Analysis of Technology Management Functions in Finnish High Tech Companies

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Abstract: Technology management (TM) for companies is about sustaining and improving a company's competitiveness in the long-term. The aim of this study is to identify the common perception of TM functions in Finnish high tech companies, which elements are the most critical for them, and where the biggest development needs are in practice. The study was realised qualitatively in 15 Finnish high tech companies. Interviews were held with persons responsible for company management activities in the area of technology. The results show many similar characteristics in the case companies, such as the nature of the technology strategy, the mode of co-operation in technology development, or the ways of acquiring technologies. However, differences were also identified mainly in the companies' business models and company size. None of the functions of TM, were evaluated as the most important by the case companies. However, certain functions of TM were highly appreciated and are mostly related to the engineering activities, such as product development, technology development, information and knowledge management, life cycle management, and production process management.

Key Words: Technology management, technology management functions, high tech companies.

INTRODUCTION

The aim of technology management (TM) is to sustain and improve the competitive position of a company's technology exploitation. The management of technology should comprise three major factors: leadership, motivation of employees and appropriate management of technology [1]. The goal of TM is to create a synergy among all the factors (i.e. research, development, planning, engineering, machines, software, production, and communication) to make them work together in the most efficient way to produce profit for the company in the long-term.

Companies are under constant pressure to be innovative, to introduce new products and services to create difference in the market, and to make process innovations to improve their business performance [2]. Rapid changes in the business environment and global competition forces companies to understand the business opportunities and risks of new technologies, and how important technological innovations are for industrial competitiveness [3, 4]. Technological innovations can involve changes in products and services or changes in the ways of operating (i.e. process innovation) [5]. To create these changes, technology management is an inevitable necessity for companies to survive in global competition and sustain their business. However, there is ongoing discussion in the scientific community about what really is the content of TM. Also the practitioners in industry are setting different practices for managing technology. This makes the situation more complicated in real management situations.

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Finnish companies have been well known for their technical engineering and product development related capability, but there are shortcomings in the strategic and business management levels [6]. Thus we decided to collect knowledge about the current state of TM in Finnish companies. Before analysing the practices, we outline the functions of technology management according to the current literature. After that, we examine these functions in practice and identify the areas for development and importance of those. This approach is condensed into the following research questions:

RQ1. What are the main functions in Technology Management?

RQ2. How do these functions emerge in some Finnish high technology companies?

The paper is organised as follows: first, the functions of TM are defined; the methodology section describes how the empirical research was carried out; the empirical results are compiled and presented in relation to the research question; finally, the results are discussed and conclusions are drawn.

FUNCTIONS OF TECHNOLOGY MANAGEMENT

Technology management (TM) or Management of Technology (MoT) is extensively discussed in recent research and literature. A wide range of literature on new product development (NPD) management, R&D management, strategic management, management of innovation, long-range planning, technological forecasting etc. can be found in the journals and text books. Nevertheless, technology management is a separate field of management science since the 1970s and early 1980s. The National Research Council (NRC) and U.S. industry organised a cross disciplinary workshop in 1986 to define a theoretical foundation for MoT [7]. After

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that, a significant amount of literature was produced on operationalising technology management into other approaches in management (see e.g. [8-15]). Dussauge [13], Bhalla [16], Steele [8], and Betz [11] among others introduced their generic MoT books from a strategic viewpoint, and defined key considerations and concepts in the MoT area. Steele [8] presented a classification of product, manufacturing and information technology. Mitchell and Hamilton [17] proposed a model for the strategic positioning of R&D efforts using strategic technological options. Matthews [18] further developed the model to reduce technological uncertainty based on Mitchell's and Hamilton's work. After that Matthews [10] introduced a holistic conceptual framework for integrating technology into business strategy. Dodgson [19] and Carayannis [20] combined technology management, organisational, and a learning point of view.

