is attached or alternatively both are printed. The inlay is typically then placed on a label substrate. (Lynn 2005)

According to Harrop & Das (2008), low cost flexible substrates are needed in order to open up new potential markets, since the applications of printed electronics are very price sensitive. The most popular substrates today are polyethylene thin films, but paper substrates offer low costs for processes, which can tolerate the rough surface of paper. (Harrop & Das 2008) Typical characteristics of different substrates are illustrated in figure 12.

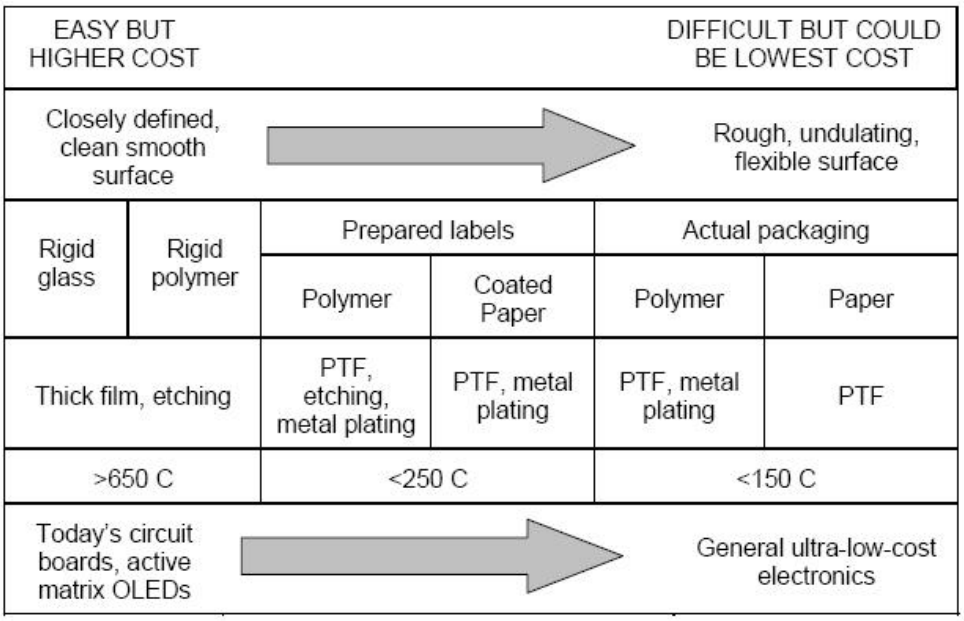

Figure 12: Typical characteristics of substrates (Harrop & Das 2008)

There's a strong interest to use biopolymers like cellulose for electronic applications due to their cost efficiency and environmental issues. In spite of the bias for the suitability of paper as a substrate for example because of its rough surface, successful experiments have recently been executed. (Fortunato et al. 2008; Österbacka 2008)

Most of the Finnish specialists also predicted that paper as RFID tag substrate will eventually substitute plastic substrate in spite of the fact that there still are technological issues to be solved. The key arguments behind this reasoning are environmental and cost factors, which favor paper substrate. Some of the industry representatives, in particular, did not respond to the issue. (Table 8)

Table 8: Paper vs. plastic RFID tag substrate

Interviewees	Issue areas Paper vs. plastic material as future RFID tag substrate
Person 1 Project manager, academic	**Paper replaces plastics.** "There exist promising experiments in using paper as substrate. Paper is environmentally friendly material."
Person 2 Marketing director, ICT company	No opinion.
Person 3 Professor, academic	No opinion.
Person 4 Director, forest company	No opinion.
Person 5 Research director, academic	**Paper has advantages.** "Ecological issues, e.g. recyclable tags have increasing importance."
Person 6 Manager, forest company	**Paper and plastics co-exist.** "Plastics have still to be used, but eventually price and environmental issues favor paper substrate."
Person 7 Vice president, forest company	**Paper has advantages.** "Paper as environmentally friendly recyclable material favors PPI."
Person 8 Entrepreneur, ICT company	**Paper has advantages.** "Paper is environmentally friendly, but what about the conductive inks."
Person 9 Project manager, academic	**Paper has advantages.** "Paper has advantages, and after all information is printed on paper."
Person 10 Director, ICT company	No opinion.
Person 11 Technology manager, ICT company	No opinion.
Person 12 Team leader, academic	**Paper replaces plastics.** "Paper is eventually likely to win because of environmental issues."

One possibility is that history will repeat itself, and RFID market will develop as its predecessor, bar code market evolved. The bar code label market peaked about 15 years ago, but since then, the label market has diminished, because today estimated 85 to 95 per cent of the used bar codes are printed directly on consumer goods and packages

without using self adhesive labels as substrate. However, unlike bar codes, printed RFID requires special inks in order to be printed directly onto matters, and this leads to the fact that directly printed RFID could probably never be as cheap as directly printed bar codes. Also, the most sophisticated tags may potentially not be directly printed in the near future. Transition to directly printed RFID may occur after approximately 15 years. (Das & Harrop 2008) Figure 13 illustrates the possible progression of high volume item level RFID tagging.

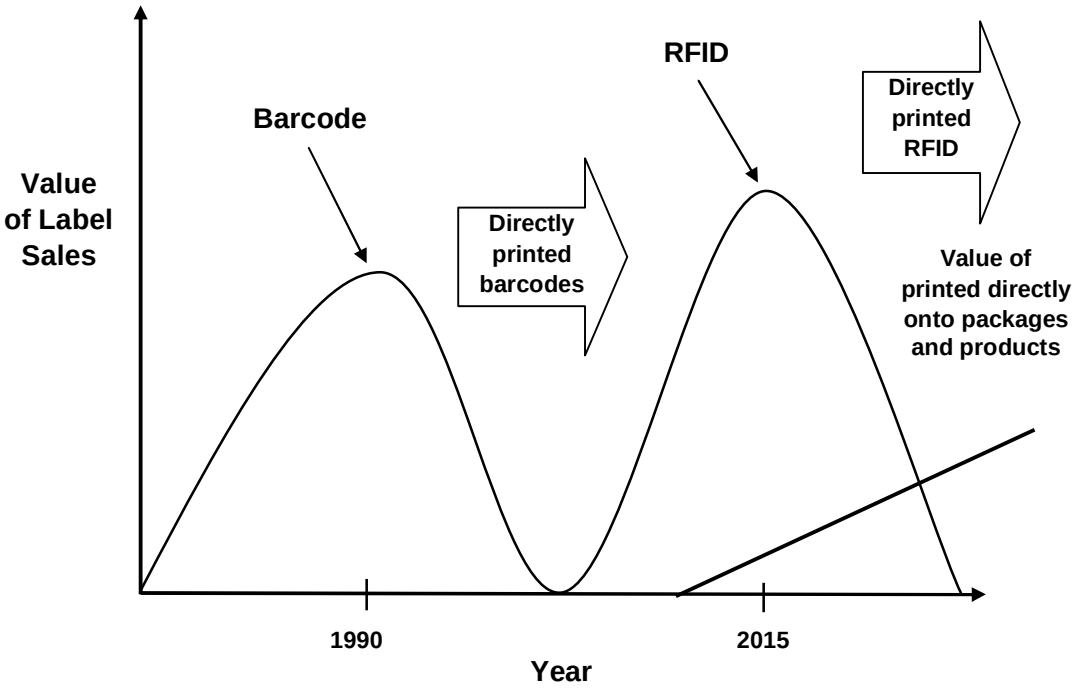

Figure 13: High volume item level RFID tagging (Das & Harrop 2008)

Figure 13 shows clearly that the timeframe, when bar codes were mainly printed on self-adhesive labels was relatively short, about 15 to 20 years. It is noteworthy that, in case similar development is going to take place for RFID labels, the window of opportunity for instance for label manufacturers is limited.

The interviewed experts agreed strongly that RFID will not substitute barcodes within the next decade, but both optical and electronic codes will co-exist for a long time supplementing one to another. In general, RFID provides more functionality than barcodes, but inexpensive barcodes cannot be replaced quickly. As a matter of fact, inexpensive two-dimensional (2D) barcodes can contain more information than the simplest RFID tags. (Table 9)

Table 9: Electronic vs. optical codes

Interviewees	Issue areas Electronic (RFID) vs. optical codes (barcodes)
Person 1 Project manager, academic	**RFID and barcodes co-exist.** "Inexpensive barcodes can not be replaced."
Person 2 Marketing Director, ICT company	**RFID and barcodes co-exist.** "The use of barcodes may increase due to generally increasing identification."
Person 3 Professor, academic	**RFID bring more value-added.** "RFID could bring new characteristics compared to barcodes."
Person 4 Director, forest company	**RFID and barcodes co-exist.** "Inexpensive 2D-barcodes evolve. Barcodes will be used for item-level tracking, RFID for pallet-level identification."
Person 5 Research director, academic	**RFID and barcodes co-exist.** "RFID provides more characteristics. It will gain more market share in case price competitiveness is better."
Person 6 Manager, forest company	**RFID and barcodes co-exist.** "RFID is not price competitive."
Person 7 Vice president, forest company	**RFID and barcodes co-exist.** "RFID offers more functionality, but will probably remain more expensive than barcodes."
Person 8 Entrepreneur, ICT company	**RFID and barcodes co-exist.** "Different codes supplement each other. RFID is used in places, where barcodes do not fit."
Person 9 Project manager, academic	**RFID and barcodes co-exist.**
Person 10 Director, ICT company	**RFID and barcodes co-exist.**
Person 11 Technology manager, ICT company	**RFID and barcodes co-exist.** "Barcodes inexpensive and 2D-barcodes are able to store more data than passive RFID tags."
Person 12 Team leader, academic	**RFID and barcodes co-exist.** "Especially 2D-barcodes remain in the market."

The majority of the Finnish experts also shared the opinion that it will still take several years before printed RFID is in commercial use and could possibly substitute silicon chips in RFID tags. Silicon chip technology is today still more reliable and cheaper, and

after all printing technology might not provide significant value added. One industry representative even commented, *"It will still take a long time, before printing technology could replace silicon chips from tags, if ever."* However, some interviewees predicted that printed and also directly printed RFID could gain market share already after few years. (Table 10)

Table 10: Printed vs. conventional RFID tag

Interviewees	Issue areas Chipless printed RFID vs. conventional RFID tag with silicon chip
Person 1 Project Manager, academic	**Silicon dominates.** "Printed or directly printed RFID does not necessarily bring added value."
Person 2 Marketing director, ICT company	**Silicon dominates.** "Possible shift from silicon chips to printed RFID would be a disruptive innovation."
Person 3 Professor, academic	**Silicon dominates.** "Silicon chip technology still cheaper and more reliable than printed technology."
Person 4 Director, forest company	No opinion.
Person 5 Research director, academic	No opinion.
Person 6 Manager, forest company	**Silicon dominates.** "Chipless technology still in the beginning of its era."
Person 7 Vice president, forest company	**Silicon dominates.** "Implementation of printed and directly printed RFID takes long. Label substrates remain in use. "
Person 8 Entrepreneur, ICT company	**Silicon dominates.** "Printed technology do not replace silicon based IC for long, if ever."
Person 9 Project manager, academic	**Silicon dominates.** "Printed RFID technology is not ready yet."
Person 10 Director, ICT company	**RFID partly printed directly.** "One possibility is that RFID follows the development of barcodes, and will be partly printed directly on products within ten years."
Person 11 Technology manager, ICT company	**Silicon dominates.** "Directly printing technology still under development, actually label usage increase."
Person 12 Team leader, academic	**Printed RFID emerge.** "Within 3-5 years part of HF tags will be printed and after five years part of UHF tags."

As a synthesis, the interviewees did not expect printed functionality and RFID to evolve as rapidly as some analysts had predicted, although some experts were more optimistic. It will probably also take a long time before printed RFID will begin to replace the use

of silicon chips in tags. Electronic and optical codes are likely to co-exist, and eventually paper will substitute plastic substrate.

All in all, RFID business has evolved rapidly during the past few years, partly because of the vast identification program in China and the mandatory pallet tagging required by retail giants, such as Wall-Mart. However, the lack of integrated standards and the suspicions about privacy and security issues have hindered the bandwagon. In case these issues are successfully solved, the prices of devices, especially the tag prices, will decline and the various involved industries will start to collaborate more intensively. If that happens, it is likely that the optimistic business forecasts could eventually materialize.

6 RFID INDUSTRY ANALYSIS

In this chapter, the results of the RFID industry's value chain analysis are described as well as the outcomes of the interviews of the RFID-specialists and industry representatives. In addition to the general industry value chain analysis, some of the typical key players are examined more specifically.

6.1 Value chain analysis

The value chain has in this analysis been divided into upstream-, downstream- and vertically integrated players. Upstream players include companies involved in developing, manufacturing and selling identifiers such as chips, antennas, tags and labels, or devices such as readers and printers. Downstream focused firms are involved in software and integration, and they operate closely in the end customer interface, especially with business to business (B2B) customers. Vertically integrated firms may operate broadly in the whole value chain or they may focus on either end of the value chain, but have activities also on the other end of the chain. Material suppliers and contract manufacturers as well as machinery and equipment manufacturers supplement the mainstream players. Universities, research institutes, consultants, and non-profit institutes add value to the chain by R&D and education for example. Figure 14 illustrates the RFID value chain.

