Technologie- und Innovationsmanagement

W o r k i n g   P a p e r

The Chief Technology Officer (CTO) in Theory and Practice

A literature review and results from field research in Japan

Cornelius Herstatt, Frank Tietze, Akio Nagahira and

David Probert

no. 41,

November 2006

The Chief Technology Officer (CTO) in Theory and Practice

A literature review and results from field research in Japan

Cornelius Herstatt*, Frank Tietze**, Akio Nagahira ***, David Probert****

** Hamburg University of Technology (Hamburg, Germany),
Institute for Technology and Innovation Management,
c.herstatt@tuhh.de; f.tietze@tuhh.de

*** Tohoku Technical University (Sendai, Japan),
Graduate School of Engineering,
nagahira-akio@nifty.com

**** Cambridge University (UK),
Institute for Manufacturing,
drp@eng.cam.ac.uk

Abstract

This paper presents a literature review discussing empirical as well as conceptual papers concerning the CTO – the Chief Technology Officer – his tasks, responsibilities and authority and his relations with other corporate functions. It further presents first results of a CTO survey conducted in the Japanese electrical engineering industry in the fall of 2006. Based on both, a set of propositions is presented which the authors test via a large forthcoming empirical study in the same industry.

1.   Introduction

Since the late 1980s, companies began to appoint R+D laboratory directors as Chief Technology Officers (CTO). Today, hundreds of CTOs operate in companies of different sizes and in various industries around the world to perform a variety of technology management related tasks including technology assessment, road mapping or managing R+D resources and corporate R+D projects. A CTO is furthermore often expected to foster the interdivisional cooperation to achieve technological synergies or to fulfil tasks like representing technology on the board level, networking with external partners, etc.

Despite the attention the CTO has gained in practice, only a few researchers have closely looked into this management function. For example, using the abbreviation *CTO* and the full concept expression *Chief Techn* Officer* (in title and abstract) as search strings, we conducted a literature review in the summer of 2006 in the German Common Library Network (GBV), EBSCO (academic source premier and business source premier) and Proquest database. To our surprise our search revealed in total only 37 articles specifically addressing the CTO, the first articles going back to the beginning of the 1990s. Screening this material we found very few empirically grounded papers presenting results concerning the personal backgrounds of CTOs, his tasks, duties and authority as well as his relation with other corporate functions including the top management. Besides these we found a limited number of conceptual papers stipulating the ideal set of a CTO´s characteristics, tasks, etc.

Talking to a number of practitioners in various industrial and service companies including CEOs (Chief Executive Officer), R+D-Managers, Vice Presidents for Technology and others, we observed that obviously a very dispersed understanding of what a CTO is or should be exists in practice. Therefore, this paper aims to develop a more profound understanding of what a CTO is or might be by shedding light on the existing literature and looking closely into practice. To do so, we scrutinize task-related issues as well as the relation of the CTO to other groups and functions within his firm. From that we further extract and discuss a number of questions, which have either not been addressed by researchers so far or were neglected for a long period, and report about a survey, we conducted with CTOs in Japan in the fall of 2006. Based on this, we further outline a set of propositions which will be further investigated through an empirical survey in the following year.

The paper is structured into five sections. After this introduction, in the second section we present the literature review of prior CTO studies. This review presents the existing literature splitted into empirically grounded work in contrast to (purely) conceptual papers. We discuss major findings from these and raise a number of questions in the third section, and will further argue that there is a need to carry out more research in this field. In the fourth section of this paper - after a short methodological overview of the research approach - we present the results of a first explorative study in the Japanese electrical engineering industry including eight in-depth interviews with either CTOs or executives responsible for R+D of their firm. This research was conducted in the fall of 2006 based on a semi-structured interview guideline. We present these interview results in five subsections (general observations, authority and organizational influence, task/responsibilities, future trends on the CTO agenda, and career development and professional background). Based on the results of this explorative study we propose a set of propositions at the end of each subsection. In the fifth section we reflect our research findings with the literature presented in the second chapter. Finally, we close the paper with some conclusions, limitations of research and give implications for future work in this field.

2.   The CTO in Theory – A summary of the literature

The first article specifically discussing the "Chief Technology Officer" (CTO) as a corporate function was presented in the early 1990 by Adler and Ferdows (1990). Since then a limited number of conceptual and/or empirically based papers have been published, with a peak between the mid 1990ies and early 2000, but surprisingly no more empirical work on the CTO has been published since 2001. One possible conclusion for this observation might be that the interest of scholars in the CTO has been fading over the years, but it might be just too early for this conclusion and other explanations may exist.

Scanning the CTO literature we found it helpful to differentiate between empirically grounded or founded work and purely conceptual papers. In the following section we present CTO specific literature according to these two groups. We will concentrate on presenting major findings of such publications and further use these to extract major issues on a strategic, organizational and process-related level to first segment and better understand the tasks, responsibilities and authority of the CTO on these different levels. We will further present major challenges and issues being discussed in the literature to derive our research questions and to prepare our field research.

2.1   Empirically founded work

So far and to our knowledge, only four empirically founded papers have been published with issues relating to the CTO (Adler and Ferdows (1990), Uttal, Kantrow et al. (1992), Thurlings, Bert et al. (1996), and Roberts (2001)). However, although being well empirically founded, the paper by Thurlings, Bert et al. (1996) has only two pages. Notably, three of these were published in Research Technology Management, a journal targeting both scholars as well as practitioners, and (only) one article by Adler and Ferdows (1990) was published in the California Management Review, an international, peer reviewed journal. The latter is based on research carried out in the late 1980. In addition to these four papers, findings from another study conducted by Lorenzen, Tietze et al. (2006), still being a working paper, and not yet having been presented to the public will be described in the following.

Before presenting the findings from these papers in chronological order, Table 1 gives a brief overview of the empirical studies which have been conducted on the CTO in the past and in recent years.

	Sample size (N=)	Main contents / issues
Adler (1990)	29 QNs + 22 phone interviews	(1) budgetary authority and the power to approve appointments, (2) areas of responsibility, (3) personal backgrounds, and (4) why the CTO position had been created
Uttal (1992)	25 company interviews	(1) leadership styles (functional, strategic, supra-functional), (2) match of leadership style, (3) credibility, (4) relationship to CEO
Thurlings (1996)	25 interviews with corporate CTOs, 22 academics	Emerging issues on the CTO agenda
Roberts (2001)	209 QNs	(1) CTOs on different organizational levels in Japanese, European, US corporations, (2) CTO-CEO relationship and involvement in decisions
Lorenzen (2006) *(unpublished working paper)*	18 QNs	(1) tasks, (2) responsibilities of CTOs, and (3) required skills/ qualifications.