Technology, especially in the strategic context, refers to technological competence or knowledge rather than explicit technical solutions. Dodgson [12] crystallized, technological competence as simply competence with a technological basis – an ability to compete with technology. Several technology definitions support this conclusion. For example, Steele [8] defines the capability that an enterprise needs. Burgelman *et al.* [9] refers to theoretical and practical knowledge. Dussauge [13] proposes the application of scientific knowledge. In conclusion, the key implication is that the aim of technology management is to understand the real difference between competitive advantage achieved by technological competence and competitive advantage achieved by certain technical solutions. When competence is core or strategic, it gives a sustainable competitive advantage that cannot be copied or imitated by competitors. From a company's viewpoint, an essential issue is that only by developing technology itself can it learn about, and achieve this kind of profound competence. Another choice is to buy technology from an external source, but then an individual company is dependent upon the competence, and perhaps loyalty, of collaborators and technology suppliers. It could even be said that technical solutions can be bought, but technology is impossible to buy. [21].

Overall, TM overlaps several other approaches, schools and paradigms for managing technology and R&D in the strategic context. However, two main streams of literature can be identified in science and engineering (e.g. R&D management and innovation management), and in economics and management science (strategic management and business administration). The field of technology management has also been approached from other management paradigms and areas of science (e.g., organisational theory and quality management). According to Talonen [21] it is fair to say that management of technology is more a set of conceptual approaches than an exact paradigm or field of science.

Because of the interdisciplinary evolvement and the nature of technology management, and lack of commensurable frameworks, there are several typologies and approaches for defining functions in technology management. These different views of TM functions (see e.g. [2,8,9,12,22]) are not included in this article, because the approaches used are multiple and thus the function represented are always a consequence of the dominant mind setting. Therefore we outlined a theoretical framework for functions of TM especially for an industrial organisation (Fig. **1**). This framework is a synthesis of our theoretical study and explains how the technology management functions are understood in this study.

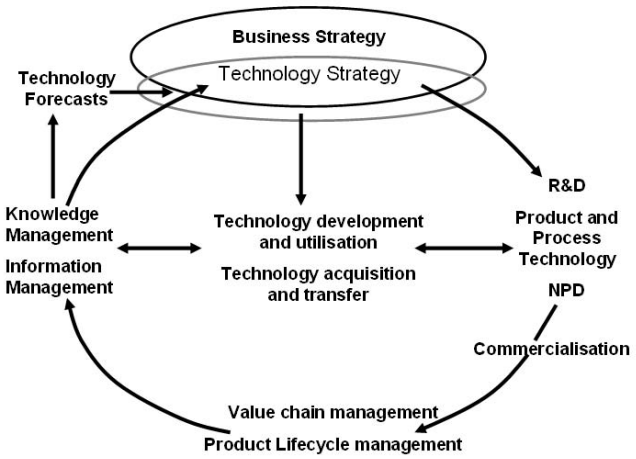

Fig. (1). The managerial functions of TM from the view point of the industrial company.

Technology Management involves management of all the key factors of production to create wealth. The main branches are research, development, planning, engineering, machines, software, production, and communication. The goal of technology management is to make everything work together in the most efficient way to produce profit for the company in the long-term. In this respect, the emphasis is on the word 'long-term'. The goal of big profits cannot be pursued without a future. Sometimes, managing for the short term is necessary, but to secure continuity of the company the long-term aspect is essential. For this reason, all the decisions must lie on a sound base and good business ethics, and ongoing organisational development must be planned. Accurately handled management can create a huge advantage against competitors, whereas inadequate management can damage a whole company. There is no benefit from good employees if the management cannot use them. Furthermore, managing a company is not always the same, it is dynamic in nature. It is not possible to just copy the management style from a successful company because there are no two identical companies. In addition, the culture of the firm affects the management style too (see e.g. [23-26]).

To be as successful as planned, it is important to identify what to produce and how and have answers to the following issues: why to be in the business, what customers' problems can be solved, both from a technology point of view, and from an engineering point of view. In other words: a company needs a strategy. The strategy defines the company's future. In simple terms, a strategy can be said to consist of a mission and a vision. The mission defines what the company will do, and the vision defines where it is aiming. However, it is not enough to establish a fancy strategy, it has to be executed.

A strategy cannot be just decided at the board of directors. It needs information to support its guidelines. For that purpose the business environment must be studied and a

forecast made for the industry and its products. It should be noted that the industry, where the company acts, influences the competitive rules of the business as well as the strategies exploitable in a company [27].