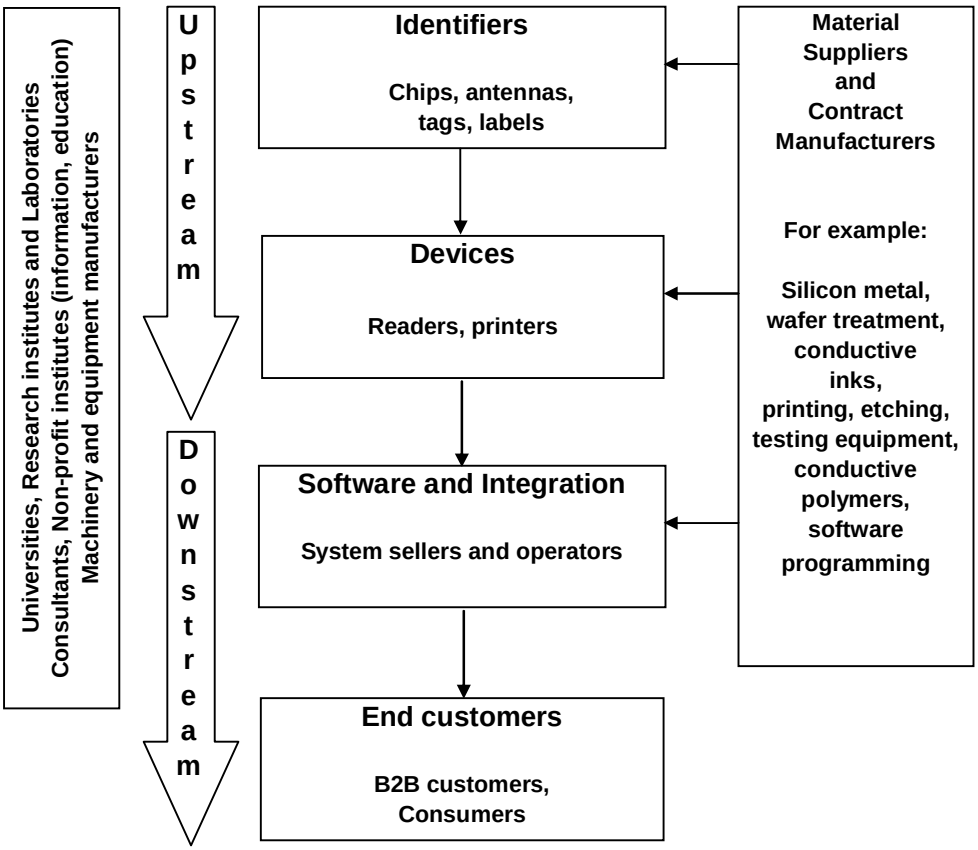

Figure 14: RFID value chain

6.1.1 General industry analysis

In the industry analysis there were altogether 202 firms, employing 4.27 million people and making a turnover of 1054 billion euros. Most of the companies with available data were publicly listed large-scale enterprises, although few smaller companies were also included in the sample. Financial data from Thomson ONE Banker (2008), (Thomson) was available from 80 companies, from which 61 per cent were from USA origin. There were 54 vertically integrated firms operating in the whole value chain, 63 firms were upstream players, and 85 firms were downstream focused ones. Twenty firms were categorized as PPI and printing companies. Table 11 summarizes the number of firms,

the availability of financial data, and the country of origin and the year of foundation of the companies.

Table 11: Summary of the analysed firms

	Firms	Financial data available	Country of origin	Year of foundation
Vertically integrated players (Whole value chain)	54	18	USA=12 (67 %) FIN=2 (11 %) OTHER=4 (22 %)	Average 1973 Median 1990
Upstream players (Chips /Tags, Readers, Printers)	63	26	USA=11 (42 %) Japan=6 (23 %) GBR=2 (8 %) OTHER=7(27 %)	Average 1966 Median 1984
Downstream players (Software& integration)	85	36	USA=26 (72%) GBR=3 (8 %) FRA=2 (6%) CAN=2 (6%) OTHER=3 (8%)	Average 1977 Median 1992
TOTAL	202	80	USA=49 (61 %) Japan=7 (9%) GBR=5 (6 %) FRA=3 (4%) CAN=3 (4%) FIN=3 (4%) OTHER=10 12%)	Average 1973 Median 1989
PPI & printing industry	20	8	USA=4 (50%) JPN=3 (38%) FIN=1 (12%)	Average 1914 Median 1932

The age distribution of the firms

The foundation year of the company was available for 158 firms either from Thomson or from companies' Internet home pages. Average foundation year was 1973 and the median 1989, revealing that most of the firms were relatively young ones. However, approximately 50 per cent of the firms were founded before 1990, and on the other hand, 27 per cent in the year 2000 or later. Figure 15 shows the age distribution of the companies.

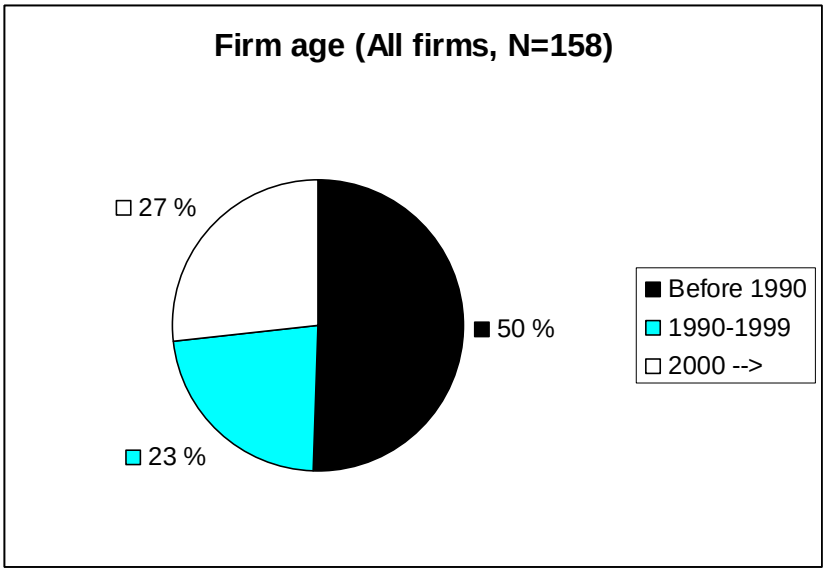

Figure 15: The age of all RFID firms

The age distributions of vertically integrated players, and upstream focused ones, as well as downstream focused firms were rather similar to the general foundation year distribution. PPI and printing companies composed totally different distribution; no less than 93 per cent of firms were founded before 1990, and the rest in 2000 or later. PPI and printing is a mature industry; the average year of foundation was 1914 and the median 1932. Figure 16 illustrates the age distribution of PPI and printing industry.

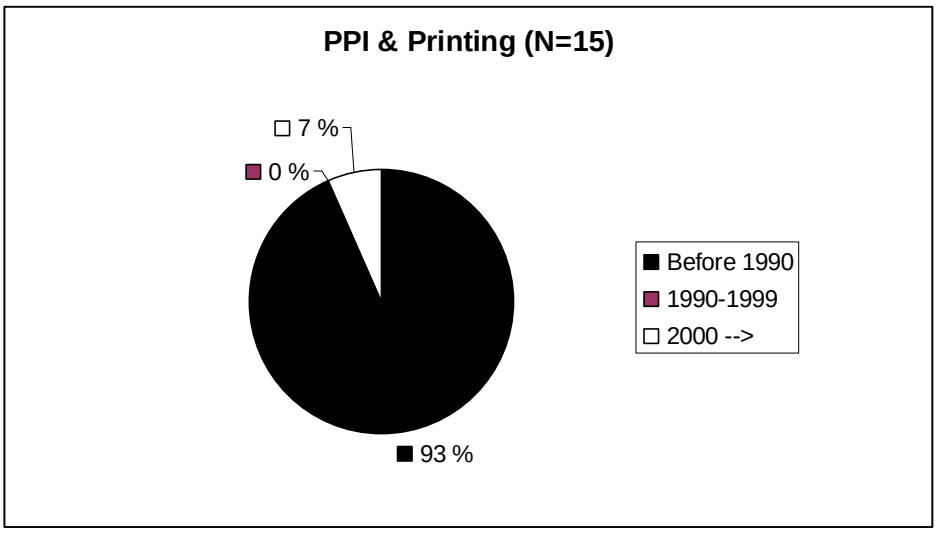

Figure 16: The age of PPI and printing firms

The results indicate that PPI and printing firms entered into RFID are more mature than the other firms under perusal. However, the sample of PPI and printing firms is significantly lesser than the ones of the other groups, and thus one has to be cautious, while drawing conclusions.

All RFID firms

Firms employed in average 54 723 people in 2007, and had an average revenue of 12 852 million Euros. However, considerable standard deviations (86001, 20652) reveal that there are significant variations in company sizes. Companies' revenue had grown in average 11.7 per cent during the past five years, whereas employee growth had been 4.9 per cent respectively. Average ROIC % during the past five years was 7 per cent, which seemed to be a typical return on invested capital within the industry. Average EBIT was 1 304 million Euros in 2007 with significant variations between companies. EBIT had typically grown by 9.5 per cent during the past five years. R&D expenditure was 760 million Euros in 2007 with significant variations, and typical R&D % during the past five years had been 9.5 per cent of net sales.

Categorizing the companies by using primary SIC codes with three digits revealed that 24 per cent of the companies belonged to the computer programming and data processing category (737). The second biggest group (15 %) was electronic components and accessories category (367), and the third biggest one (10 %) was computer and office equipment group (357). Industry classifications of all firms are shown in figure 17.

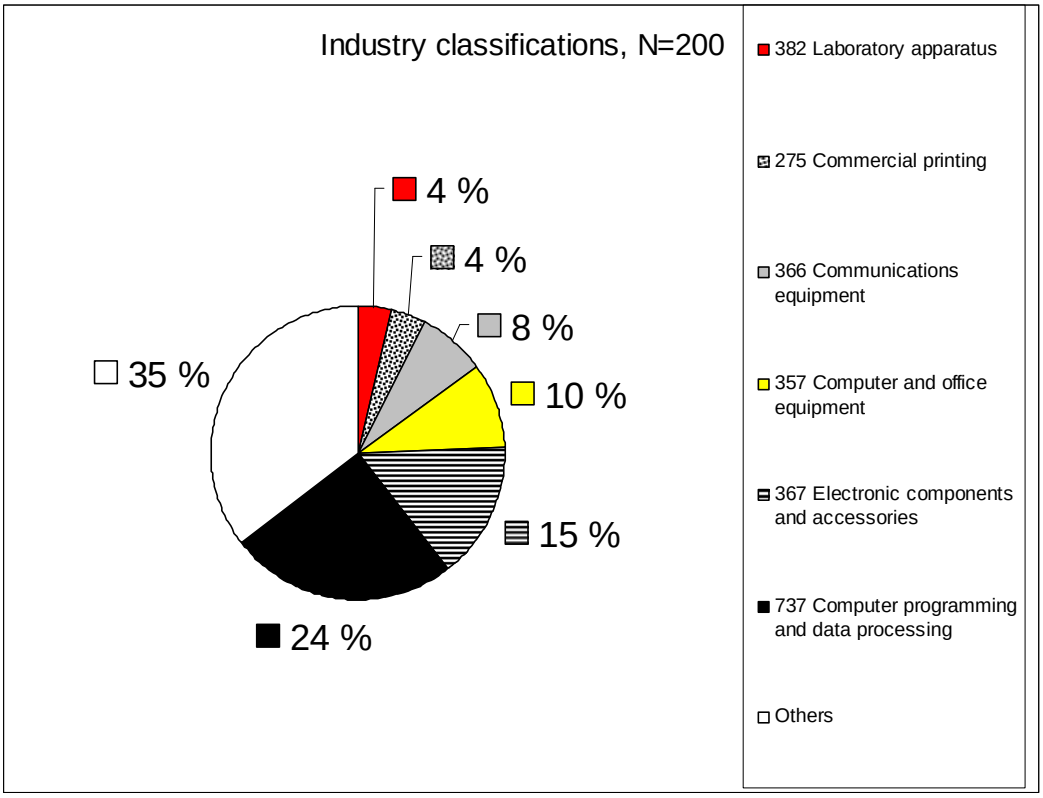

Figure 17: Industry classifications of all firms

It is noteworthy that the four biggest business areas representing 57 per cent of the sample of the firms have ICT related business activity as the company's primary business area. The fifth biggest line of primary business is commercial printing representing four per cent of the sample. The RFID firms are studied further in the respective categories: the vertically integrated players, upstream focused firms, downstream focused firms, and PPI and printing companies.

Vertically integrated firms

While categorizing vertically integrated companies by their number of employees into big players (over 70 000 employees), small players (under 1000 employees), and mid-size ones it was observed that 55 per cent were midsize companies and one third were big players. It is obvious that RFID does not represent a significant portion of the business of the big players.