Table 1: Overview of empirical CTO studies in chronological order

Adler and Ferdows (1990) conducted a questionnaire study based on 25 in-depth telephone interviews with Fortune 100 companies in the US. They studied "corporate officers with explicit technology responsibilities and with titles other than *VP for R+D*" regarding four main issues: (1) budgetary authority and the power to approve appointments, (2) areas of responsibility, (3) personal backgrounds, and (4) why the CTO position had been created.

The authors found that all CTOs considered themselves to be the "most senior executive responsible for technical matters in the corporation". Further, Adler and Ferdows (1990) analyzed the CTO´s **budgetary authority and the power to approve appointments**. They identified two types of CTOs: the "line manager" and the "staff position". Five out of 25 CTOs had full authority over technical budgets and appointments of new technical staff in the business units. These five were the most like "line managers" in their sample. In another five cases, the CTOs were in purely "staff" positions in the sense that they had neither formal authority over budgets nor personal appointments in the various business units nor even within corporate research; hence, their likely influence concerning strategic or operational decisions affecting technologies, budgets and people inside the company was rather weak and of a purely informal nature.

According to Adler and Ferdows (1990) the CTOs included in their research mentioned five **areas of responsibility** to be the most important from their perspective: (1) Coordination among business units' technological efforts to ensure synergies and hence economies of scale; (2) representation of technology within the top management team; (3) supervision of new technology developments; (4) assessment of technological aspects of major strategic initiatives; (5) and management of the external technology environment.

Regarding their **personal backgrounds** Adler and Ferdows (1990) found that 16 out of the 25 interviewed CTOs had general management experience and 24 CTOs had spent a considerable part of their career in technology functions (R+D or engineering). 15 out of 25 had a PhD and only 5 had experience in manufacturing; none of them had any significant experience in IT. Four CTOs were recruited from outside the company, seven from internal R+D positions, while the rest had originated from other functions within the company. Further 9 out of the 25 companies, reported to have installed CTO positions with broad responsibilities for more than one technology domain one divisional level. These CTOs were labelled by Adler and Ferdows (1990) as "technology director".

Adler and Ferdows (1990) further asked **why the CTO position had been created** in the respective companies. In seven cases the decision to install a CTO was triggered by the availability of the right individual. Furthermore, they found that the "motivations differed depending on whether the corporation had a central R+D organization or not". Companies with a central R+D organization reported the "need to foster greater responsiveness on the part of central R+D and greater receptiveness on the part of the business units", while companies without a central R+D reported the "need to avoid duplication of businesses' R+D efforts". Additionally, a reason that was mentioned was to ensure the "cross fertilization" of businesses' technology efforts, and to "exercise overall leadership" and to maintain the technological base of the company, in particular, by serving as a "window to outside technologies".

The second study that explicitly looked at the CTO was conducted by Uttal, Kantrow et al. (1992). These researchers focused on **different leadership styles** of CTOs and conducted a study, by interviewing 24 CTOs in large US companies. The authors propose a model of three different leadership styles. With "functional leadership" they mean the "traditional, effective management of R+D organizations. It includes the day-to-day tasks that are familiar to all R+D managers…. In sum, effective functional leadership means delivering the R+D "goods" that other managers traditionally expect as the outputs of the R+D function". In contrast, "strategic leadership" has its "goal to link and integrate R+D strategy with corporate strategy." Thirdly, "supra-functional leadership" occurs mainly "beyond the R+D function and drives to build sustainable competitive advantage of the corporation by melding the technology function with the business". As a key finding from their study, the authors argue that in many corporations CTOs exercise an inappropriate leadership style, i.e. their personal leadership style does not match the type of leadership style demanded by the corporation (leadership gap).

From their research, four main findings emerged concerning the **match of leadership style** with the demanded leadership style of the corporation: (1) While CTOs play a variety of leadership roles, ranging from the purely "functional leader" to the "supra-functional" leader. The authors find a divergence

between the leadership style CTOs exercise and the kinds of leadership that best serve their corporations ("A leadership gap"). (2) Lack of credibility with the CEO is a fundamental barrier for CTOs trying to close such leadership gaps. (3) CTOs can improve their credibility by building a strong function/role for technology in the company, particularly by acting as "technical businessmen" (e.g. by making themselves and the organizations accountable to the corporation, using and reporting on various measures of the overall R+D performance, involving general managers in R+D decision-makings, etc.). (4) CTOs can gauge the existence of leadership gaps, and start improving their credibility, if necessary, by taking a straightforward set of steps. Furthermore, the authors stress that the appropriate leadership style should depend on two **contextual factors**: (1) the technological intensity of an industry and (2) the importance of technology to corporate strategy.

Uttal, Kantrow et al. (1992) argue further that the **credibility** of the CTO and in particular their **relation to the CEO** (Chief Executive Officer) is of vital importance. In order to successfully position a CTO in a company they propose that CTOs should act as "technical businessmen, making R+D accountable to the corporation, and regularly involving general managers in R+D decisions". CTOs have to build up a trustful relation with CEOs and vice versa.

As third empirically grounded study by Thurlings, Bert et al. (1996) was presented in a very short paper consisting of just two pages. Based on semi structured interviews and an iterative survey approach with 25 corporate CTOs and 22 academics these researchers identified four "**trends in managing industrial innovations**". The CTOs themselves were not the direct focus of this study, but rather CTO´s opinions of the future technology management agenda. However we report on their findings because implicitly these issues directly relate to major issues of importance for their role in the organization. Firstly, as an important point, CTOs pointed out that "design will be the incorporation of the full context of the application, meaning the interrelation with other products in that application, and the change of the customer's perception. Obviously, products will still be developed, but only as part of interrelated products and services". Secondly, CTOs expected a change in the "evolution of the innovation process", i.e. that technical specialists will become more and more substituted by cross-functional experts and this change will deeply influence the organization for innovation. Thirdly, CTOs included in this research pointed out that the "strategic management of innovative activities will become increasingly value chain focused, i.e. integrating competitors and other key players like customers or suppliers in the company's innovation strategy". Further, academics and CTOs agreed on three important issues on the agenda for managing technology: (1) the role of technology in corporate strategy, (2) understanding the efficient and effective organization of intra-company innovation processes, and (3) an improved understanding of the management of large and complex projects.

The fourth study was presented by MIT Professor Roberts (2001) based on a large empirical survey. Roberts investigated R+D management in 209 international corporations on a global scale. Although this research did not specifically deal with CTO matters, some statistical data was collected regarding the CTO function and reported upon in a specific section of his paper. Robert's focus within this research was mainly on **regional differences concerning the organization of R+D**. One interesting finding was that over 90 percent of Japanese companies had installed a CTO on the "board of directors/ main board", while in Europe this applied to only 35 percent and in the US only to 8 percent. In comparison with an earlier study from 1992, Roberts (2001) even found that for Europe and the US these numbers had declined. Unfortunately Roberts (2001) neither found a reasonable explanation for the fact that so much more Japanese companies have CTOs nor for the decline in Europe and the US.