For a company to make the right decisions related to its technology strategy, it needs reliable evaluations of the possible direction of the technology. This means close interaction between the industry and other relevant parties like universities and independent research units. It is necessary to study how the competitors are acting and how the technology will evolve in the future. In this study, the issue of the community forecasting on technology is outside the scope and concentrates on company level forecasting activities which are understood as a way of creating information for the purpose of TM and strategic management [28]. Equally with the technology forecasting, it is important to know what the customers need and how to serve them best. It is necessary to know the customers' needs better than they do themselves. That knowledge creates competitive advantage. Moreover, the company must know what is its' most valuable capability, core competency. According to Teece [27], the winning companies in high technology industries have rapid and flexible product innovation together with the management capability to effectively coordinate and redeploy internal and external competencies.

When the strategy is defined it gives direction to the whole company. The company starts to concentrate to produce its products leaning on its strengths. Needed technology is either produced in the company, or acquired or transferred into the company. The strategy gives direction to the departments and defines how to execute it.

In the end, the management's purpose is to support the strategy. They have to ensure that the right steps are taken and things are done right. Success depends on the company's two key ingredients – technical resources and the capabilities to manage those [5]. Managers have to create a good target-oriented atmosphere, and make sure that all the necessary material is available for developing the individuals and the organisation. The organisation must evolve all the time to remain competitive in a turbulent business environment. Controlling resources and risk management can ensure that random backlashes do not jeopardise the company's future.

Information management is one important part of management. Without a fast and functional information system, projects fail and delays or even cancellations reduce a company's profit and reputation as a reliable manufacturer, co-operator or supplier. The companies develop their information systems all the time – however when organisations make improvements in the area of information and knowledge management, they often make it only for explicit knowledge. However, they should notice that it is tacit knowledge which gives strategic advantage [29]. Tacit knowledge is more complex to understand and handle. Companies require solutions for tacit knowledge management because highly tacit knowledge indicates that the underlying structures are not well understood. An organisation cannot improve those aspects which it does not understand [27].

As presented in Fig. (**1**), strategy is affected by forecasts and the company's core competence. On the other hand strategy affects technology development, acquisition, transfer, innovation and R&D. Through these operations input comes for new product development. R&D is a separate part from new product development, and refers more to basic research and advanced research to find new technologies, not to engineer products.

METHODOLOGY

The empirical study was conducted to obtain an understanding of the current state of TM in Finnish high tech companies. The number of Finnish high tech oriented companies is extensive, but many of these companies are micro companies and thus not relevant for this study. For that reason, we selected the companies which represent average Finnish high tech oriented companies. The companies were selected because of their clear high technology orientation, and thus have an interest in technology management issues.

Because of the limited resources, but in compliance with the requirements of qualitative research, the selected companies have to be easily and reliably available. In total, 19 responses were received from the industry representatives *via* interviews or questionnaire (Table **1**). None of the contacted persons refused an interview. The amount of responses is considered to be sufficient for this research purpose to increase understanding of the studied field. The sample can be seen to be representative as, during the last interviews, we did not find any new and different information.

Table 1. Background Information of the Respondents

	Amount of Companies	Amount of Responses
Large companies (over 400 employees)	7	11
Small companies (below 400 employees)	8	8
In total	15	19

Overall, the research was carried out in 15 companies. 7 of these companies are classified as large companies, and 8 represent small companies. Of the larger companies, more than 1 participant was usually interviewed to triangulate the answers, but also to gain information from the different business units.

The interviewed participants were chosen on the basis of their professional background and expertise. The interviewees hold responsible positions in management activities related to technology and thus have up-to-date knowledge of the discussed topics. The job titles of the respondents include the following: the CEO, CTO, Development Manager, Director of R&D, Product Development Manager, Senior Director of Competence Centre, Director of Product and Technology Management, Head of Technology and Architecture Management, Director of Rich Internet Services, Engineering and Site Manager, and the Head of Division.

The study was carried out in spring 2008 using the normative research approach to improve existing knowledge of technology management. The research process started studying the field of TM. The questionnaire used was structural and contained qualitative and quantitative parts. The qualita-

tive questions were used to identify what each function of TM means to the companies – how they describe the content of each area of TM and what are the practical implications in the specific function of TM. The quantitative part focuses on identifying the importance of each subfield of TM and what is the current state of operation. The evaluation scale used in this part was the Likert-scale 1-10, where number one is "not important" (measure of importance) or "not practised" (current state measurement), and number ten is "extremely important" or "a well established practice".