The biggest segment (20 %) of the vertically integrated firms belonged to computer programming and data processing group (737). The next segments, electronic components and accessories (367) and communications equipment (366) were equal in size (13 %) (figure 18).

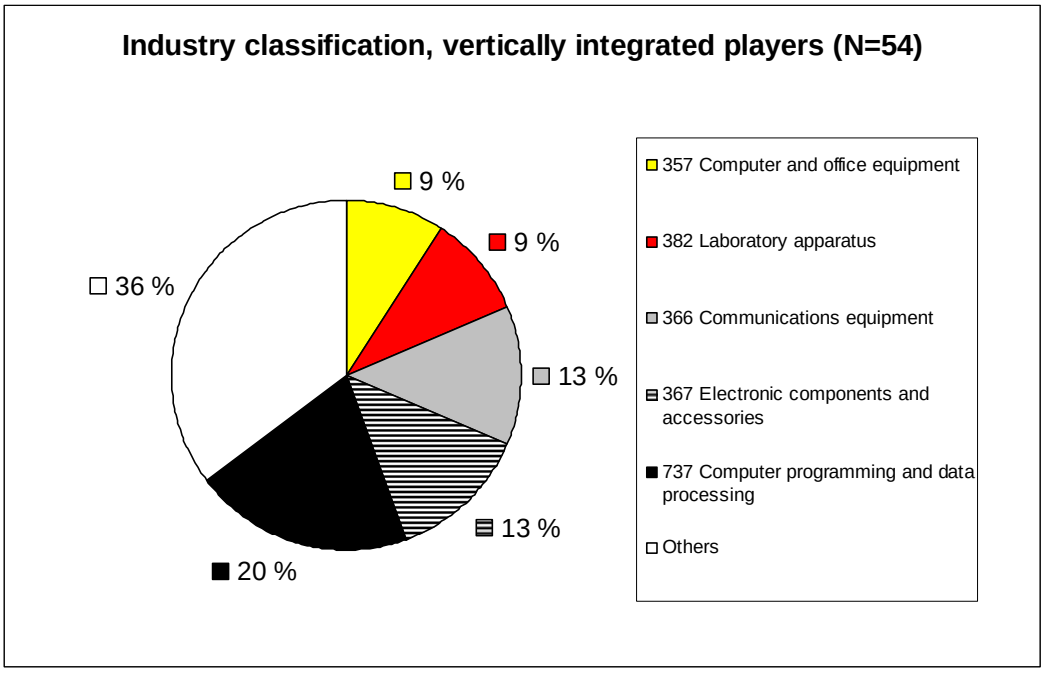

Figure 18: Industry classification of vertically integrated firms

Most of the vertically integrated firms operate broadly within the entire value chain including tags, readers, and software and integration in their offering. Seven firms also have printers in their product assortment. Many of the vertically integrated players are

also very diversified firms; 21 firms of the sample (39 %) had two or more lines of business activity, and 10 firms had five or more areas of business.

According to the interviewed Finnish experts, one of the main driving forces for vertical integration, especially downstream, is that there typically is more value added in the end customer interface than in the beginning of the value chain. However, vertical integration in RFID value chain is challenging. As one industry specialist put it: *"The required competences in the beginning and at the end of the value chain differ completely from one to another."* As a matter of fact, partly because of the lack of the new competences required, upstream or downstream focused firms may seek for scale of economics through horizontal consolidation.

Upstream focused firms

Firms operating at the beginning of the value chain were mainly midsize companies (73 %). Only two firms were large-scale enterprises and five were small players. Electronic components and accessories (367) represented the largest industry classification category (31 %), followed by computer and office equipment (357) (13 %), and commercial printing (275) (10 %) (figure 19).

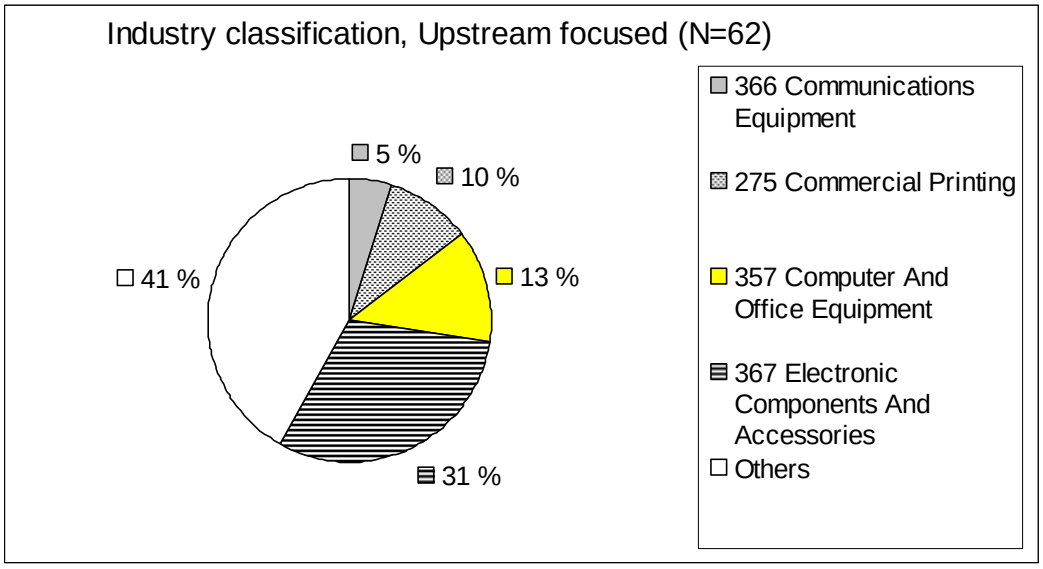

Figure 19: Industrial classification of upstream focused firms

As an exception to the other categories, on top of the ICT related businesses, commercial printing firms represented 10 per cent of the sample. Among upstream focused enterprises 22 companies (35 % of the sample) had two or more lines of business.

Downstream focused firms

Companies operating at the end of the value chain, offering software and integration, are mainly midsize companies (61 %) or large-scale enterprises (25 %). Computer programming and data processing represent the biggest industry classification category (45 %), followed by computer and office equipment (7 %) and communications equipment (6 %) (figure 20).

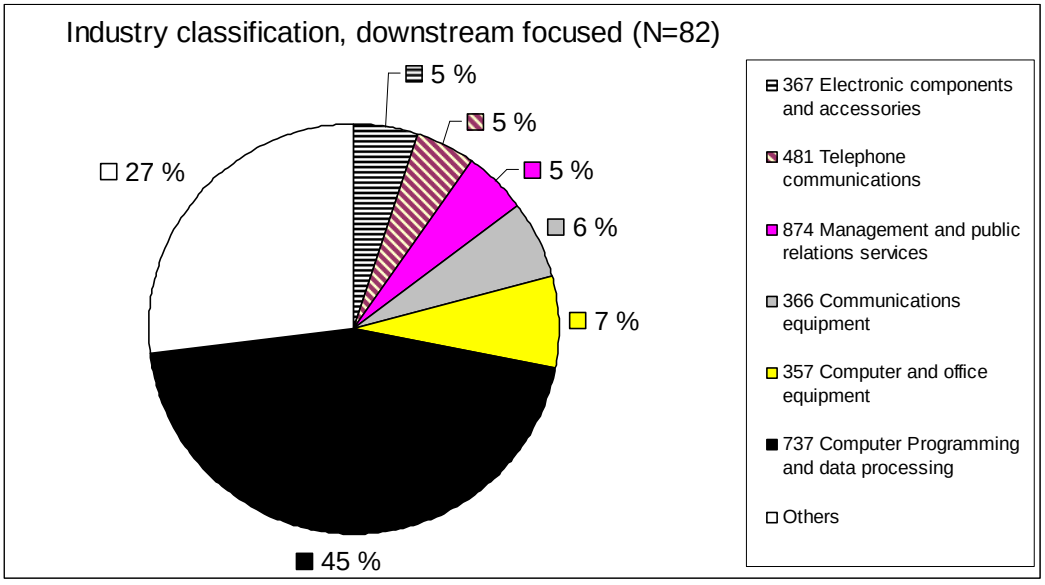

Figure 20: Industry classification of downstream focused firms

Downstream focused players typically had many ICT related business areas. Approximately 45 per cent of the companies (37) had two or more lines of business.

PPI and printing firms

The pulp and paper industry and printing companies were mainly large-scale enterprises; seven out of eight companies were large-scale ones and one was a small player. Commercial printing (275) represented the biggest industry classification category (40 %), followed by paper mills (262) (15 %) (figure 21)

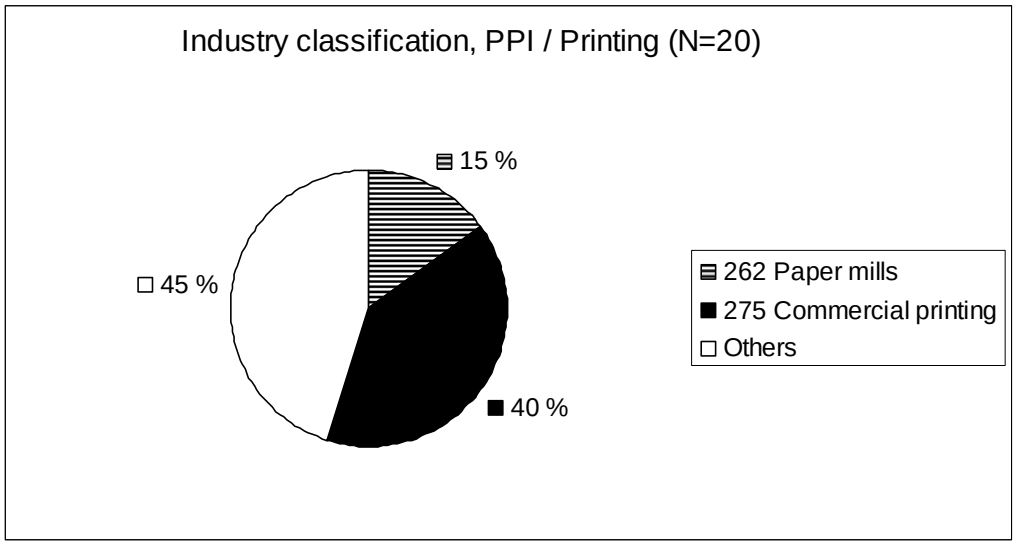

Figure 21: Industrial classification of PPI and printing firms

The sample of PPI and printing firms belongs to the earlier presented categories, mostly into the group of upstream focused firms. The PPI and printing firms were diversified mainly into PPI and ICT sectors. Nine firms (45 %) had three or more different business areas.

6.1.2 Comparative analysis of RFID players

The vertically integrated, upstream focused, downstream focused, as well as the PPI and printing companies are compared on several financial and non-financial factors. The groups of companies are compared by analyzing their average number of employees,

revenue, R&D expenditure and EBIT in 2007. Furthermore, analyses of the development of the above factors and ROIC during the past five years reveal the growth, investments in R&D and profitability development of each company category. Table 12 summarizes the comparisons between the RFID firms.

Table 12: Comparison between RFID firms

	All Firms	Vertically Integrated	Upstream focused	Downstream focused	PPI & Printing
Employees 2007, average (STDEV)	54723 (86001)	75620 (121771)	40188 (74346)	54739 (70932)	30605 (20766)
Employees median	29221	16726	18689	32175	36879
Employee Growth % 5 y	4,9 (11,3)	19,4 (68,6)	3,2 (11,0)	7,4 (10,7)	3,1 (9,3)
Revenue 2007, MEUR	12852 (20652)	15244 (23576)	8073 (14953)	15166 (22562)	6745 (4461)
Median Revenue	3534	1437	3402	5019	8918
Revenue Growth % 5y	11,7 (36,9)	5,7 (12,4)	6,5 (9,3)	18,6 (54,1)	5,1 (7,3)
ROIC % 5 y Average	7,0 (14,1)	12,9 (8,3)	4,3 (11,8)	6,3 (17,1)	6,0 (2,9)
R&D 2007, MEUR	760 (1266)	1080 (1701)	546 (922)	756 (1231)	78 (78)
Median R&D	104	50	82	162	50
R&D % 5 y Average	9,5 (11,5)	11,6 (20,4)	7,7 (6,0)	10,2 (7,1)	1,2 (0,7)
EBIT 2007, MEUR	1304 (3941)	2107 (3297)	354 (675)	1601 (5410)	316 (224)
Median EBIT	160	298	46	198	331
EBIT Growth % 5 y	9,5 (11,5)	11,4 (21,2)	7,7 (6,0)	10,2 (7,1)	1,2 (0,7)

Employees in 2007 and five-year growth

Vertically integrated firms had the highest average number of employees (75 620) in 2007. However, the high standard deviation (STDEV) (121771) reveals that there are few large-scale enterprises and a number of small firms. Upstream focused and downstream focused firms also had a high average number of employees (40 188; 54 739), but high STDEV as well (74 346; 70 932), which reveals these groups as heterogeneous as well. PPI and printing firms, on the other hand, had the lowest average number of employees (30605), but also the lowest STDEV (20766) meaning that this group is the most homogeneous in size. PPI and printing had the highest median figure (36 879), whereas the figures of vertically integrated firms (16 726), upstream (18 689) and downstream focused firms (32 175) were lower. Figure 22 shows the average number of employees in 2007.