However, on a lower lever, CTOs were quite well represented in the management committees of European as well as US companies. While Japanese companies in total reported to have the highest share of CTOs (above 90 percent), around 60 percent of all European and US companies report to have a CTO at least on lower hierarchical levels.

In a further part of his study, Roberts (2001) analyzed the **CEO's involvement in technological strategy decisions** and their relationship to the CTO. He briefly notes, that "technically trained CEOs show no special bias in regard to appointing CTOs either to the company board of directors or even to the firm's senior management committee". Further, Roberts (2001) reports that in general CEOs are often highly involved in five aspects of technology management: 1) technology strategy development, 2) overall R+D budget decisions, 3) R+D project selection/prioritization, 4) internal technology resource

allocation, and 5) selection of outside technology investments. This involvement might influence the relationship of the CTO and CEO and thereby the role of the CTO.

Finally, the most recent empirical study by Lorenzen, Tietze et al. (2006), not having being published yet, shall be mentioned here. Lorenzen, Tietze et al. (2006) surveyed 18 executive head-hunters in Germany regarding their perceptions of CTO responsibilities and qualifications. This survey revealed, in decreasing order of relevance, the following nine **tasks of importance to CTOs**: (1) observation of the technical surroundings to search for important innovative technologies for the company, (2) observation of development activities and technology portfolios of competitors, (3) coordination and realization of due diligence in mergers and acquisitions (incl. Start-Ups), (4) building and maintain networks to experts, universities and other CTOs, (5) consulting the CEO and other members of the executive board in strategic matters, (6) communicational and representational tasks such as presentation of new products in the media, (7) development of IT – infrastructure, (8) strategic, cross-sectional management of the technology portfolio (including technology acquisition, technology utilization and development cooperations), (9) coordination of R+D projects.

Additionally, the paper analyzed 34 international CTO job advertisements. Again, in decreasing order of relevance, Lorenzen, Tietze et al. (2006) identified the following six **qualifications to be relevant for CTOs**: (1) specific long term experience in business area, (2) experience as a CTO or senior project manager, (3) long term experience in team management, (4) experience in negotiating with suppliers and third parties, (5) a record of achievement, (6) international experience.

Concerning the needed **skills required from CTOs** they identified the following eight areas: (1) broad based technical background and knowledge in business area, (2) strong verbal/written communicational skills, (3) team/people leadership skills, (4) language skills, (5) project management skills, (6) ability to be the top technical role for engineers, (7) visionary skills, (8) problem solving/ analytical skills.

In summary we can conclude that a very limited solid, empirically founded understanding of the CTO has been developed so far. The few empirical studies that focus exclusively on the CTO or topics directly related to the CTO, draw mainly on pretty small samples. The following list summarizes briefly the few topics being investigated by the authors of the papers presented above:

- installing a CTO in a firm (including the motivations),
- typical tasks ("job descriptions"), the breath and depth of their responsibilities and personal backgrounds,
- leadership styles of CTOs and their relationship with other executives of their firm, especially the CEO and
- finally, the distribution of CTOs on different hierarchical levels in a global perspective.

Industry- or company-size specific investigations do not exist to our knowledge, and as mentioned above, no more recent studies are available. Other issues like the "more strategical versus operational responsibility" of a CTO or the direct project – responsibility have not been specifically investigated. Further, trends and shifts in the perception of tasks and responsibilities of the CTO have not yet been closely studied by researchers. However, this topic in particular might be of relevance since technology management has changed so much during the last decade. Therefore it seems most likely that the tasks and responsibilities and thereby not only the required skills and qualifications but also their organizational integration and power might have changed dramatically.

In the following section we will continue to present a number of models and discussion presented in "more" conceptual papers having no solid empirical foundation, but being of general interest in relation to the CTO.

2.2 Conceptual papers and non-empirically founded work

In general we found conceptual papers published on the CTO or related issues in 14 journals with the earliest being published by O'Neill and Bridenbaugh (1992) 14 years ago. These papers were pub-

lished in various journals mostly targeting practitioners. Notably, by far the majority of the papers were published in the journal "Research Technology Management". Some of the CTO papers that we found but do not present here were even published in non-core technology management journals, such as Health Management Technology, Journal of Clinical Engineering.

Most of the conceptual papers we found are presented on just about two to three pages, and often are field or experience reports of individual CTOs (e.g. Fox (2005), Grochow (2003; Melymuka (2003), Lamparter (2000), Spencer and Cram (2004), Takahashi (2002), Zachary (2000)). Therefore we concentrate on reviewing six articles in chronological order in more detail, which we believe to be of certain theoretical value and presume to be relevant for the purpose developing a better understanding of the CTO (O'Neill and Bridenbaugh (1992), Gwynne (1996), Larson (1996; D.P. Parker and Associates (2002), Smith (2003), and Smith (2004)).

Additionally, we present findings from two very recent papers (Medcof (2006), Pala (2006)) that we found relevant and useful, but did not appear in our literature search, but were brought to us from colleagues during our research. Table 2 gives a brief overview of these papers and their major contents.

Paper	Main content
O'Neill and Bridenbaugh (1992); Larson (1996)	credibility of CTOs, ways to achieve/strengthen credibility
D.P. Parker and Associates (2002); Smith (2003); Medcof (2006)	authority, responsibilities, power and influence, skills and qualifications of CTOs
Gwynne (1996);	CTO as line manager with profit and loss responsibility
Smith (2003)	key responsibilities of CTOs, CTO relationships with other corporate functions and especially with the CEO
Smith (2004)	roles/types of CTOs, barriers respectively enablers
Giordan (2004))	developments and trends for the CTO, especially towards a "Chief Asset Officer" (CAO)
Pala (2006)	CTOs' contribution to company performance
Melymuka (2003); Grochow (2003)	comparison/delimitation of the CTO vs. the CIO

Table 2: Overview of CTO related topics in conceptual papers

The earliest paper was presented by O'Neill and Bridenbaugh (1992), who particularly discuss the issue of the **CTO's credibility and the relation between the CTO and the CEO**. They distinguish three different attributes of enabling or allowing the CTO to build up credibility on three different levels: (1) personal (respect for others, integrity, trust, accountability, independence), (2) professional (technical excellence, business savvy, customer understanding, global perspective, ability to collaborate/build partnerships), and (3) organizational (results delivered in a timely manner and satisfying specific customer needs). While each of these levels is of importance, O'Neill and Bridenbaugh (1992) suggest that specifically the "ability to develop and lead a technical organization focused on the application of scientific and engineering knowledge to satisfy the customers" is of paramount importance. They further highlight that CTOs should "possess commercial savvy, a global perspective and the ability to form productive partnerships that complement their acumen".