In the questionnaire we briefly defined all the TM functions presented in the theoretical framework (see Fig. **1**), in order to obtain valid information from the respondents. This was done because TM consists of many different functions which are somehow related to each other. These descriptions are presented in Table **2**.

RESULTS

The research is qualitative but includes some numerical data. The qualitative research methods and requirements guide this study. The qualitative part illustrates the common perception of TM in the case companies, but also analyses the differences between the companies, and possible root causes of these differences. The quantitative part of the study concentrates on determining the importance and current state of certain functions of TM in the case companies.

The Perception of Technology Management in Finnish High Tech Companies

The summary of the results from the qualitative questions about the content of certain functions of technology management is presented in Tables **3** and **4**. The covered functions of TM were strategy related as in Matthews' [18] approach in grouping R&D projects which links the strategy and product development aspects, technology development and utilisation, information and knowledge management, technology acquisition and transfer, technology forecasting, product development and innovation actions outside product development, life cycle management, and production process management.

Table 2. Operationalised Definitions of the TM Functions of this Study

Technology Management Function	Definition of TM Function
Technology strategy	Technology strategy consists of the definition, development and use of those technological competencies that constitute the company's competitive advantage [12]. To define the technology strategy, organisational context, environmental context, and technology evolution are assessed according to the strategic decisions (e.g. make or buy, licensing in/out etc.) [2,9]. The technology strategy is the basis for the business strategy [9,12].
Technology development and utilisation	Technology development consists of basic and applied research, practical solution development, and technology enhancement [22]. Technologies are utilised during product development, but on a wider scale than a single product or product family. Technologies can be also patented and offer intellectual property rights (IPR) for sale. Technology utilisation contains also the elements of technology infrastructure.
Information and knowledge management	Knowledge management contains both tacit and explicit knowledge [30]. "Knowledge is the "key to control" over technology as a whole" [1]. Information is processed data whereas knowledge is context-related.
Technology acquisition and transfer	Technology transfer is the movement of technological capability (artefacts, information, rights, and services) [12], within a company or from a company to another company. The ways of technology acquisition are multiple. It can take the form of internal R&D, joint venturing, contracting out for R&D, licensing in, and buying technology [22].
Technology forecasting	Forecasting is predicting future technologies and assessing an organisation's capability to handle them [8] and thus decrease the level of uncertainty. Forecasting includes continuous monitoring of technological developments leading to an early identification of promising future technology fields and validation of their potentials. Technology foresight is a tool assisting decision makers to optimise the decisions of R&D at a strategic level [31, 28].
Product development	R&D refers to the generation of basic research (for example technology development) and new ideas. Companies should have different types of R&D projects to ensure profits over a long period (see e.g. [18]). Product development aims to create a saleable product (physical product, software, service etc.) (see e.g. [32-35]) but also to develop product technologies.
Life cycle management	Technology life cycle consists of embryonic, growth, and maturity phases. "Most technologies will be replaced and most efforts to replace them will fail", [18]. When the natural limits of technology have been reached, the technology has become vulnerable to substitution or obsolescence. Discontinued technologies replace obsolete products on the market and developing old technology is no longer worth it [2, 22].
Commercialisation	Commercialisation involves delivering products from development to the market, and thus is not only a synonym of launching. Technology commercialisation includes finding applications for immature technologies, and captures the iterative nature of such efforts [36]. Commercialisation means also technological commercialisation including the aspects of IPR and licensing activities, for example [12].
Production process management	Selection of the inputs, operations and methods (process technologies) that transform the inputs to desired outputs [37]. A production system creates deliverables as defined in product development.

In Tables **3** and **4**, the practices of TM are summarised. On the TM function level, there are similarities within the case companies, although differences between the companies are visible too (Tables **3** and **4**, third column). The company size seems to play an important role in the differences which arise about how a particular company addresses technology management.

In addition to company size, the nature of the business causes differences between companies depending on whether the company is an ICT company or not. For example, the business clock speed is affected in the range of technology planning period, i.e. in ICT companies the planning period is shorter than in the other case high tech (non-ICT) companies.