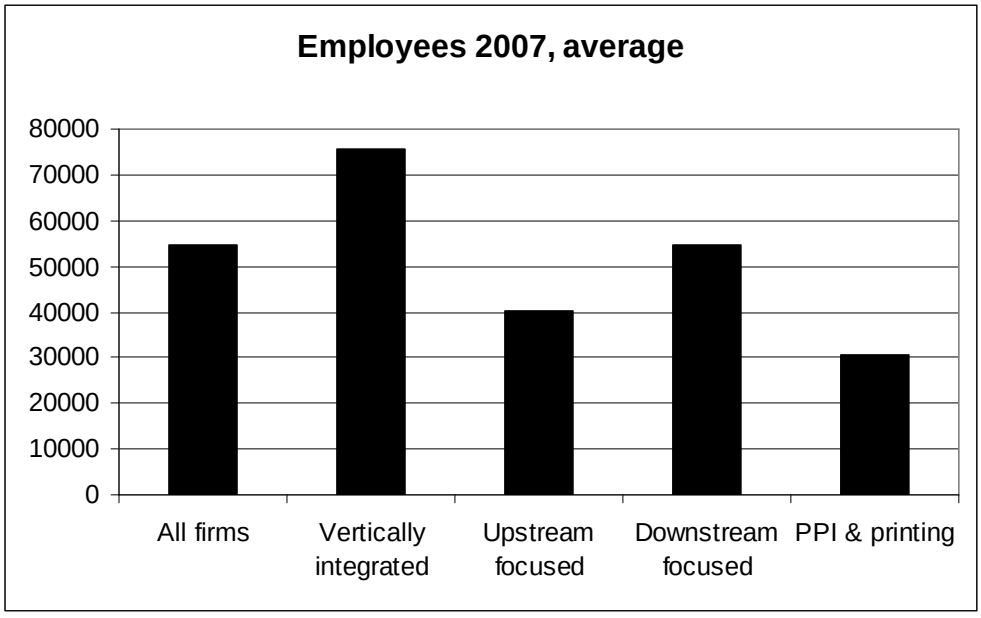

Figure 22: Average number of employees in 2007

The average growth in the number of employees during the past five years had been fastest (19.4 %) among the vertically integrated firms, but high STDEV (68) show significant variation between the companies of this group. The PPI and printing companies

delivered the most modest growth in the number of employees (3.1 %) during the period (figure 23).

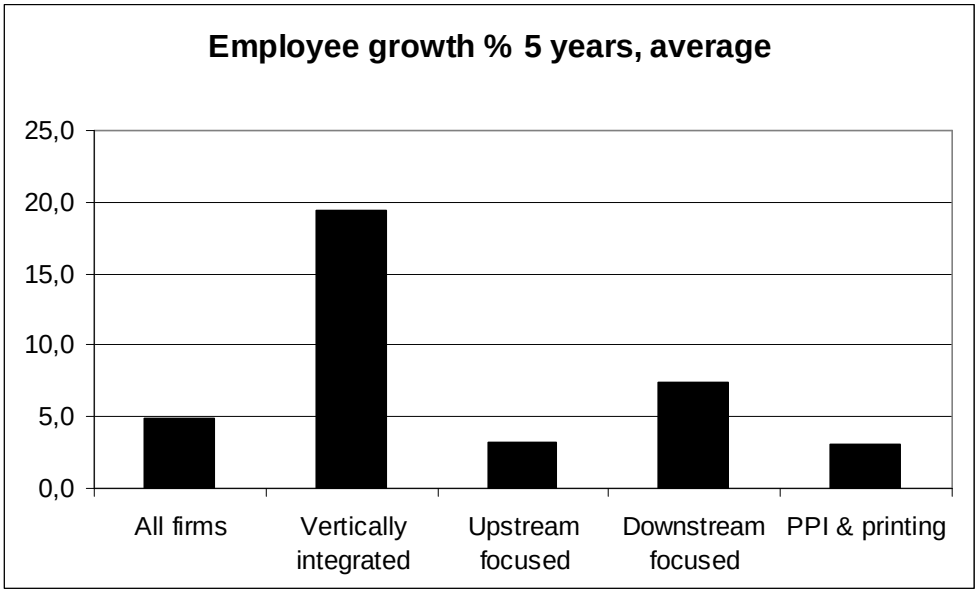

Figure 23: Average employee growth %, 5 years

To sum up, PPI and printing companies are typically large-scale enterprises equal in size, and their number of employees has grown modestly during the past five years. The firms in the other groups, on the other hand, vary significantly in size and growth.

Revenue in 2007 and five-year growth

Average revenues of vertically integrated (15 244 million Euros) and downstream focused firms (15 166) were almost identical in 2007. The average revenues of upstream focused players (8 073) and PPI and printing companies (6 745) were lower. However, the high STDEV of vertically integrated (23 576), upstream focused (14 953) and downstream focused firms (22 562) exposes remarkable variation in the respective group results. Median revenues of vertically integrated, upstream focused, downstream focused and PPI and printing companies were 1 437, 3402, 5019 and 8918 respectively. The results suggest that PPI and printing firms are more equal in size, while there are

few large-scale enterprises in other groups along with a number of smaller firms (figure 24).

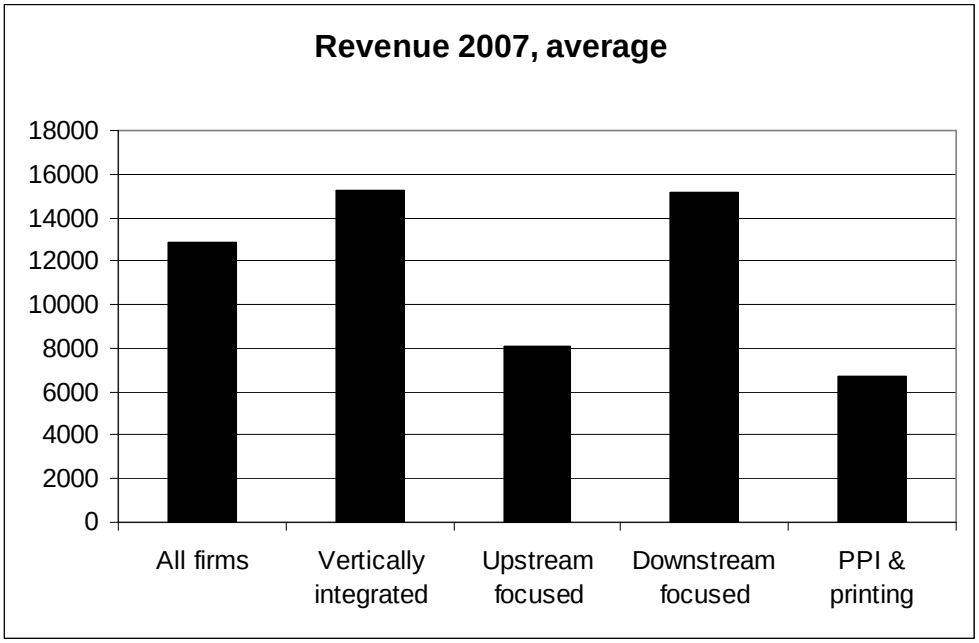

Figure 24: Average revenue (MEUR) in 2007

During the past five years, downstream focused firms had grown most rapidly, with annual average growth of 18.6 per cent. However, STDEV (54) was also the highest of the groups, and this dropped the median growth to 11.7 per cent. Figure 25 illustrates the average revenue growth percentage during the five years.

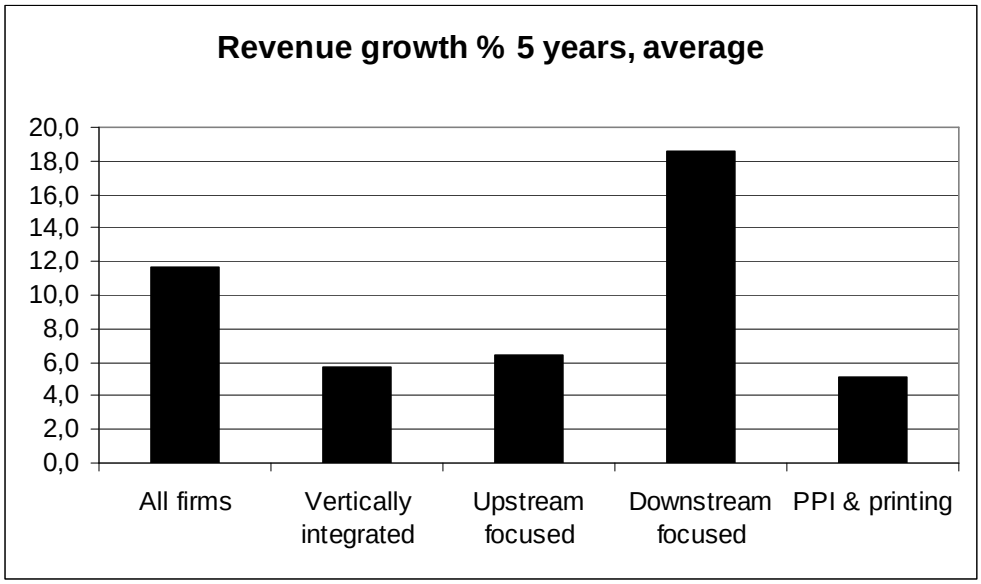

Figure 25: Average revenue growth %, 5 years

The revenue figures confirm that PPI and printing firms are large-scale enterprises rather equal in size, and are growing slowly. In the other categories, the companies are significantly different in size and their growth also varies remarkably from one to another.

Return on invested capital

Vertically integrated firms have had the highest return on invested capital during the past five years. Their average ROIC % was 12.9, while it was significantly lesser in the other groups. Upstream focused firms' ROIC % was 4.3, downstream focused ones' 6.3, and PPI and printing firms' 6.0 (figure 26).

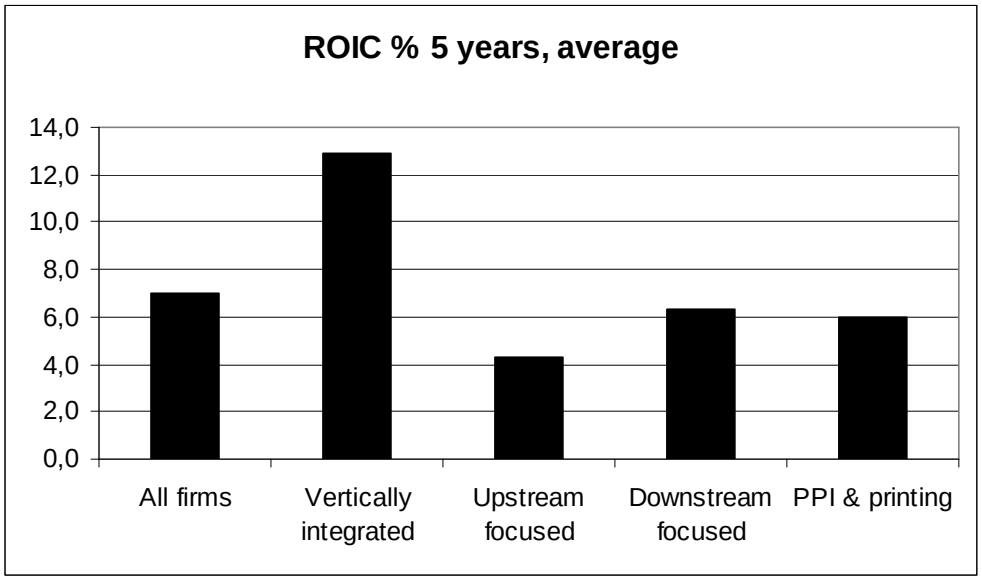

Figure 26: Average ROIC %, 5 years

The results suggest that the profitability of the vertically integrated firms is significantly higher than that of the other groups. The other alternative could be that the own capital of the vertically integrated firms is in average lesser than the invested capital of the other groups.

Research and development

The vertically integrated players had the highest average R&D expenditure (1080 million EUR) in 2007. The average R&D expenses of upstream focused (546) and downstream focused firms (756) were also substantial, whereas PPI and printing firms spent considerably less (50) in R&D. STDEV for vertically integrated (1701), upstream focused (922) and downstream focused firms (1231) were also high exposing significant variation within the groups. The median R&D figures of vertically integrated (50), upstream focused (82), downstream focused (162), and PPI and printing firms (50) were considerably more equal. Figure 27 illustrates the average R&D expenditure in 2007.