Gwynne (1996) in his paper advocates the **role of the CTO as a line manager**. His criticism is that CTOs „often lack credibility in a management culture focused on the bottom line". Adding line re-

sponsibility to their role "helps CTOs to understand the pressures that drive the companies" amd a „line job provides these CTOs with a true feeling for customer's needs". "The profit and loss responsibility that accompanies the line job will earn the CTO credibility with both top management and business units". He concludes that "the more line responsibility the CTO has, the better he can deliver on his promises".

In a another paper, Larson (1996) argues in a similar manner that "the most critical factor for an R+D leader is his or her **credibility"** and discusses different issues affecting the credibility of CTOs. He further argues that strong performing CTOs can be distinguished by a "number of traits, among which credibility is foremost". Maintaining credibility in the future will require leaders to leverage internal R+D capabilities with external resources from around the world, to deliver long-term as well as short-term value, to facilitate rapid learning, and to focus on speed in the commercialization of new technology.

In their paper, D.P. Parker and Associates (2002), an executive search firm that serves clients in a spectrum of technology-related industries, reports conclusions based on their own experience concerning **wanted/needed skills and qualifications,** that guides them "in seeking out today's most desirable and impactful CTOs". This list includes the following eight personal skills: (1) Strong leadership characteristics; (2) a broad interdisciplinary, technical background; (3) experience in operations, marketing and/or general management; (4) having been involved in an international assignment; (5) a strategic/conceptual orientation; (6) experience in evaluating and negotiating partnerships, joint ventures, acquisitions; (7) advanced communication skills and (8) a persuasive personality.

From his experience as acting as a CTO, Smith (2003) reports some insights on how the **role of R+D leadership has been changing** since the 1980s up to the creation of CTO positions since the 1980s. He thereby presents a list of **six key responsibilities** for CTOs: (1) monitoring new technologies and assessing their potential to become new products or services, (2) overseeing the selection of research projects, (3) ensuring that technologies have the potential to and add value to the company (strategic innovation), (4) providing reliable technical assessments of potential M&As, (5) presenting the company and it's products including future plans to the trade media (marketing and media relations), (6) participating in government, academia, and industry groups where there are opportunities to promote the company's reputation and to capture valuable information. Additionally, Smith (2003) discusses the **relationships of CTOs with other key stakeholders** of the firm, such as the CEO and the executive committee, the CIO, chief scientists, R+D labs and its manager as well as the sales and marketing department.

In a second paper, after having reflected upon the backgrounds, responsibilities, and missions of "a number of CTOs", Smith (2004) proposes a model with six distinct categories or **types of CTOs**. According to the business phase in which a company currently operates (emergence, stabilization, expansion or dominance), he develops the following typologies for a CTO: Genius (founder/creator of major product innovations), director (scientist /researcher in innovation management), administrator (manager/accountant for efficient deployment), advocate (service/user, customer feature), executive (engineer/scientist for strategic management) and finally void (no CTO/no new technology).

Like the work by D.P. Parker and Associates (2002) presented in this section, the "wish list" of Smith is conceptually interesting but not based on a solid empirical foundation. It also idealizes certain personality traits as being key for fulfilling the CTO function. Besides its theoretical value there will always remain the practical problem of identifying a person who possesses all such wanted traits or skills in the real world.

Medcof (2006) based on his literature review suggests that CTOs who aspire to have significant influence in their organizations should build their **power bases in ownership positions** in the firm, in strong personal relationships in networks inside and outside of the firm, and in general business savvy. He further discusses the importance of a good **relationship with the CEO** and argues that the CEO **leadership style** is of vital importance to the success of the CTO. Based on this review and conceptual discussions, Medcof (2006) develops a set of three propositions: (1) The higher the CTO on the inclusion gradient (percentage of top team meetings attended) the greater his influence on the strategy of the organization; (2) The more different positions the CTO has held in the firm (by interview or access

to resumes) the greater his power; (3) The greater the number of corporate boards the CTO sits on (by interview or access to resumes) the greater his power.

Finally Pala (2006) (still unpublished) proposes a model showing how the **CTOs' effect on the overall company performance** can be assessed. From reviewing the literature, he argues that in particular three factors are of vital influence in this context: (1) the technological intensity of the industry, (2) the importance of technology for the company, and (3) the chairman's perception of the environment. This however is strongly influenced by the company size and the industry growth rate (serving as control variables in a likely research).

Besides the findings presented from the papers above, we would finally like to highlight some additional topics that are touched upon by a few authors in various short papers. Although not very detailed, we found that there seems to be an ongoing discussion of the **delimitation of CTOs and CIOs** (see e.g. Melymuka (2003), Grochow (2003)). Whether this is just a concern in particular companies or industries will be seen in the years to come. Further, Giordan (2004) starts a discussion about the **further development of the CTO** towards the Chief Asset Officer (CAO), especially in context of the growing importance of Intellectual Property for many companies.

3. The current role of the CTO

In the following two sections we will argue (1) that there is need to do more specific research on the CTO and (2) present our research approach. We will argue in favour of an explorative approach, followed by a larger empirical survey. Because of the presumably existing impact of industry as well as context specific factors, we will further argue the need to carry out research within the boundaries of separate industries. This will however not solve the problem that even within one industry companies are often very differently structured, characterized by different cultures and follow different strategies. Nevertheless we will discuss such differences when we present the results of our own research in chapter four, so far these exist.

3.1 Updating the CTO research agenda

Reviewing the CTO specific literature shows that a stream of researchers in the past have concentrated (1) on motives to install a CTO from a board- or CEO perspective, (2) task-related issues (deliverables, responsibilities and authority of the CTO) and (3) leadership-roles expected to be fulfilled by a CTO (e.g. styles and motivational roles). Researchers in this field have further looked into cultural or context specific questions (e.g. like the distribution of CTOs in the US versus Japan or Europe). Again other researchers have tried to identify and sketch typical characteristics or traits of the "ideal" CTO and his relations to other functions, specifically the CEO.

Most of the empirically grounded work in this field as well as the "conceptual" work was conducted more then 10 years ago and it is questionable if the findings reported by these researchers still reflect industrial practice. Besides the "conceptual" work, presented in this paper, has not yet been challenged by empirical work and most of this work was presented in the 1990ies.

Since no more actual data on the CTO are available it is difficult to judge, if this position today has become a "standard" in the industry or not, and whether this is country and industry specific. Furthermore, if the task-profiles, granted authorizations and responsibilities have remained more or less the same as described in the literature or if a change in the understanding of the CTO-role(s) and his duties have taken place in the meanwhile (e.g. a shift from strategic to more operational tasks).