Evaluating the Importance of TM Functions

Table **5** presents the quantitative results of the research. The importance of a certain function of TM and current status is evaluated using a range from 1 to 10. Even though the scale used is ordinal, the mean value is used in the analysis, as is often used in this kind of research. By using the mean value, we are simplifying the results and thus losing part of the statistical information. However, it is not the aim to be very specific in this respect, when the main objective of the research is to identify the main streams of technology management functions so as to gain a better understanding about the current situation of technology management in Finnish high tech companies. The mean value tells more about the relative order of the evaluated TM functions and is the basis for the gap analysis presented later.

In summary, none of the functions is ranked as extremely important or not important at all. All of the functions, excluding technology commercialisation, are evaluated between 7.1 to 8.6 and thus prove that most of the operations of TM are important and there is not just one most important area. However, it should be noted that we have already

Table 3. Description of Technology Management Functions in Finnish High Tech Companies (Part 1)

Function of TM	Common Perception	Differentials
Technology strategy	85 % of the companies have a technology strategy and about 70 % can clearly define it. In most of the cases the strategy is strongly based on the customers needs and it is mostly executed as part of the annual planning process. 60 % clearly stated that the business and technology strategies go hand in hand and the technology strategy supports the whole business strategy and its needs.	2 companies reported being a subcontractor so they are fulfilling customers' needs and thus do not need their own technology strategy. And in 2 other companies the meaning of technology strategy seems to be a little different to that understood in this study generally.
Technology development and utilisation	47 % of the organisations, which develop technology, has a clear formula for technology development. These companies generally do not sell developed technologies, at least not systematically. Almost 80 % of the respondents reported having co-operation with other companies. Especially all the small firms co-operate as a way to get competence, technology, and special skills.	Only 1 response showed that one organisation does not have a clear formula for technology development, even though they are developing technologies. Non-ICT firms are doing much less co-operation with other companies than ICT firms.
Information and knowledge management	The results of tacit information management were reflected as poorly controlled in all the companies. Explicit knowledge appeared to be controlled very well, at least in most of the companies. All the companies have databases, wikis, version control systems, intranets, and so on, to manage explicit data. Many systems and methods are in use to make communication flow more easily between the departments. Communication inside companies is seen to be problematic on some level but almost all the interviewees regard the communication with customers as in good condition.	Also the importance of managing tacit knowledge was questioned in some companies. Even small companies use very formal documentation and the importance of created knowledge is understood. Communication related problems arise because of personnel's attitudes towards communication (communication between departments is seen to be unnecessary in some cases) and also physical distance creates challenges for communication (location and time differences).
Technology acquisition and transfer	47 % of the respondents reported not developing their own technology. These companies, without technology development, are mainly small companies and the bigger ones, without technology development, are non-ICT companies. The most common way for technology acquisition is to buy needed technology, tools, etc. in all the case companies. Also licensing in is a very common way of acquiring technology and is more often used in small companies.	Only 2 companies are selling technologies, and 3 large companies are licensing them out. Small companies cannot sell technology because more often they do not develop it. Large companies have the possibility of buying other companies to acquire certain technology

Table 4. Description of Technology Management Functions in Finnish High Tech Companies (Part 2)