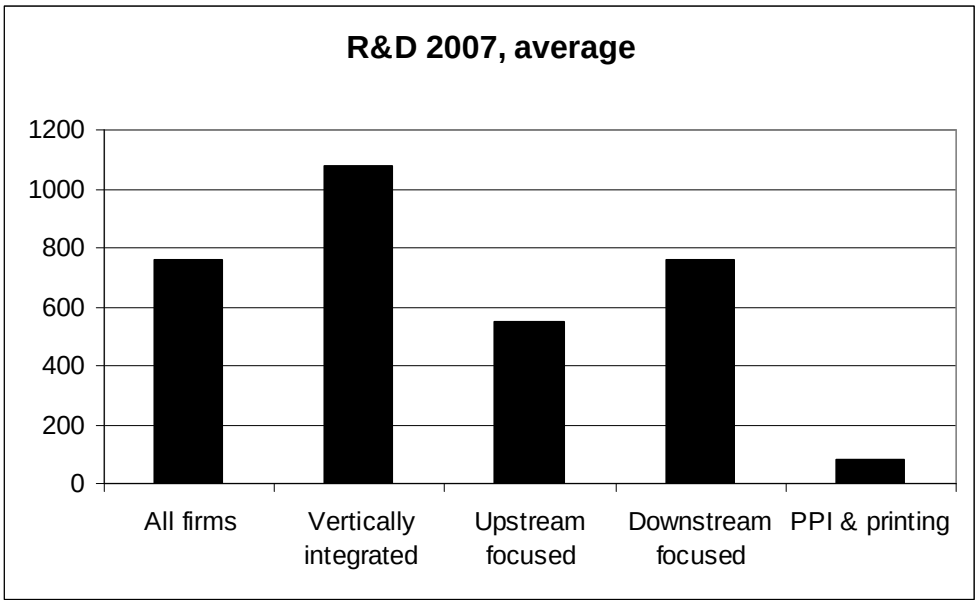

Figure 27: Average R&D expenditure (MEUR) in 2007

The PPI and printing companies invested significantly less in R&D than the companies in the other groups. The PPI and printing firms also spent rather equal sums in R&D, whereas the variation within the other groups were outstanding partly due to considerable differences in company sizes.

Average R&D % of the company's net sales during the past five years was highest (11.6) for the vertically integrated firms. The proportional R&D expenditure was rather similar for upstream focused (7.7) and downstream focused firms (10.2). During the five-year period the PPI and printing companies had invested just tiny portion (1.2) of their net sales into R&D. Figure 28 shows the average R&D percentage in the five-year period.

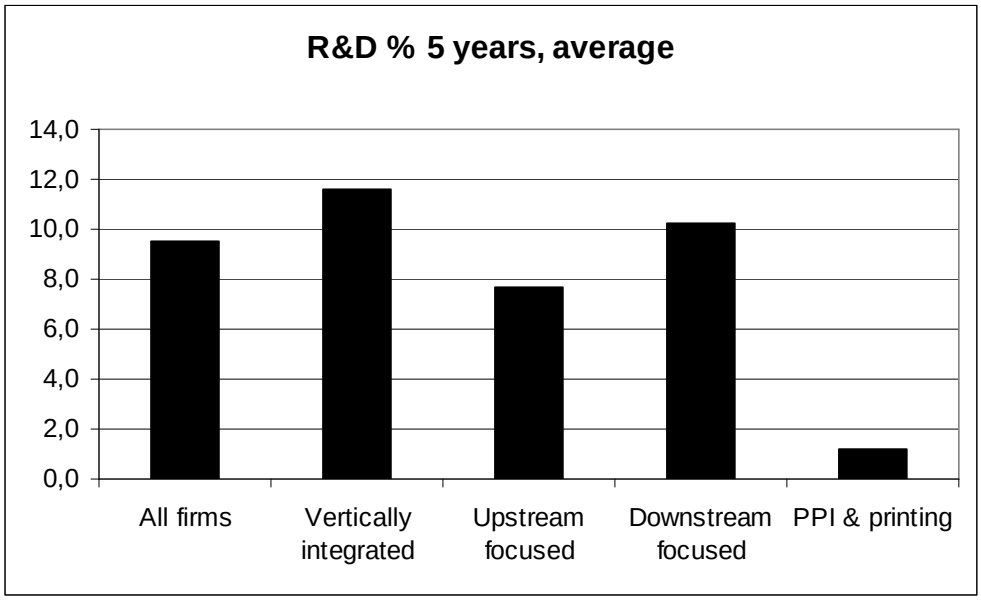

Figure 28: Average R&D %, 5 years

The relative R&D expenditure of the PPI and printing firms differs entirely from the R&D activities of the other companies, which relative investments are significantly higher. A considerable number of the studied companies have ICT related business as the company's primary business area. The ICT industry tends to compete through fundamental product innovations, and typically has high patenting and R&D intensity. PPI typically compete with optimising price and quality ratio, incremental process innovations, and low patenting and R&D activities.

Earnings before interest and taxes

Vertically integrated players had the highest average EBIT (2107 million EUR) in 2007 followed by downstream focused players (1601). The average EBIT of upstream focused (354), and PPI and printing firms (316) were considerably lower. High STDEV of vertically integrated (3297), upstream focused (675) and downstream focused firms (5410) reveal remarkable variation between companies. Median EBIT of vertically integrated (298), upstream focused (46), and downstream focused firms (198) confirm the variation in profitability. Median EBIT of PPI and printing companies was 331. Average EBIT in 2007 are shown in figure 29.

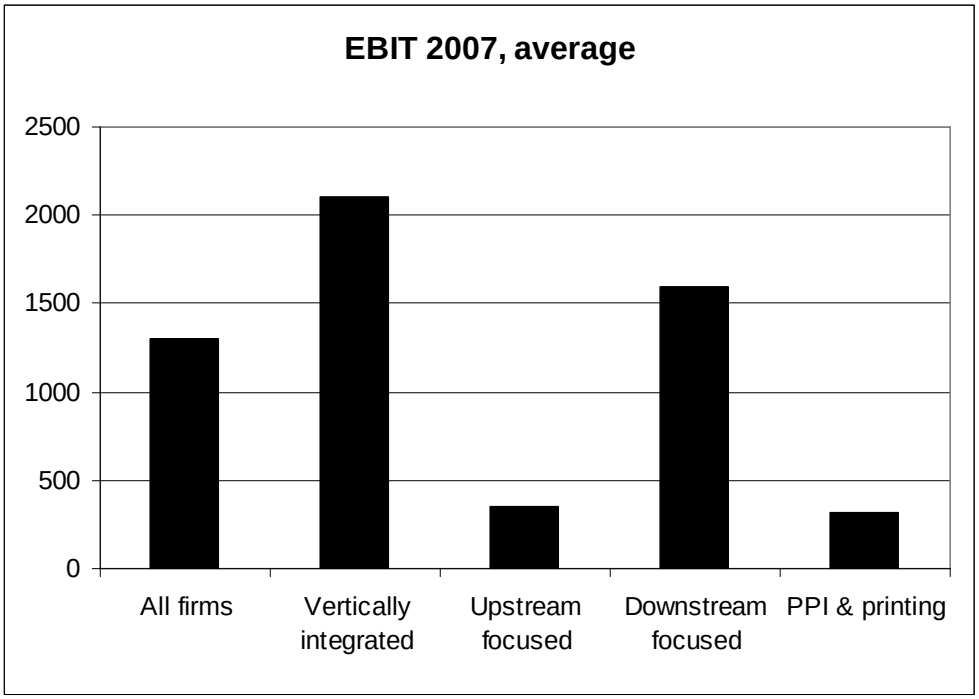

Figure 29: Average EBIT (MEUR) in 2007

During the past five-years, the EBIT of vertically integrated firms has grown most rapidly (11.4 %). The EBIT growth of upstream focused (7.7 %), and downstream focused firms (10.2 %) was almost as intense, whereas the EBIT of PPI and printing companies grew only by 1.2 per cent annually. Low STDEV figures suggest that the growth within the groups was rather equal. Figure 30 illustrates the EBIT growth during the five-year period.

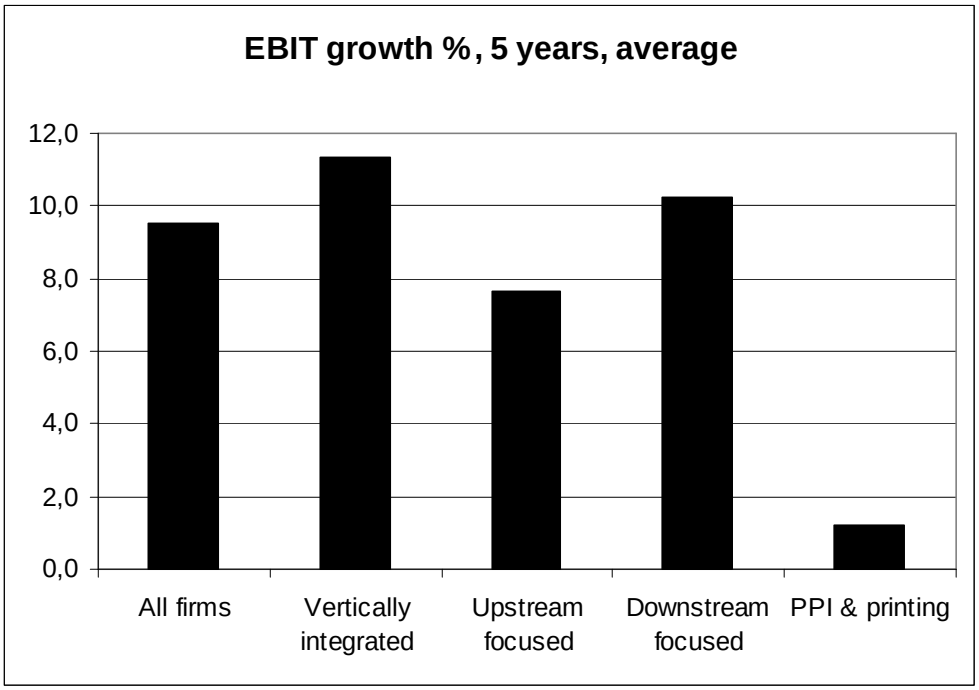

Figure 30: Average EBIT growth %, 5 years

Both the EBIT in 2007 and the growth figures confirm that the average profitability of PPI and printing firms is lower and the development significantly weaker than those of the other companies.

All in all, the age distribution of the sample of firms was rather equal with the exception of PPI and printing firms that were mostly founded much earlier than the other firms. Majority of the firms within the industry had ICT related business activity as their primary business area, and the biggest single PPI related business activity represented just four per cent of the sample. Vertically integrated and downstream focused companies were the largest ones, although there was significant variation in the groups, whereas PPI and printing group was the most homogeneous one. Vertically integrated and downstream focused enterprises had also grown most rapidly and they were more profitable than the firms in the other groups. However, it can be determined that some of the studied companies had grown not only through organic growth, but also by mergers and acquisitions. Furthermore, it is noteworthy that some of the firms are diversified large-scale corporations, and RFID represents just a tiny part of their business activity. PPI

and printing firms had modest growth in the past years, their profitability was inadequate, and R&D expenditure significantly smaller than with others.

6.2 Typical key players

The most significant firms in the industry operate typically either broadly in the value chain or are focused in the upstream of the chain in specific segments like identifiers and devices or operate in the downstream in software and integration. Most of the key players are publicly listed companies; some of them diversified global giants, but small and medium size enterprises (SME) specialized into RFID also exist. It is worth mentioning that for instance such major corporations like IBM, Intel and Nokia operate vertically in the value chain. Hitachi, Motorola and NXP Semiconductors are upstream focused firms, and Accenture, AT&T, BT, HP, Microsoft and Oracle are downstream focused companies. However, for these corporations RFID usually represents just a tiny portion of their revenue, and thus adequate information about their RFID business is scantly available. Some of the typical, mostly midsize key players are presented as follows.