Besides the need to "update" the research on the CTO and to thereby find answers for those questions, which have been addressed by researchers in the past, there are a number of "new" questions which have not been addressed so far and which deserve consideration. For example one key question addresses the existence and prevalence of CTOs in various industries, countries and contextual environments (countries, firm-size and industry). Another question would be, if companies have different types of CTOs (e.g. on different hierarchical levels or in different organizational formats like central functions or divisions). A third question is whether the "label" CTOs reflects a common understanding

of roles, tasks and authority, or if very different interpretations exist. During our literature research, we observed many indications that this might not be the case to a significant degree, and that a very heterogenic understanding seems to be prevalent. In order to develop a better understanding concerning these various issues we decided to first carry out a number of in-depth interviews with CTOs or responsible R+D-Managers fulfilling "typical" CTO tasks.

3.2 Research approach

Based on the literature presented in this paper we designed a semi structured interview questionnaire addressing CTOs with task- and responsibility-related questions (see appendix 1). This questionnaire further contained questions concerning the CTO´s career- and educational-background, the size and qualification of his team, his interaction with internal/external networks as well as his perception of future trends.

As Roberts (2001) demonstrated that most large corporations in Japan positioned a CTO on the highest corporate level (highest penetration/diffusion rate), we choose the Japanese market for our interviews. Our motivation was to develop a fresh view of CTOs, focusing on large corporations in the manufacturing and electronics industries. The research project was welcomed in Japan and even sponsored by the JSPS (Japanese Society for the Promotion of Science), which we would kindly like to thank for their support.

Our research was further supported by our Japanese partner Prof. Akio Nagahira from the Tohoku University in Sendai. He approached about 100 large electrical engineering companies in Japan in order to locate CTOs and to arrange personal interviews. 20 companies responded saying that they have a CTO or an equivalent position, although only eight companies finally agreed to participate in our research. These companies were Omron, Olympus, Yokogawa, Ishikawaija, Richo, Fujitsu, Toshiba and Denso Electric, all large Japanese electrical corporations with more then 50.000 employees and revenues of more then 10 billion EURO. All of these companies are globally active, with large manufacturing facilities oversees. Furthermore, all companies are divisionally organized, have a centrally organized R+D plus application-oriented R+D in their various (product) divisions. All companies massively invest into developing new products and services, spending between 10-15% of their revenues.

4. Results from interviews in Japan

In the following section we present the results from the eight interviews conducted during September 2006. Following the questionnaire, this section is divided into five parts. The first part presents some general observations we made within the course of our field work in Japan. The second part relates to the organizational influence and authority of CTOs, while the third part discusses major findings regarding tasks and responsibilities of CTOs. The fourth part presents trends on the agenda of CTOs, and the final section describes the career paths of our interview partners giving some insights into their professional backgrounds. At the end of each section, a number of propositions are presented, summarizing major observations. Due to the limited number of our interviews, we do not claim, that these have the quality of hypotheses.

4.1 General observations

A first remarkable observation within the course of our work is that "only" 20% of the 100 companies that were approached to participate in our research claimed to have a CTO or an equivalent position.

Interviewing eight Japanese managers, we further realized that only three of them were explicitly using the title CTO and perceived themselves as being the CTO of their firm. In all other companies, the term was avoided as it does not reflect Japanese corporate language. In the companies not using the CTO label, titles like *Senior Vice President Technology*, *General Manager Technology* or *Director Corporate Research* were used for managers, who are fulfilling tasks, that are typically associated with a CTO.

Irrespective of their formal titles, in two cases, our interviewees were board members, in two cases interviewees were a member of the executive management committee, while in four cases interviewees were a member of both. In one case, the CTO, actually with the particular CTO label, was additionally part of a specific executive management inner core group, which the company calls Group Management Committee (GMC). This committee includes besides the CTO, the CFO (Chief Financial Officer), the CEO and the CIO (Chief Information Officer).

These observations can be summarized in the following three propositions:

P 1.1: *Only a relatively small number (less then 20%) of large Japanese Electrical Engineering Companies of today have **formally** installed a CTO.*

P 1.2: *The CTO in the Japanese Industry is typically a board member, an executive board member or a member of both management groups.*

P1.3: *A CTO in the Japanese Industry is assumed to be the highest executive responsible for all major technology related matters and decisions, directly reporting to the President/CEO and/or the board of the company, and based in the corporation's headquarters or corporate R+D centre.*

4.2 Authority and organizational influence

To develop a clearer picture concerning the organizational influence and authority of CTOs, we asked our interviewees three sets of questions: (1) How many employees are working directly for you, i.e. are directly subordinated (span of control), (2) Do you have full or shared budget and approval authority over appointments of senior staff in combination with different organizational units (e.g. central R+D, divisional R+D, etc.), (3) How much do you need to involve your CEO or the board for certain decisions (e.g. Technology strategy of the firm, project selection, etc.), and how often do you personally and/or formally meet your CEO/ President.

We chose these three categories of questions as indicators to describe the legal and formal authority as well as the informal influence of the CTO in an organisation as these are mentioned in the literature being of particular importance. Question one affects the span of control and is an indicator for assessing the workload a CTO can manage either based on his own or with the support of other staff, not directly reporting to him (e.g. for checking budget proposals, technology analysis, etc). Surprisingly there was no data, regarding the size of the CTO department, reported in the literature so far. Question two related to the study of Adler and Ferdows (1990) and can be interpreted as a measure for the de-facto influence of the CTO concerning resource allocations, e.g. in combination with R+D portfolio decisions and corresponding budgets. The list of issues regarding the CEO involvement in the work of the CTO relates to a list proposed by Roberts (2001). This question can be seen as an indicator for the freedom to decide without further involving other organizational parties, specifically the CEO, the president or the board of the company.

Span of control

When asked how many employees are "directly working" for the interview partner, answers varied from zero up to 150 (the latter being the case when the CTO was responsible for a corporate R+D-Center). Only in one case, our interviewee was supported by dedicated administrative managers. In the other seven cases none of the interviewees had such "special" administrative group, and are instead relying on people in various departments (central and decentralised R+D). Interestingly, none of the interviewees reported that a significant share of their staff had a business background.

In one case, the CTO is limited to giving only "recommendations" to other executives, but he explained that his recommendations have a strong impact and are taken seriously. Asked why, he gave a reasonable explanation, which is strongly rooted in the Japanese company culture and the seniority

principle, which still plays an important role. This provides executives with much authority and allows them to receive strong support by departments, even if they do not directly report to them.