Function of TM	Common Perception	Differentials
Technology forecasting	About 60 % of the interviewees regard technology forecasting as a systematic operation in their organisation. Almost all the companies use some kind of competitor analysis in their forecasting activity.	The methods and approaches to forecasting are varied. The most mentioned were the conversations with the vendors, customers and partners. Others are more company specific tools: collaboration with universities and independent research centres, publications, consultants, observing trends and patents, analyst sessions. Some of the firms divided technology into smaller parts to facilitate observation, and roadmap techniques were used too.
Product development	Excluding the big ICT companies, which invest a lot in product development, there is no common picture about the amount of investment in product development. Parallel technology development is not used: companies do not have resources for it and thus it is thought to be impossible especially in the small companies. 87 % of all the companies use platforms in their product development. The small companies regard the platforms as being very important. 68 % of all the companies use the Matthews' "blue box" (grouping R&D projects) model and which describes ICT companies approach to R&D and product development activities. However, in the ICT companies, the time scale of the Mathews' original "Blue Box" –approach was clearly too long. 40 % of all interviewees said that the time scale is shorter than in the Matthew's model. Twofold results on innovation activities: the big companies have at least some kind of innovation activities outside product development but none of the small companies have innovation actions separate from the product development.	Some of the case companies understood that they do only product development, so all the investment goes into product development. Non-ICT, large companies do not invest much, compared with their turnover, in product development. 3 of the companies reported that they use parallel development in small details inside technologies etc. Only 2 of the companies did not use platforms at all and the main reasons were because of the nature of the industry where they operated. Big differences appear between the big and small companies: 10 of 11 big company representatives said that the Matthews' "blue box" (grouping R&D projects) model is used, but only 3 of 8 small companies said this kind of model is used. Clearly the non-ICT respondents were more familiar with the approach than the respondents the ICT firms. Innovation outside product development did not seem to be very systematic, but there were some exceptions for example a company having extensive innovation council etc.
Life cycle management	The importance of life cycle management was regarded as equally important in both groups of companies. In several companies lifecycle management is a very important part to handle, but not enough effort has been invested in it currently. Lifecycle management was regarded as linear from the research of product to end of its life. It included maintenance and development as well as timing to markets and pricing. Old technologies should be able to get grip of early, because they incur costs even after they are not longer used in the form of maintenance and spare part deliveries.	In big companies, it was regarded as important to control a product portfolio. It was also about respecting green values and the environment.
Commercialisation	Commercialisation was much more important for the small companies, but it was regarded as the least important field by both groups. Interviewees in the big companies were thinking commercialisation as the way to make profit from the know-how.	The understanding of commercialisation was fragmented. Also the importance and current state in both groups varied greatly. Partly this can be explained by the different interpretations of what commercialisation means. Technology commercialisation was regarded in small firms in two ways: (1) some of the respondents of the small firms thought it meant selling their own product, and (2) some thought it could be selling and licensing self developed architecture and patents.
Production process management	Production technology was seen mostly as machinery and methods for producing products. It is important to keep the costs of big volume production down and stay competitive. One respondent included a whole delivery chain under production technology. Lifecycle planning should take into account the whole chain from raw materials to cast-off products.	The respondents of the small companies regarded production technology as the control of a production process and techniques. It includes also tools used to make and maintain products. In addition, the type of product affects the production technology.

selected the most important functions from the literature review for the evaluation, and thus the importance of all the functions of TM presented in this study is already assumed.

Deviation among the respondents is not high and mostly less than 2 units. The definitions of certain functions by the interviewees explain some of the deviations. For example, production process management and its sub-part, production technology, are variously understood – some interviewees are closely bound to the production process and methods, or even to the whole delivery chain, when some others regard interconnections between a product and production technology so that the product affects to production technology. Deviation in the concept of technology strategy arises from the industry where the company operates – non-ICT companies and also the subcontractors do not regard technology strategy as important at all, which appears also in the results presented in Tables **3** and **4**.

Table 5. Importance and Current Status of the Functions of TM in Finnish High Tech Companies

Function of TM	Importance (1-10)	Current Status (1-10)
Technology Strategy	7,7	6,7
Technology Development	8,3	7,0
Technology Utilisation	8,0 6	,9
Information and Knowledge Management	8,2 7,	4
Technology Acquisition	7,7 7,	4
Technology Transfer	7,1	6,5
Technology Forecasting	7,8	6,9
Product Development	8,6	7,1
Life cycle Management	8,2	6,8
Commercialisation	6,4 5,	3
Production Process Management	8,1	6,8

According to the results, the most important functions of technology management vary between the large and small companies (Table **6**). In the list of top five of the most important functions of TM, the same three functions can be found, regardless of the group of respondents. Both small and large companies value product development high and, therefore, product development is number one on the lists of all the respondents. The second important function, on all the companies' lists, is technology development, and the third is information and knowledge management.

The commercialisation of technology is evaluated as the least significant within small and large companies. It is also interesting to note that the commercialisation is much less valued by the large companies than the small companies. In addition, the current status of technology commercialisation is regarded as most critical (i.e. the lowest rate). These results are quite contradictory since the respondents regard commercialisation as the method by which to gain profits from the knowledge.

The gaps between the importance of certain functions of TM and the current status are not very deep overall (see Fig. **2**). However, certain differences between large and small companies are visible (see Table **7**). Small companies consider that their biggest gaps are in: technology commercialisation, technology development, and product development – even when they are engineering technology oriented organisations.