6.2.1 Vertically integrated firms

Intermec

The company was formed in 1966 under the name Interface Mechanism. During the decades, Intermec's business focus has changed from manufacturing systems for automotive and aerospace industries to mobile computing and data collection technologies. The ownership and name of the company has likewise changed in the past. By acquiring IBM's RFID semiconductor business in 1997, Intermec moved into identification business, which was further reinforced by acquiring Amtech Corporation's HF RFID division in 1998. The company employed 2300 people in 2007, and the turnover was 850 million US dollars (USD), about half of which came from North America. Intermec's product range includes RFID tags, smart labels, fixed and mobile readers, antennas,

printers and software. The company also has bar code devices, computers and OEM products in its offering. In order to complement its supply, Intermec collaborates with partners such as Cisco, IBM, Oracle, SAP and Microsoft, which secure seamless product integration for customers. Leadership in the chosen strategic business areas requires leadership in the respective key technologies. Intermec's R&D expenditure during the past years has been about 70 million USD (9% of sales) annually. Investments in technology are secured by intellectual property (IP) protection, and the company has obtained almost 600 patents and trademarks. In addition, the company makes use of others' IP by having presently agreements with 24 licensees, and thus holding more than 150 external patents. (Intermec 2008)

Tagsys RFID

The company was founded in 1996 and incorporated in 2001. Tagsys has 120 employees worldwide, and offices in the USA, France and Hong Kong. The company manufactures HF and UHF tags, readers and antennas and also provides software for a variety of industries. During over a decade Tagsys has served over 500 customers in about 40 countries with the help of its global partner network providing vertical expertise. Item level design competency is one of the core competencies of the company, and pioneering innovations have lead to over 40 existing patents and almost 30 pending ones. The company is funded by several venture capital firms as well as other investors. (Tagsys RFID 2008)

Zebra

Zebra Technologies was incorporated in 1969, net sales were about 760 million USD in 2006, and it had 2800 employees. The company is a global provider of various types of printers including RFID and bar code printers. Zebra changed its focus to specialty labeling and ticketing systems, and entered into bar code business more than 20 years ago. RFID printers extended its offering a few years later. Today, Zebra's international sales and distribution network covers over 90 countries. Heretofore over six million printers have been sold and more than 90 per cent of Fortune 500 and global 2000 com-

panies are using the company's products. In addition to printers, Zebra provides for instance software and networking for its customers. (Zebra 2008)

6.2.2 Upstream focused firms

Alien Technology

Alien Technology Corporation was founded in 1994, and today it is a privately held company funded by venture capital. The company product and service offering includes RFID tags and readers as well as training and consultancy. Alien's products are sold mainly to consumer goods suppliers and retailers, transportation companies, government defense department and life sciences such as hospitals and laboratories. Typical application areas cover supply chain, brand authorization and asset tracking, and new application areas are regularly emerging. The company holds numerous patents for identifiers, devices and RFID protocols. It operates on four continents, and has a significant partner network consisting of firms that either complete the company offering or operate as merchandisers. (Alien Technology 2008)

Assa Abloy

Assa Abloy is one of the world leading companies providing door opening solutions. The company was founded in 1994, and today the global group employs about 32 000 people and has sales worth about 3.5 billion Euros (EUR). Hughes Identification Devices (HID) was formed in 1991, and was acquired by Assa Abloy in 2000 and later in 2002 it became part of Assa Abloy Identification Technology Group (ITG). Today Assa Abloy's secure identity solutions are concentrated into the HID Group that manufactures RFID tags, readers, antennas and smart cards, and integrates its offerings into parent group's door opening solutions as well as sells its products to external customers. In addition to RFID, the company also uses such technologies as magnetic stripes and biometrics in its products. HID group has grown rapidly partly because of several acquisitions executed during the past years. Products are sold under brand names such as

HID, Integrated Engineering, Fargo, Sokymat, ACG and Omnikey. HID has over 2000 employees in over 100 countries worldwide, and its sales in 2007 were worth 5 billion SEK (550 million EUR). The company is seeking further growth by introducing new products and investing into growing markets, with special attention on the Asian region. In order to make sure that its products would be compatible with many different types of technologies and various standards, HID has successfully collaborated with software provides such as Microsoft. (Assa Abloy 2008)

6.2.3 Downstream focused firms

Certicom

Certicom was founded in 1985, employs about 120 people today. Its headquarters is in Canada and there are offices in the USA and Europe as well. The company offers security solutions to protect the value of the customers' content, applications and devices. Certicom has developed innovative security solutions for approximately 20 years, and holds over 450 patents and patent pending worldwide at the moment. The company is a market leader in Elliptic Curve Cryptography, and today, the company's security offerings are licensed to more than 300 customers including a number of world-class corporations. Certicom claims to posses one of the most capable R&D teams in the industry, but the company also collaborates with partners for instance from semiconductor, hardware and software industries as well as with universities. (Certicom 2008)

SAP

The Systems Applications and Products in Data Processing company (SAP) was established in 1972. During the past three decades SAP has evolved from a regional enterprise to an international corporation employing over 51 400 people today, and with more than 43 400 customers in over 120 countries. The company net sales in 2007 were approx. 7.44 billion EUR, and the company claims to be the world's leading business software provider. The company's RFID solutions are divided into three components:

Auto-ID Infrastructure, object event repository and Event Management. Auto-ID converts the data from local devices into meaningful business events. Object event repository supports applications that need visibility between company sites, or between enterprises, by using the Electronic Product Code (EPC) Information Services standard. Event Management leverages Auto-ID data to identify and manage exceptions in processes providing the real time tools for management to respond to events as they happen. SAP's RFID customers include aerospace, defense and automotive industries as well as consumer products and life sciences. (SAP 2008)

6.2.4 PPI and printing firms

Avery Dennison

Avery Dennison was established in 1935, and today it employs over 30 000 people in more than 60 countries and 150 locations. It has a turnover of 6.3 billion USD, two thirds of which come from North America and Western Europe. During the past decades the company has grown through mergers and acquisitions; the largest in the company history took place in 2007, when Paxar was acquired. The company's businesses are divided into pressure-sensitive materials, office and consumer products, and retail information services. RFID products include RFID-enabled label stock, printed RFID labels and information management services. Among other emerging business areas, RFID is considered a lucrative growth area. Company products are sold world wide to about 90 countries under for instance Avery and Fasson brand names. Innovative company culture has been one of the core values all through Avery Dennison's history, and has lead to several breakthrough innovations. The key technologies have earned the company a reputation of an innovative industry pioneer, and they comprise of different competencies for example in adhesives, high-speed precision coating, printing and RFID. Due to advanced R&D, and the know-how in electronics and roll to roll manufacturing, the company was the first to develop a high volume, high yield manufacturing process for RFID inlays. The company is a leading innovator in passive RFID inlays and labels, and has expertise also in developing orientation insensitive products as well

as combining antennas and silicon chips efficiently with the assistance of advanced assembly technology. (Avery Dennison 2008)

Toppan Printing

Toppan Printing was founded in 1900, and comprises today of more than 170 group companies, each of which specialize in unique competitive capabilities and utilize their particular networks by serving customers. The company is divided into seven business areas: securities and cards, commercial printing, publications printing, packaging, industrial materials, electronics and semiconductors. Toppan Forms is one of the group subsidiaries, and was established in 1955. The businesses of the company include business forms, data print service, e-business, RFID and smart cards, forms processors, office supplies and equipment. Net sales of Toppan Forms in the fiscal year, which ended end of March 2008, were worth 2.3 billion USD. RFID products made by Toppan Forms are for example smart cards and tags. The company is also developing RFID readers, and aiming at a system integrator and software vendor on the growing RFID market. The aim of the company is to become a dominant player in the digital media. The company's turnover in the fiscal year 2008 in digital media including RFID and e-business was over 80 million USD. (Toppan Printing 2008)

UPM Raflatac

As part of UPM, one of the world's leading forest products companies, UPM Raflatac employs 2700 people today and has annual sales of one billion EUR, from which about two thirds came from European markets. The company is a global supplier of self-adhesive label stock and RFID tags and inlays. UPM Raflatac has global customer service network including 11 manufacturing units on five continents. RFID products are produced in the USA and Finland, where the production capacity was recently doubled in order to respond to an increased worldwide demand. In addition, the company will also start production of RFID identifiers in China in the latter half of 2008. In RFID SBU the company has specialized in cost-effective high-volume production of high-quality HF and UHF tags and inlays. Typical application areas include supply chain

management (SCM), pharmaceutical, health services, libraries, product brand protection, transportation and ticketing. UPM Raflatac collaborates with leading industry partners in the value network consisting of partners such as device and IC suppliers, machine manufacturers, software companies and system integrators. (UPM Raflatac 2008)

As a whole, in order to complement their own competences and areas of business, virtually all key players collaborate with other companies. Alien Technology seems to possess the most extensive partner network completing the company offering or acting as its merchandiser. Intermec and Zebra had made strategic shifts by changing their focus and entered RFID business, Intermec by acquiring a company in the area of business and Zebra through entering the barcode business. Other companies have also grown through acquisitions, and Assa Abloy has been one of the most active ones by acquiring RFID specialized companies. Toppan Printing has announced its desire to become a dominant player by aiming at a system integrator and software vendor in RFID, and this could hardly take place without acquisitions. Alien Technology, Avery Dennison, Certicom and Intermec hold myriad patens for identifiers, devices and RFID protocols. Avery Dennison relies on their own innovative in-house culture, whereas Alien Technology and Intermec also make use of others' IP, and thus to some extend utilizing the open innovation paradigm. Alien Technology is an intense marketer, providing consultancy, and trains specialists in its own academy and thus puts RFID on the map. Among other things, UPM Raflatac develops its processes in order yet to improve its cost efficient R2R production methods.

6.3 Expert views about industry development

The interviewed Finnish experts shared the view that today’s fragmented RFID industry will be concentrated on the future. Most probably large-scale players already within the industry lead the development and acquire innovative small and medium size firms. Both vertical integration, especially downstream towards end customers, and horizontal consolidation will be witnessed. Typically, there are more value added and bigger busi-

ness opportunities at the end of the value chain than in the beginning of the chain and thus many vertically integrating firms are striving towards end customer interface. However, it is noteworthy that the necessary competences in the beginning and end of the value chain differ significantly from one to another. This causes challenges for those enterprises that seek vertical growth. On the other hand, those enterprises that have made the strategic choice to grow horizontally exploit their present competences and strive to benefit from economics of scale.

From end customer point of view logistics, sufficient return on investments and large-scale chain of stores are the key driving forces of the industry development. Furthermore, large-scale customers prefer to co-operate with fewer and bigger vendors. One alternative for the industry evolution along with mergers and acquisitions is also deeper collaboration and partnerships within companies. One interviewee mentioned: *"It is not necessary to do everything by oneself, but to collaborate and provide complete offering to end customers, since especially bigger customers prefer to purchase turn-key projects from large-scale vendors."* Table 13 illustrates the Finnish specialists' views about the value chain development.

Table 13: RFID value chain development

Interviewees	Issue areas Vertical integration vs. horizontal consolidation
Person 1 Project manager, academic	No opinion.
Person 2 Marketing director, ICT company	**Consolidation is likely.** "Specialization into different segments may occur. New firms may though still enter the industry."
Person 3 Professor, academic	**Consolidation is likely.** "The value chain will be streamlined. Large-scale customers want to operate with large-scale vendors. Smaller specialized service firms may though evolve or enter the industry."
Person 4 Director, forest company	**Consolidation is likely.** "Global players are necessary for the worldwide expansion of the industry."
Person 5 Research director, academic	No opinion.
Person 6 Manager, forest company	**Vertical integration towards end customers probable.** "In software and integration exist more value added than in the beginning of the value chain."
Person 7 Vice president, forest company	**Both horizontal consolidation and vertical integration exist.** "Horizontal consolidation is driven by scale of economics, vertical integration by bigger value added within end customer interface."
Person 8 Entrepreneur, ICT company	**Both horizontal consolidation and vertical integration exist.** "New service concepts may also evolve."
Person 9 Project manager, academic	**Consolidation is likely.** "Today it is common that a bigger firm wins the tender, which is then subcontracted to smaller specialized vendors. Bigger players are likely to acquire smaller innovative firms."
Person 10 Director, ICT company	**Both horizontal consolidation and vertical integration exist.** "Bigger players probably acquire smaller innovative firms. End customers insist strategic partners, with whom to execute their RFID projects. Required competences in the beginning and end of the value chain differ considerably from each other."
Person 11 Technology manager, ICT company	**Both horizontal consolidation and vertical integration exist.** "Horizontal acquisitions reinforce company business, vertical integration extends the offering. Large-scale enterprises dominate and acquire smaller innovative firms. Alliances and collaboration also increase within the industry."
Person 12 Team leader, academic	**Vertical integration towards end customers probable.** "More value added exists with software and integration. Large-scale end customers prefer to purchase from fewer large-scale vendors."

As a conclusion, the fragmented industry will be concentrated and as a result, established large-scale firms will lead the development. Some firms might also specialize in different niche segments. Large-scale customers prefer to operate with strategic partners that support the concentration. World-class players are also necessary for effective global expansion of the industry. The value chain will be streamlined, but there is also space for new service innovations and new entrants.

6.4 Summary of the key issues

The most essential findings concerning the RFID industry development are summarized in this chapter. To some extend the interpretations may lead to simplifications, but on the other hand the results provide an overall impression about the interviews.