Budget and approval authority over appointments

The results of our questions regarding the CTO's *budget* and *approval authority* are as follows: Notably, in all companies, the CTOs or equivalents had full budget and approval authority for corporate R+D. In one company the CTO additionally has authority for all divisional R+D-activities with full budget and approval authority including appointments of senior R+D staff. In four cases the CTOs or equivalent positions are involved in budget and approval decisions within the divisional R+D units, but cannot solely make decisions. In one of these cases, the advice was mandatory if the divisional R+D are engaging in a project of high technological novelty. In another case, the CTO leads the "Technology & Intellectual Property Group" on top of his other duties, which include - besides the Corporate Research and Development Centre - the Technology Planning Division, the Intellectual Property Division and the Software Engineering Center. Again, he has no authority for divisional R+D, but instead so-called CTEs (Chief Technology Executive) in each product division. The role of these CTEs is to support and steer the implementation of quality assurance measures, specifically Six-Sigma, in combination with development and manufacturing connected to their organizational unit. Furthermore, they have to support their division head and the CTO to plan and schedule development budgets, especially projects and activities, where central and divisional R+D staff works together. The CTEs are not directly subordinated to the CTO, but closely work together with him and his staff to plan and coordinate development activities. In another case the CTO is additionally involved in technology related decisions in M&A, working jointly with a specific company unit dealing only with M&As.

Involving the President and/or the CEO

When asked about the independency in decision making from the CEO, and therefore the own power of the CTO, i.e. by asking how much the CEO and/or the President of the company needs to be involved for certain decisions, our interviews revealed a relatively homogeneous picture.

CTOs can generally on their own allocate internal resources and select/prioritize technology development and R+D projects, corresponding to the full corporate R+D budget and approval authority. The overall R+D budget is decided jointly with the CEO. In contrast the CEO/president needs to be fully involved, i.e. fully decides, when it comes to "selections of outside technology investments" or the "technology strategy development".

How much do you have to involve your President/ CEO or the board in the following issues	Average value (N=8) [1]	Median value
Internal technology resource allocation	2,63	3,00
Project selection/prioritization	3,13	3,50
Overall R&D budget	3,75	4,00
Selection of outside technology investments	4,00	4,00
Technology strategy development	4,50	5,00

[1] Scale: 1=not involved / 5= highly involved

Table 3 - CEO involvement in CTO work

In this context we further wanted to know how closely our interviewees are connected with their CEO/President and how they influence *his* decision making. Therefore we asked "how often do you "personally and/or formally meet your CEO/ President". Besides all interviewees agreed on the importance of this issue, and meet the CEO/President at least monthly (3) or even weekly (5), the interview-

ees said that important issues were not only discussed during formal meetings but instead often during informal meetings ("Luncheons"). Apparently, CTOs meet their CEO/President much more frequently informally, and use these opportunities to discuss technological issues.

If we try to summarize the various observations presented in this section, the following picture emerges: Looking at all the cases illustrated above, we first see the variety of different CTO models implemented in the Japanese Electrical Engineering Industry, which could be described by the three dimensions. This variety affects the **breadth of authority**, ranging from authority for corporate research activities only, corporate research plus (e.g. IP, software development, quality assurance, etc.), or full authority for basically all research and development activities of their firm. It further affects their **depth of authority** or more specific the *span of control*, since some CTOs only have a small number of staff or a large organisation, which they directly supervise. In one case, the CTO leads a virtual, but presumably very supportive, organization based on divisional CTEs (Chief Technology Executive). When it comes to the **independency on strategic decisions**, i.e. the involvement of the CEO/president in certain issues, our interviews revealed a very homogenous picture that shows that CTOs generally can decide on their own on all issues related to internal processes of corporate R+D (e.g. Internal technology resource allocation, Project selection/prioritization). While the Overall R+D budget is decided jointly with the CEO, the CEO needs to be fully involved in issues relevant to the overall corporate strategy, i.e. the "selection of outside technology investments" and "technology strategy development".

Furthermore, concerning *budget and approval authority*, two cases become visible:

(A) One CTO is responsible for basically all R+D activities of his firm, including central research as well as divisional development work. He is the highest ranked technology leader in his firm, and has full budget (corporate/divisional) and approval authority for senior manager. Consequently the need to involve the CEO and the board concerning "his" budget and allocation decisions are limited to decisions which substantially affect the strategy of the company. Official meetings with the CEO are organized on a monthly basis.

(B) In all other cases CTOs are head of the central R+D of their firm. Their budget and approval authority is limited to this corporate unit and he has none or *shared* authority concerning divisional development work. The latter depends very much on the nature of that work and the need to staff divisional projects with technical expertise from central R+D ("case by case"). Consequently the need to involve the CEO and the board concerning important decisions is much more important compared to the first case. Official meetings with the CEO are organized again monthly.

A first, very careful interpretation of these observations may lead us to the following three propositions, which are clearly not representing the quality of hypotheses:

P 2.1: *CTOs in large Japanese Electrical Engineering companies are typically supported by technical/non-technical staff from corporate and/or divisional R+D. CTOs that have their own group of dedicated administrative staff are the exception.*

P 2.2: *In the majority of cases the CTOs have authority for all central R+D-activities (Corporate R+D) with full budget and approval authority concerning appointments of senior R+D staff for this function only. In only few cases (less then 10%) the CTO has full control over all R+D activities (corporate and divisional), including full budget and approval authority.*

P 2.3: *CTOs without authority over either corporate research or both, corporate and divisional R+D, function as either "pure" coordinators or internal consultants, are not to be found in large Japanese Electrical Engineering companies.*

4.3 Tasks and responsibilities of CTOs

We asked our interviewees which tasks and responsibilities they rated to be *how* important in fulfilling their work based on a five-point Likert scale for a given list of activities (see Table 3) mainly derived from prior studies by Adler and Ferdows (1990; Smith (2003) and to some extent from Lorenzen, Tietze et al. (2006).

Although the number of our interviews was small, we received a homogeneous picture concerning what they rated to be very important tasks with minimal deviations. Two tasks/responsibilities were pointed out to be of highest importance through all interviews: (1) "Managing the selection of research projects to ensure that these have the potential to add value to the company (strategic innovation)", (2) "Consulting the CEO and the top management team in technology decisions". Further four tasks were ranked to be important "Coordination among different business units and across functional areas, to ensure synergy and efficiency", "Managing technology development teams/projects" and "Participating in governmental, academic or industrial groups to promote the company, to capture valuable data and to support networking", and "Assessing potential M&As, alliances or co operations from a technological and a business perspective". However, especially for these tasks, few interviewees pointed out that they are solely responsible for technology matters for M&As. The two tasks "Monitoring new technologies and assessing their potential for new products/services for your company" and "Representing the company, its products and technologies to the "external world" including the media" scored lowest, and are therefore of lowest importance. In addition to this ranking, all tasks were rated to be of above average importance.