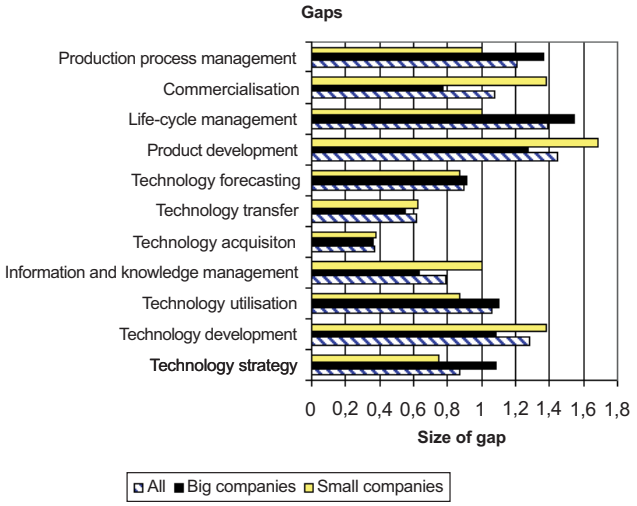

Fig. (2). The gaps between the importance and current status of TM functions in Finnish high tech companies.

Table 6. Most Important Functions of TM Wide

Priority	All Respondents	Large Companies	Small Companies
1 P	roduct development	Product development & Production process management	Technology development
2	Technology development		Product development
3	Information & knowledge management	Life cycle management	Technology utilisation
4	Life cycle management	Information & knowledge management	Information & knowledge management
5	Production process management	Technology development	Life cycle management

Table 7. The Biggest and Smallest Gaps Between the Importance and Current Status from the Group of Respondents

	All Respondents	Large Companies	Small Companies
Biggest Gap	1. Product development 2. Life cycle management 3. Technology development 4. Production process management 5. Technology utilisation	1. Life cycle management 2. Production process management 3. Product development 4. Technology utilisation 5. Technology strategy & Technology development	1. Product development 2. Technology development & Commercialisation 3. Production process management & Information and knowledge management & Life cycle management
Smallest Gap	1. Technology acquisition 2. Technology transfer 3. Information and knowledge management 4. Technology strategy 5. Technology forecasting	1. Technology acquisition 2. Technology transfer 3. Information and knowledge management 4. Commercialisation 5. Technology forecasting	1. Technology acquisition 2. Technology transfer 3. Technology strategy 4. Technology utilisation & Technology forecasting

Among the larger companies, the different functions of TM are regarded as follows: life cycle management, production process management as well as product development are the most challenging operations followed by technology development, technology strategy and technology utilisation, which are regarded as being especially related to the technology infrastructure.

Technology transfer and acquisition functions were regarded as being managed quite well in all the companies. Acquiring technologies was not considered a problem as the results show, and technology transfer is in good shape.

DISCUSSION

When evaluating the importance of different TM functions, it became clear that some functions are not so relevant in certain types of companies. For example, software developers do not value production process management and especially production technology, or technology development because most of these companies are not developing the technology utilised. Furthermore, the software developers do not regard their operative process as "software production". From a business management point of view, this is rather strange, because this process "should" be operative as a "order-delivery process" from the organisation point of view. Also the importance of the technology strategy and especially the strategy time span relates to the industry in which the company operates, and thus a common and general perception of TM is elusive.

The most valued functions of TM in the case Finnish high tech companies were product development, technology development, and technology utilisation. Also the lifecycle approach and production process management are amongst the most highly valued. However, small and large companies have different challenges, which can be seen in the gap analysis.

The importance of technology development is conflicts with the fact that almost half of the case companies do not develop technology themselves and the technology acquisition is experienced as being well managed. One explanation might be that they just do not understand the difference between order-delivery and product creation process from the organisational perspective.

The product and engineering related TM functions are highlighted. Finnish companies have a very strong engineering background [6] which can be seen also in these results. Product development and production process management, developing technology, the engineering-linked lifecycle aspect together with technology utilisation and information and knowledge management are the most highly valued functions of TM. The view of technology utilisation and information management is very application-related.