Most of the interviewees shared the opinion that RFID market is going to evolve slower than the most optimistic analysts' estimates. Large-scale wholesalers and logistics are driving the development, whereas lacking industry infrastructure may hinder the evolution. (Table 14)

Table 14: RFID market evolution, drivers and hindering factors

Interviewees	Issue areas and statements		
	RFID market develops rapidly during the next decade	**Large-scale wholesalers & logistics are industry drivers**	**Lacking infrastructure hinder development**
Person 1 Project manager, academic	Yes	Yes	Yes
Person 2 Marketing director, ICT company	No	Yes	Yes
Person 3 Professor, academic	No	Yes	Yes
Person 4 Director, forest company	No	Yes	Yes
Person 5 Research director, academic	No	No opinion	Yes
Person 6 Manager, forest company	No	Yes	Yes
Person 7 Vice president, forest company	No	Yes	Yes
Person 8 Entrepreneur, ICT company	No	No	No
Person 9 Project manager, academic	Yes	Yes	Yes
Person 10 Director, ICT company	Yes	No	No
Person 11 Technology manager, ICT company	No	No	Yes
Person 12 Team leader, academic	Yes	Yes	Yes

The interviewees were almost unanimous in their opinion that electronic and optical codes are going to co-exist for long time still. Environmentally friendly paper as RFID tag substrate will eventually probably substitute plastic in spite of the fact that there still are technological challenges, especially, while combining paper with printed RFID. However, it will still take long before printed RFID will replace conventional silicon chip technology from RFID tags. (Table 15)

Table 15: RFID vs. barcodes, RFID tag substrates and technology

Interviewees	**Issue areas and statements**		
	RFID and barcodes co-exist	**Paper substrate replaces plastic**	**Conventional chip technology dominates**
Person 1 Project manager, academic	Yes	Yes	Yes
Person 2 Marketing Director, ICT company	Yes	No opinion	Yes
Person 3 Professor, academic	Yes / No	No opinion	Yes
Person 4 Director, forest company	Yes	No opinion	No opinion
Person 5 Research director, academic	Yes	Yes	No opinion
Person 6 Manager, forest company	Yes	Yes / No	Yes
Person 7 Vice president, forest company	Yes	Yes	Yes
Person 8 Entrepreneur, ICT company	Yes	Yes	Yes
Person 9 Project manager, academic	Yes	Yes	Yes
Person 10 Director, ICT company	Yes	No opinion	No
Person 11 Technology manager, ICT company	Yes	No opinion	Yes
Person 12 Team leader, academic	Yes	Yes	No

RFID value chain is going to concentrate in the future, and vertical integration, especially towards the end customer interface, as well as horizontal consolidation will be witnessed. Large-scale customers operate with large-scale vendors, and the big players together with concrete customer benefits are the true industry drivers. Eventually, printed RFID manufactured by efficient R2R-manufacturing method is probably going to gain market share, and low-cost item-level RFID tagging could lead to peak in the industry sales. However, the present world economic recession is likely to delay the industry evolution for some time. (Figure 31)

The stars in the figure 31 illustrate positive phenomena that are likely to increase the volume of the RFID industry, and they probably also add the lucrativeness of the industry from paper industry's point of view. The red triangles in the figure, on the other hand, are factors that are likely to hinder the bandwagon of the fast emergence of the RFID industry. The stars and triangles in the figure are placed roughly in the period of the next decade, when their influence is estimated to be the most extensive, or when the influence is expected to begin to increase or decrease significantly.

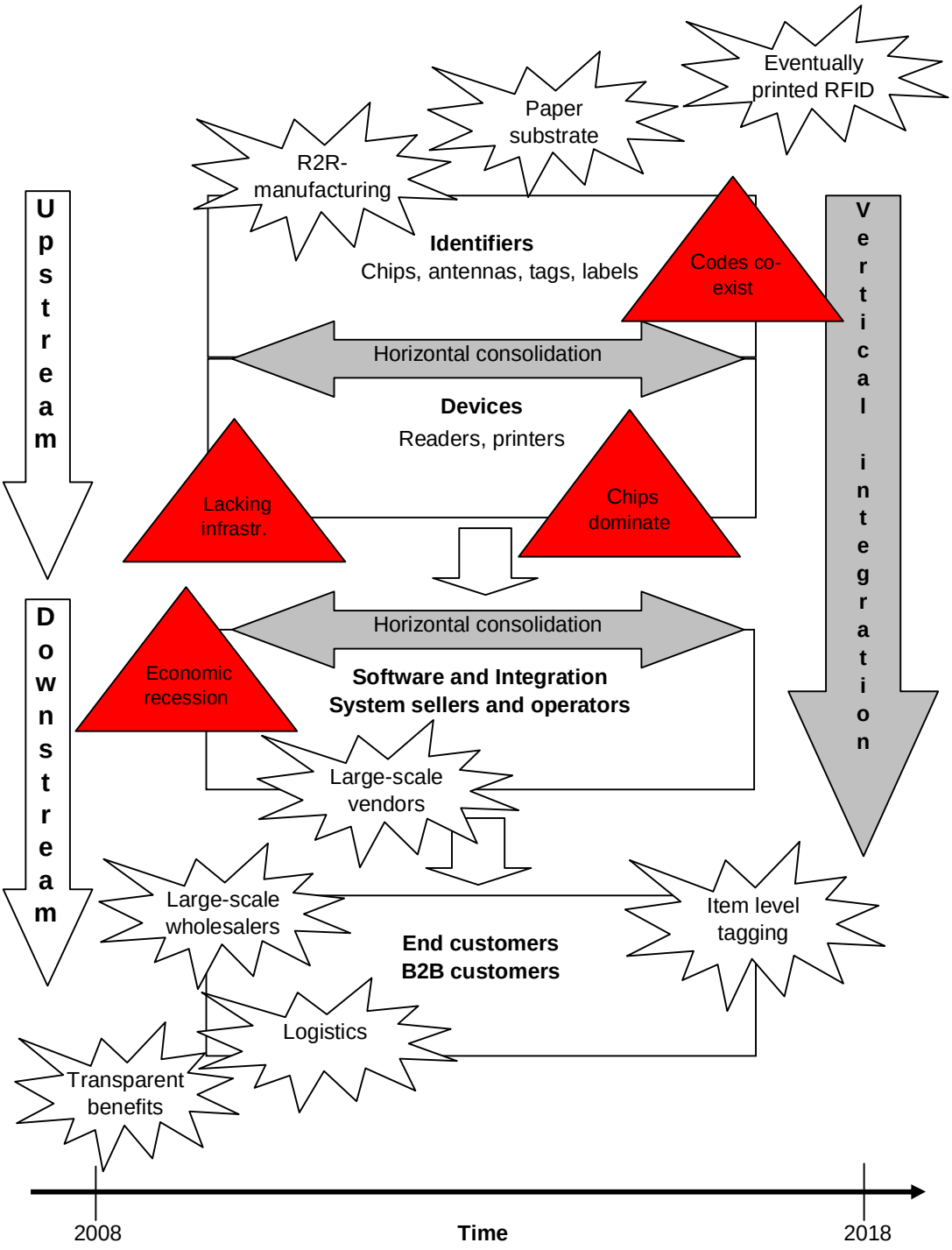

Figure 31: RFID value chain development

7 Future opportunities for paper industry

Opinions of the interviewed Finnish specialists related to the future opportunities that RFID could provide for paper industry are reviewed in this chapter. Furthermore, future visions for paper industry are composed.

7.1 RFID benefits for paper industry

The paper industry has to restructure its core businesses before entering novel business areas. Scale-intensive pulp and paper industry face challenges, while possibly entering ICT related RFID industry. According to the interviewed Finnish experts, PPI possess principally different competences that are typical for successful entering into RFID industry. Scale-intensive PPI and science-based ICT industries have significantly different characters, and due to path dependence, it will be challenging for PPI to quickly obtain the required competences in some other way than by acquiring them or collaboration with other firms. Efficient R2R manufacturing process is one of the key competences of PPI and this production method is cost efficient also, while manufacturing RFID identifiers. However, the volume of RFID tags demanded in the near future does not require many mass production sites, and thus the production equipment has to be adjusted accordingly.

According to specialists, paper industry has business potential for instance by integrating intelligent packaging and RFID, but until now the industry, without few exceptions, has not largely entered printed intelligence and RFID industry. In fact, like one interviewee mentioned: *"The forest industry is suspicious about the potential printed functionality could offer, and may consider the industry more as a threat than an opportunity."* The majority of the interviewees shared the opinion that RFID industry could not alone offer living for paper industry, since the market potential at least in the near future is not adequate. However, paper industry could enter into the novel industry and form RFID and printed intelligence as a new strategic business unit (SBU). (Table 16)

Table 16: RFID benefits for paper industry

Interviewees	Issue areas The attractiveness of RFID industry to paper industry
Person 1 Project manager, academic	**Paper industry has not notably entered the industry.** "Scale-intensive PPI need new competences to enter ICT related RFID. Finland possesses potential due to strong ICT and forest industries. R2R manufacturing capabilities may not become an important factor."
Person 2 Marketing director, ICT company	**RFID offers opportunities for paper industry.** "PPI may enter into downstream of the value chain. However, volumes and profits might not be lucrative enough. New competences are required in case entering the industry."
Person 3 Professor, academic	**To invest into global growth in primary business or enter into novel businesses.** "New competences and radical innovations required if entering in RFID. Basic business should be streamlined before investing into novel products."
Person 4 Director, forest company	**If enter is seen as a strategic alternative, acquisitions can be considered.** "First the basic business has to be healthy, and then invest into novel products. Entirety can be controlled by collaboration and subcontracting, not only manufacturing by oneself."
Person 5 Research director, academic	**Paper industry considers the new industry as a threat rather than an opportunity.** "PPI might be interested in RFID, but the concern is related to volume and profitability it could offer. Bioenergy, intelligent packaging and building materials offer options."
Person 6 Manager, forest company	**RFID should provide sufficient business potential.** "PPI needs to acquire new competences. The volumes do not call for R2R production competences."
Person 7 Vice president, forest company	**RFID do not offer big volumes, although growth is lucrative.** "New competences can be obtained through acquisition or collaboration. R2R technology provides required cost efficiency, but the volumes do not yet require it."
Person 8 Entrepreneur, ICT company	**Paper industry might not necessarily realize the benefits of RFID.**
Person 9 Project manager, academic	**Integrating e.g. intelligent packaging and RFID could provide business potential.**
Person 10 Director, ICT company	**Paper industry could invest into RFID and thus create a new SBU.** "PPI can not close down paper mills and invest in RFID only; potential is not adequate. New ICT related competences are required in case entering into the industry."
Person 11 Technology manager, ICT company	**The new industry does not offer adequate potential.** "PPI survives by restructuring its core business, not by entering into new industries."
Person 12 Team leader, academic	**RFID and printed intelligence interests paper industry.** "However, potential should be big enough before investments can be expected. New competences are required through acquisition or collaboration."

Pulp and paper industry is a mature industry, which has based its strategies mainly on new production technology and scale of economics. Inevitably, the industry has to continue to increase its productivity also in the future, but these actions are not adequate enough, because the industry is in the middle of structural changes and is facing new challenges ahead. Systematic R&D has to be allocated into new business areas and markets in order to generate new innovations enabling new business opportunities. In case existing company recourses are inadequate, corporations have to collaborate or acquire the necessary competences. There are encouraging examples that paper compa-

nies are able to undergo a transformation, create new innovations and leap into new business areas.

7.2 Visions for paper industry

One of the objectives of this thesis was to compose visions for the Finnish paper industry through better understanding of the PPI and RFID value chains. The executed literary research, the industry analysis and the interviews with the Finnish RFID professionals largely scaled up this knowledge. It is worth mentioning that the visions to put forward in the following are not the ones of the interviewees alone, but a synthesis from literature, interviews and industry analysis. Forest industry, along with ICT-industry, has significant implications on Finnish national economy, and the imaginary, but potential corporate visions *"Business as usual"* and *"Green gold"* are introduced next.

7.2.1 Business as usual – Corporate A

Paper industry is a mature line of business and yet globally a fragmented industry, since the top five companies represent just approx. one third of the world market. The markets in North America, Western Europe and Japan are mature, but the demand still increases for example in Asia, particularly in China.

Forest industry enterprise A has to continue to restructure its operations by closing down the oldest, smallest and most inefficient pulp and paper mills, rather than trying to trade them to competitors. In this way, local overcapacity can be reduced and balanced to meet the expected future demand by product brand. The efficiency and profitability of the company has to be increased, and healthy cash flow and strong balance sheet secured.

The top management has to make strategic choices concerning the future direction and investments of the company: what is the focus of the corporation, is the focus on paper production or also on mechanical forest industry, what market areas should the com-

pany concentrate in, what product brands are the most lucrative, should the company invest into new capacities in emerging markets, or should it reserve resources for mergers and acquisitions.

Corporate A made a strategic decision to focus on high-quality value-added paper products, where demand is expected to increase worldwide in spite of the generally decelerating demand growth. The other focus areas are packaging and hygiene products, where demand are expected to increase in the future. Corporate A has a strong presence in the growing markets: China, India, other selected Asian countries, Russia and South-America. Inexpensive raw material supply is secured by forest plantations in South-America and own forests in Russia, where adequate pulp plants also exist. The company has merged with some other paper companies during past decades, acquired a few other ones and bought modern paper mills, whenever there has been a strategic fit to corporate market and product portfolio. Alternatively, necessary production capacity on strategic market and product areas has been constructed.

The ultimate long term target of the company is to remain the world leading forest industry enterprise in the selected product and market areas. The company strategy is to continuously improve its competitiveness by incremental innovations. As a dominant player in the selected market areas the fiercest competition can be avoided, since the other giant players are mainly operating in other fields of the mature markets.

As one of the leading global forest industry enterprises corporate A has for long focused its operations into the growing markets and the activities in Finland have diminished remarkably. Partly because of the mergers and acquisitions and increased interest of international institutional investors, the ownership of the company has also dispersed universally. The headquarters of the corporation is located in Asia. One of the corporate research centers is, however, still mainly located in Finland, because it can benefit from the Finnish innovation system, the still existing forest industry cluster and the competitive Finnish researchers. Finland's position as one of the leading forest industry nations that it long attempted to defend, has been eroded.

7.2.2 Green Gold – Corporate B

Corporate B has also streamlined its operations, and the oldest and most inefficient plants have been closed. A strategic choice has been made concerning the markets and products, the company aims to focus on. The corporation has invested in the selected business areas to ensure its profitability, competitiveness and position in the PPI related business areas. Company's cash flow and solvency are healthy and prepare the way for new strategic moves.