How important do you rate the following responsibilities in fulfilling your work?	Average value (N=8) [1]	Median value
Managing the selection of research projects to ensure that these add value to the company	4,75	5,00
Consulting the CEO and the top management team in technology decisions	4,75	5,00
Coordination among different business units and across functional areas, to ensure synergy and efficiency	4,50	5,00
Managing technology development teams/projects	4,25	5,00
Participating in governmental, academic or industrial groups to promote the company, to capture valuable data and to support networking	4,13	4,50
Assessing potential M&As, alliances or co operations from a technological and a business perspective	4,13	4,00
Monitoring new technologies and assessing their potential for new products/services for your company	4,00	4,00
Representing the company, its products and technologies to the "external world" including the media	3,75	3,50

[1] Scale: 1 = of no importance / 5 = of high importance

Table 3: List of tasks and responsibilities; values representing average (median)

We further asked the interviewees how they did the ratings and why certain tasks play a higher or lower important role in their daily work. All of our interview partners are members of the board or their executive committee, either directly reporting to the President/CEO of their company or to the board. Because of their hierarchical position and the breadth of responsibilities, their personal involvement in project work (e.g. being personally involved in technology or product development projects) and routine activities (e.g. technology monitoring) is limited. Such activities are typically fulfilled by others, who are either subordinated to the CTO (e.g. managers/staff from the corporate R+D) or are from a different organizational unit (e.g. business unit R+D).

We further asked whether *other* tasks were of vital importance to CTOs. In total during our eight interviews, only nine different additional tasks were mentioned by the interviewees.

Five interviewees highlighted the importance to develop a technology strategy, while three interviewees particularly emphasised the growing importance of managing Intellectual Property (IP). They mentioned the need to harmonize IP-related activities with the standardization of new technologies and products.

Three interviewees dedicated a certain part of their time on human resources or career development issues of future corporate top managers or highly qualified engineering staff. As being specifically important, interviewees mentioned that "identifying future team leaders to run development projects and supporting these high potentials to become leaders is one of their key tasks".

Two interviewees mentioned that they were also responsible for the company's information systems, including the manufacturing systems, a task typically dedicated to the CIO (Chief Information Officer).

Furthermore, one interviewee said that his role was to create a corporation wide awareness for the importance of breakthrough innovations: "*Corporate R+D today just follows the technological roadmap, but we need to develop breakthrough innovations. I need to protect the company from such a mood*".

Additionally, another interviewee mentioned the need to supervise the quality control activities for which CTEs in their respective product divisions are held responsible. This task seems to be obviously connected to the company's efforts to implement a Six-Sigma quality control system throughout the whole corporation.

Finally, three additional tasks were mentioned by one of the interviewees: "finding new ideas (technology road mapping)", "engagement in product development", and "management of the early stages in the development of cutting edge products".

To sum up – again under the restriction of the small number of cases we looked at – we suggest the following four further propositions:

P 3.1: *The most important tasks and responsibilities of CTOs in the Japanese Electrical Engineering industry include (1) managing the selection of major research projects, (2) consulting the CEO and the top management team in technology related decisions, and (3) coordinating among different business units and across functional areas, to ensure synergy and efficiency of technologies.*

P 3.2: *Further important activities of the CTO include the growing importance of Intellectual Property (IP) and the need to harmonize all IP-related activities with the standardization of new technologies and products as well as creating a corporation wide awareness for the importance of breakthrough innovations.*

P3.3: *Identifying future team leaders to run research hence technology development projects and supporting these high potentials to become leaders is another important CTO task*

P3.4: *In some companies, there is no clear delimitation between the CTO (Chief Information Officer) and the CIO. That is to say the tasks of the CTOs include tasks typically associated with the CIO, e.g. the company's information systems as well for manufacturing.*

4.4 Important trends and key-issues on the CTO agenda

Next we asked the interviewees, which issues and trends they assumed would become highly relevant for their firms over the next 3-5 years. They were asked to assess the importance of personal technology management issues based on a list derived by Thurlings, Bert et al. (1996) from interviews with leading scholars and senior technology managers. Table 4 presents the results from these estimations in decreasing order of relevance.

What issues do you see as being highly relevant for your company over the next 3-5 years?	Average value (N=8) [1]	Median value
The role and proper use of technology in order to develop a competitive strategy	4,50	5,00
Creating and implementing an efficient and effective innovation process	4,50	5,00
Developing an Intellectual Property Strategy	4,38	5,00
Managing large and complex innovation projects	4,13	5,00
Managing interfunctional and divisional cooperation to significantly reduce product development cycles	3,63	3,00

[1] Scale: 1 = of no importance / 5 = of high importance

Table 4: Issues/trends on the technology management agenda to become highly relevant for the company over the next 3-5 years.

Despite the small number of our interviews, we again found a homogeneous picture from our interview partners concerning what they rated to become major issues and challenges for their company in the near future. Basically all items on this list were - despite that the list is already ten years old - still ranked to be of significant importance. The three items "The role and proper use of technology in order to develop a competitive strategy", "Creating and implementing an efficient and effective innovation process", and "Developing an Intellectual Property Strategy" ranked highest with each six out of the eight interviewees ticking the highest mark. "Managing large and complex innovation projects" still seems to be of importance, with five interviewees ticking the highest mark. Only the point „Managing interdivisional cooperation to significantly reduce product development cycles" was rated as being of less importance in the future (probably because this reflects the challenges of the past and Japanese companies are generally considered to be able to develop products quickly relative to others). Notably, none of the interviewees gave the lowest mark to any of these items.

We then asked if any other important trends existed that were not covered by the list to check for any new important items on the technology management agenda and to determine that whether the list has become outdated. Five new items appeared to be of importance to the CTOs, which included the following aspects (count of times mentioned in brackets):

- Creating promising project teams, including the design of career development plans for successful technology project leaders (4)

- Integrating the corporate R+D-, and technology strategy within the overall (competitive) strategy of the firm (2)

- Implementing portfolio management to better manage enterprise resources (1),

- Diversification by identifying attractive new product opportunities (1)

- Fostering cooperation with external partners including competitors to create new business opportunities (2)

Due to time restrictions we did not discuss these trends and issues any further especially not in relation to the role of the CTO.

These observations can be summarized in the following proposition:

P 4.1: *Creating promising project teams, including the design of career development plans for successful technology project leaders are becoming more important tasks for CTOs in the near future (3-5 years).*

4.5 Background and career patterns

All interviewees in the Japanese corporations spent their entire working life with the same corporation, having a cumulated working experience that varied between 23 and 39 years (34.3 years on average). Before being appointed to their current position, four interview partners worked exclusively for corporate R+D and in three cases, the managers had worked for a divisional R+D unit in later years. The average time of fulfilling a task before being promoted, was typically two years.

Three managers became General Manager of the division, for which they previously had led the R+D unit. Today, these two are "back" to corporate R+D, which they are managing as a board member.