The reasons for such a low valuation of technology strategy by the case companies might be because of, especially, the experiences of small firms. They feel they are not able to make no table decisions themselves concerning technology choices. Most of the technological choices come from the bigger players, and the small firms merely have to follow the given directions. This does reflect on, and influence, not only the technology strategy decisions but the forecasting as well. When the guidelines are set by the bigger players, it is not seen as important for the smaller players to forecast the future. However, every company needs to understand that changes in technologies create new business opportunities [3] and thus companies need to have some kind of vision about the evolving technologies to compete also in the future. One possibility is to co-operate in networks and therefore have a better vision of future technologies.

The commercialisation of technologies is generally regarded as difficult and most new technology based business ideas will fail in the market [37], because they are there too early and do not fulfil customers' needs but merely satisfy engineering desires. Finnish companies do have a strong engineering and technical drive when developing products and this study confirms the fact that Finnish companies' understanding of the commercialisation of technology is not fully internalised.

In this study, the interviewees were all working in positions where management decisions regarding technology are made. However, technology management nowadays relates to general managerial tasks and should not be taken in one

specific department and thus the same kind of study is needed in other companies to assess the importance of the technology management segment from a business management point of view. Moreover, the number of interviews per company should be higher to understand the company as a whole not just *via* one or a few persons.

CONCLUSIONS

The area of TM is very wide and offers multiple theoretical frames to practitioners. This study shows that none of the TM functions is more important than another when managing technology. One reflection on RQ1 (see Fig. **1**, Table **2**) should be that the frame is not the purpose in itself, it is more relevant to understand the context in managing technology. Furthermore the content and especially the emphasis of a certain function of TM are company related. There was a gap of 2 units between the values of the functions identified as the most and the least important function of TM. This together with some significant deviations among the responses related to some of the studied functions confirms the findings in the literature that the importance of certain functions depends on the company's business model, and all the TM functions are not as important to each company. Nonetheless, some common characteristics can be determined about how Finnish high tech companies understand TM functions.

Almost all the case companies have a clearly defined technology strategy which is integrated with the business strategy. The strategic planning period is at least in ICT companies shorter than that presented for example in Matthews' theories. 60 % of the studied companies make technology forecasts, and almost all the companies use competitor analysis as one method. Otherwise the technology forecasting methods are quite varied.

Technology acquisition does not appear to be a problematic area for Finnish companies. Licensing or buying necessary technologies are commonly used methods. Furthermore, co-operation with other companies and research centres are well used ways of developing technology and related skills. Almost all the companies utilise platforms in their product development, but companies do not have resources for parallel product development activities in principal.

The results on technology development show that only half of the studied high tech companies are actually developing technology themselves. Product development, therefore, is based heavily on the other companies' technological solutions, while the companies concentrate more on specific product creation.

The current status of TM functions is on average quite high when compared to the current status of the experienced importance of certain functions. However, there are significant differences between the small and large companies' current status evaluations, and thus it can be said that the current status and the challenges depend largely on the company, its size, business model and maturity even for companies operating in the same industry. The differences can be linked also to the role of a company in an industry sector – the position in a product value chain is a decisive factor for how the companies organise their TM functions.

In response to RQ2, product and technology development are ranked as the most important TM functions in Finnish high technology companies. It seems these operations are vitally important in TM, and one explanation of this can be the respondents' technology orientated way of thinking and also the fact that at the core of Finnish high tech companies is a product, more than technology. This could partially explain why Finnish firms have traditionally had some problems entering global markets: the products may have been superior but there has been a lack of communication with potential customers while developing the products and also the understanding of the customer needs might be inadequate. Based on that, it is interesting to note that the technical people do not value the commercialisation very highly even though it is regarded as the way to make profit.

Commercialisation was clearly seen as the least important function of TM in this study. It can be explained, at least partially, by the respondents' technology orientation, where product development is seen purely as a technical action without connection to marketing. However, the findings from the literature indicate that commercialisation should be an integral part of the new product development. Therefore, linking commercialisation to new product development should be given more attention.

The purpose of this study was to obtain an understanding of the concept of technology management in Finnish high tech companies and analyse the current status of TM. The studied area is very wide and during the research it became clear that the terms and concepts were variously understood. This raised a challenge for the analysis. This study was not intended to be all-inclusive, but rather to create a better understanding of the current status of TM in practice. As the sample was small, a wider set of interviews might have provided a somewhat different view.

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