During the past decades, the company has also methodically invested in the research of various printed intelligence applications in close co-operation with research institutes, universities and innovative ICT companies. Corporate B has efficiently employed the open innovation phenomenon, and utilized others' ideas and IP in order to build its competences. As a result of the intensive investments in well focused R&D, the company product portfolio today include such printed intelligence products as electronic codes like RFID products, displays, optics, electronics and sensors. Many printed intelligence products also complement company's intelligence packaging division's product range.

Today, in 2030, the majority of the revenue and especially the results of the company come from the novel business areas, and the strategic shift to new businesses over 20 years ago has resulted in new core competences that enable corporate B to expand further into other fast growing ICT related business areas, and employ its brand building competencies for global growth. The corporate top management and owners plan to focus the company business into ICT and evaluate at present the proposition of corporate A to acquire the profitable pulp and paper division of the company. The strategic choices that corporate B made decades ago to move into novel business areas greatly contributed to forming a new ICT related industry cluster that is today one of the cornerstones of the Finnish economy.

8 DISCUSSION

In this chapter, the key results of the study are discussed in the light of the theoretical framework and the literature. The reliability and validity of the results are discussed, and finally, suggestions for possible further studies are put forward.

8.1 Results of the study

The RFID industry has grown rapidly during the past years, and it has further business potential in the future. Industry analyst IDTechEx suggested that the industry could grow to almost 30 billion USD in ten years. Furthermore, the consultant company predicted that RFID could largely replace barcodes, and be partially printed directly onto products and packages. (Das & Harrop 2008) The interviewed specialists had more moderate opinions about the future market development. Main arguments behind their opinions were that the industry infrastructure and dominant design are still evolving, the system implementation expenses are yet high and the printing technology still has uncertainties. The dramatically worsened world economic situation during the past months probably also affected the interviewees' opinions, and the recession may actually hinder the development. The emergence of dominant design is often a combination of technological, economical and organizational factors, and industry standard then typically leads to peak in sales (e.g. Suarez & Utterback 1995; Tushman 1997). The possible break-through in printing technology, and efficient R2R production method could enable the manufacturing of inexpensive identifiers that could expedite broader adoption of RFID. According to interviewees the today's fragmented value chain is probably also going to concentrate, and large-scale global players are capable efficiently to promote the industry development. According to the writer's reasoning, the industry will possibly emerge, but perhaps later than the most optimistic forecasts.

In this study, the RFID value chain was divided into upstream focused, downstream focused and vertically integrated firms. Upstream focused firms were developing, manufacturing and marketing RFID identifiers and devices, downstream focused pro-

vided software and integration and they were typically system sellers to end customers. Vertically integrated firms' offerings included products and services from both ends of the value chain. PPI and printing firms operating in the industry were also separately studied. Companies such as material suppliers and contract manufacturers as well as research institutes and consultants supplement the main stream of the value chain, but the study focused only on the mainstream players.

The study revealed that the industry firms are relatively young in general, but PPI and printing firms had a different age distribution exposing that PPI and printing is a much more mature industry. An industry classification study revealed that the biggest primary business areas of the firms (57 % of the sample) were ICT related business activities, while the biggest PPI related business activity represented four per cent of the sample. Science-based enterprise competences are typical for example for electronics industry, whereas scale-intensive ones are typical to PPI (Tidd et al. 2005; Ebeling 2008). According to the writer's argumentation the result underpins that RFID industry favors ICT related rather than PPI related enterprise competences, at least in the short term.

Comparing the different RFID firms, PPI and printing firms were rather equal in size, while significant variation existed among the size of the other firms. It appears that the industry interests both global diversified large-scale enterprises as well as specialized smaller firms. Vertically integrated and downstream focused firms were the most profitable ones, and they had also the most considerable R&D expenditure. This result supports the interviewees' opinions that there is more value added at the end of the value chain with end customer interface. PPI and printing firms' R&D expenditure was low and their profitability inadequate. PPI and printing firms' low R&D intensity is typical for scale-intensive technology trajectory (e.g. Ebeling 2008), and the industry has also suffered from unsatisfactory profitability for several years.

While investigating a part of the firms more deeply, it became evident that most of the firms collaborate with other companies in order to complement their own competences. Partner network typically supplement the company offering or the partners act as the firm's merchandiser. Some of the companies build their competitive advantage on in-

house innovations, while others hold a substantial number of own patents and also make use of others' IP, thus utilizing the open innovation paradigm at least to some extend. Few companies had made a strategic shift by changing their business focus and entered the industry. However, mergers and acquisitions seem to be more typical than organic growth, while entering into the industry and broadening the company activities within the value chain. According to interviewees vertical integration as well as horizontal consolidation take place as a part of the natural industry development. Firms seek for the benefits of economics of scale and more value added end customer interface.

According to the interviewees, the RFID industry might interest paper industry, but the business volume at least during the next years might not be adequate enough. Innovations can be regarded as competence-destroying, when they are not based on the firms' existing knowledge (e. g. Tushman & Andersson 1986; Schilling 2008). Paper industry needs new ICT related competences, when entering the RFID industry, and it is probably worthwhile to obtain the competences through acquisitions rather than by own innovations. Transformation is fundamental to the paper industry, but it is noteworthy that the inadequate profitability of the industry makes especially large-scale acquisitions challenging. Innovations have to be managed actively and systematically in order to enable successful innovation process (e. g. Tidd et al. 2005; Apilo et al. 2007). However, companies tend to be path-dependent that constrains their technological knowledge, and channels their innovation capabilities (Tidd et al. 2005). The innovation activities of PPI and ICT industries differ from one to another (e. g. Ebeling 2008), and since the window of opportunity to enter into RFID industry is limited, it is logical to echo specialists' views that PPI has to acquire the required competences rather than attempt to attain them through their own R&D. Industry transformation is challenging due to path-dependence, and companies have to efficiently integrate their competences, business strategy and new technologies (Torkkeli & Tuominen 2002).

8.2 Reliability and validity of the results

The primary source for acquiring data concerning companies in the RFID field and their activities within the industry value chain was a consultancy company IDTechEx. The preliminary collection of firms was extended by studying their Internet home pages that unveiled a significant number of their competitors, partners, suppliers and customers. The sample was further processed individually by three researchers, and in order to ascertain the accuracy of the manually gathered data, it was finally crosschecked by other researchers. However, the data related for instance to the company activities within the value chain was mainly based on companies' commercial Internet home pages. Thus, the results should be interpreted with certain deliberation.

The final sample of companies and their financial data were eventually formed from Thomson One Banker's (2008) data source. Financial data was available from 80 firms, from which 61 per cent were of USA origin. Most of the companies were publicly listed large-scale corporations, and financial data on their RFID activities was hardly available. However, it can be estimated that for the majority of the sample of the companies RFID represents just a tiny portion of their revenue, and thus the financial influences of the RFID business on the companies are challenging to estimate.

The literature review and the quantitative analyses were complemented by interviews of altogether 12 industry and academic specialists. The key Finnish informants were interviewed by using a semistructured questionnaire that concentrated on three main issue areas: printed intelligence and RFID development during the next decade, RFID value chain development during that period and RFID industry benefits for paper industry. The semistructured questionnaire prepared the way for possible different interpretations. However, the researcher did his utmost during the interviews to avoid possible misreadings. The interviews were recorded and the results were also crosschecked by another researcher in order to ascertain their accuracy.

8.3 Limitations and possible further studies

The data from Thomson One Banker (2008) was limited to financial data from 80 firms, from which the majority were of USA origin. In order to broaden the database, other sources such as for example AMADEUS (2008) should be combined together with Thomson's data in the further studies. More in-depth analyses could also exploit commercial registers in order to get financial data from family businesses that are not publicly listed. Qualitative analyses could perhaps be extended to cover experts from various countries. More structured questionnaires and interviews, and also other methods such as, for example, Delphi could possibly be considered. The exploitation of patent data would probably also bring new perspectives to studies related for instance to technological trajectories and competitor analyses.

According to this study, the RFID industry could for the time being offer only limited business opportunities for the paper industry. However, paper industry could form a novel strategic business area from RFID or printed intelligence to complement the diminishing conventional paper business. Possible further researches should thus include the whole printed intelligence area that could provide much bigger business potential in the future.

9 CONCLUSIONS

Information and communication technologies have had considerable impacts on the paper industry that has experienced significant structural changes. Paper products alone no longer provide livelihood for the entire industry, and it is of significant importance that the industry increases investments to generate new businesses.

Quantitative industry analysis and qualitative interviews were combined in this thesis in order to form a holistic view of the RFID industry and the key players within the industry. Majority of the studied firms within the industry had ICT related business activities as the company's primary business area. Therefore, at present the industry seems to be more appropriate to ICT related firms rather than for example to forest industry related ones. Large-scale enterprises as well as innovative smaller firms operate widely in the value chain or are focused on some specific business segments either in the upstream or downstream of the value chain.

RFID industry is still in the early phases of its life cycle and has business potential in the future, like the whole printed intelligence industry. The evolution of the RFID industry depends on the development of manufacturing standards, designed to ensure the interoperability of equipment by different vendors. Large and small businesses are moving from the pilot stage to implementation of RFID with open loop and supply-chain systems in particular, while the industry's dominant design emerges. Broader adoption of RFID may take place as a result of product standardization, lower-cost devices, and improved system performance. Benefits have to be transparent and considerable to end customers. Large-scale end customers, such as wholesalers are important drivers behind the industry expansion. The development of the industry during the next decade may though be slower than the most optimistic forecasts have predicted, and the present recession of the world economy, for instance, may hinder the development for some time.

It is most likely that electronic and optical codes are going to co-exist for a long time, and it will perhaps take at least five to ten years before printed RFID becomes commer-

cial. Environmentally friendly paper is probably eventually going to substitute plastic as identifier substrate. The RFID industry is likely to concentrate, while dominant design has evolved, and the industry gradually begins to mature. Both vertical integration, especially towards the end customer interface, and horizontal consolidation will be witnessed. Large-scale enterprises will probably be the drivers of the change acquiring smaller innovative companies.

The RFID industry provides business opportunities for the paper industry. However, the business volume of the industry, at least for the time being, is not alone adequate to offer livelihood for the entire paper industry, while it seeks for novel businesses to substitute the diminishing paper markets. The paper industry also possesses different competences that are typical for the ICT related RFID industry, and since the window of opportunity to enter the industry is limited, paper industry should obtain the required competences through acquisitions rather than by own R&D. The possible entrance into the RFID industry is challenging for the paper industry due to different technological trajectories typical for the industries. However, among other alternatives, RFID could provide one option for the necessary transformation of the paper industry.

It might be valuable for the possible further studies within the field to include the whole printed intelligence industry, since it could most probably offer a much bigger business potential than the RFID industry alone in the future.

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INTERVIEWS

Person 1 Project Manager, Center of Excellence for Functional Materials. Academic, printed functionality. Interview in Espoo 22.9.2008.

Person 2 Marketing Director. ICT company. Interview in Espoo 22.9.2008.

Person 3 Professor, Faculty of Technology, Mechanical Engineering. Academic, forest. Interview in Lappeenranta 23.9.2008.

Person 4 Director, Pharmaceutical Solutions. Forest company. Interview in Lappeenranta 24.9.2008.

Person 5 Research Director. Academic, forest. Interview in Helsinki 26.9.2008.

Person 6 Manager, Intelligent Solutions. Forest company. Interview in Lappeenranta 29.9.2008.

Person 7 Vice President, Marketing RFID. Forest company. Interview in Tampere 3.10.2008.

Person 8 Sales, Entrepreneur. ICT company. Interview in Jyväskylä 3.10.2008.

Person 9 Project Manager. Academic, ICT. Interview in Vantaa 6.10.2008.

Person 10 Director, Offering and New Business Development. ICT company, integrator. Interview in Helsinki 9.10.2008.

Person 11 Technology Manager. ICT company. Interview in Vantaa 9.10.2008.

Person 12 Team Leader, Wireless Sensing. Academic, RFID. Interview in Espoo 17.10.2008.

Appendix 1: List of TBRC Research Reports

- RR1: A State-of-the-Practice Survey on Requirements Engineering in Small- and Medium Sized Enterprises. Nikula, Uolevi; Kälviäinen, Heikki; Sajaniemi, Jorma, 2000
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- RR11: Printed Functionality in the Intersection of Forest and ICT Industries. Karvonen; Matti; Kytölä, Olli; Soininen, Liisa; Kässi, Tuomo; Koivuniemi, Jouni, 2008
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- RR13: Digitizing Business Processes in the Intersection of Energy, Forest and ICT Industries. Mustonen, Tomi; Karvonen, Matti; Soininen, Liisa; Hellsten, Kirsi; Kässi, Tuomo, 2008
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- RR15: TALIKKO - creation of new business in the intersection of industries. Karvonen, Matti; Koivuniemi, Jouni; Kokkonen, Kirsi; Kytölä, Olli; Kässi, Tuomo; Pätäri, Satu, 2008
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