Two CTOs reported to having been assigned to the central marketing department for four respectively two years, and one CTO as having been sent to the Marketing and Sales department of a product division. These appointments ended with the nomination. In one case, this decision was made by the president of this company himself, since he was convinced that the "future CTO of the company would have possess up substantial knowledge and experience in this field". Another CTO reported of having participated in a national research program sponsored by METI for 4 ½ years, having been released from his company's duties for that time. This person had also spent 2 ½ years in a post-Doc program at a leading US-University. The third CTO had – besides his duties to work for the Marketing-Department in one Product Division – acted as a CTE (Chief Technology Executive), responsible for Quality Assurance and reporting to the former CTO of the group.

Looking at the university degrees the CTOs hold, we found that seven out of eight interview partners have obtained a master degree in various fields of engineering (e.g. Mechanical, Process-/Chemical, Materials etc.) from Japanese Universities including Tokyo University, Osaka University or Tohoku University in Sendai. One interviewee had received a BA in precise machinery. Two CTOs possessed PhDs (both in the US) and had participated in various university-related research programs in the US and Canada. Despite the fact that all CTOs had a technical (engineering or natural sciences) background, none of them ever went through an MBA or an equivalent program.

Besides such educational or research related engagements in other countries, none of our interview partners had ever worked and lived outside of Japan, although all interviewed companies have subsidiaries in other countries and/or continents. All interviewed CTOs had spent almost all their professional career with the corporation, and particularly close to the headquarters or the corporate R+D centre. None of them had ever worked for another company outside the corporation.

When looking at the previous position our interview partner had held, notably half of our interview partners had been head of a corporate R+D centre. Two of them additionally served as head of corporate technology strategy. Two further interviewees had been head of a certain business units before (e.g. medical systems, industrial automation). Furthermore, one interviewee was Senior Vice President of the corporation before he became president of the corporate R+D centre, that actually has the legal status of an independent company.

It is difficult and not our intention to draw final conclusions from these few findings, beside the fact that all CTOs in our sample have a technical background and have made their career within the corporate or divisional R+D of their firm, except for the three, who were transferred to a Marketing or Sales function within a particular business unit at least for some time. Although we lack the empirical data to prove, we believe that these findings are typically "Japanese" and therefore represent the style of corporate culture, which can often be found in large Japanese companies (i.e. life time employment).

Our observations lead us to the following four propositions:

P 5.1:   *CTOs in large Japanese engineering companies have a technical background in general, holding a master's degree in an Engineering related field. In addition, many CTOs have acquired a PhD or have participated in research programs in connection with nationally funded projects and/or leading university institutions.*

P 5.2:   *R+D managers were exposed to other functional areas like Marketing or Sales before being appointed to become the CTO.*

P 5.3:   *CTOs of large Japanese engineering companies have spent their career in close contact with the headquarters of their companies, and only a minority were exposed to different business environments outside of Japan for a substantial period.*

P 5.4:   *Most CTOs in large Japanese engineering companies had served as either head of the corporate R+D centre or had led a business unit of the corporation, before becoming CTO.*

5. Discussions of research findings with prior literature

Having reviewed the literature in chapter two and presented the results from our interviews, in the previous chapter, we now discuss how our results conform and therefore validate or rather sometimes contradict prior findings, in addition to discussing some new issues. In this section we follow a similar structure as in chapter four, starting with general observations, continuing with organizational influence and authority, then touching upon tasks and responsibilities, further trends on the CTO agenda, and then closing by discussing the career patterns of the interviewed CTOs.

Our **general observations** throughout this research lead us to question if there are as many CTOs in Japanese corporations as Roberts (2001) reported in his study. At least in the companies we approached, it seems that only 20% of the large electrical engineering companies employ a CTO. Roberts (2001) reports in his study a rate of about 96% on board level and 91% on the executive committee. Our results do not confirm these findings. Although some years lie in between his and our study, none of our interviewees indicated that they had heard about any corporation that had "delisted" such a function in recent years.

Comparing our results regarding the **organizational influence and authority**, especially the budget approval and appointment authority of CTOs with the study by Adler and Ferdows (1990), we cannot confirm their results that a significant share of CTOs have approval and appointment authority for all business units. Further, Adler and Ferdows (1990) showed that another portion of their interviewees had neither appointment nor approval authority for any business and R+D unit (corporate and product divisional). Again, we did not find support for this view in Japan. Most of our interviewees had approval and appointment authority for corporate R+D and sometimes shared authority for business unit R+D, but basically non had full approval and appointment authority for business units.

When looking further at the relationship of the CTO and the CEO, as mentioned as being of particularly importance by e.g. O'Neill (1992) we asked the CTOs "how often do you personally and/or formally meet your CEO/ President"? With this question we did not assess the quality of this relationship, since we only asked for the frequency of CTOs meeting their CEOs. We found that most of them meet their CEO weekly or at least monthly formally and much more frequently informally.

Furthermore, Roberts (2001) discusses the relationship of the CTO and the CEO and highlights that generally CEOs are often highly involved in five aspects of technology management: (1) technology strategy development, (2) overall R+D budget decisions, (3) R+D project selection/prioritization, (4) internal technology resource allocation, and (5) selection of outside technology investments. Although all of these points were rated as being relevant during our interviews we could just prove that (3) and (4) are particularly relevant.

The items on the list of **tasks/responsibilities** of CTOs that we tested was derived mainly from studies by Smith (2003) and Adler and Ferdows (1990) but to some extent also from a very recent study by Lorenzen, Tietze et al. (2006). Basically our findings confirm that the tasks on their lists are of certain importance to CTOs. This is noteworthy, since the study by Adler and Ferdows (1990) in particular is already more than 15 years old. However, looking at our results in more detail and comparing our results with the list and ranking from Adler and Ferdows (1990) our results are very similar. The lowest ranked task on both list was "Representing the company, its products and technologies to the "external world" including the media". Additionally, none of the interviewees specifically emphasized the importance of this point during the discussions. Comparing our results however with Lorenzen, Tietze et al. (2006) we find a more contradictory picture. Our top ranked task ("Managing the selection of research projects to ensure that these add value to the company") ranked lowest on their list, while their top ranked task ("Monitoring new technologies and assessing their potential for new products/services for your company") was the second last on our list. Actually, the second highest ranked task ("Observation of development activities and technology portfolios of competitors") on Lorenzen, Tietze et al. (2006) list, was not mentioned at all during our interviews. This might be due to the limited extent to which Japanese companies are outward oriented and carry out business intelligence,

since there is still a prevailing habit in the Japanese market to form cartels. When it comes to the task of "developing an IT-infrastructure", which ranked pretty low on the list by Lorenzen, Tietze et al. (2006), this task was also mentioned by only one interviewee. However, this tasks is discussed contradictory in the literature, e.g. by Grochow (2003) and Fisher (1999). In many companies the delimitation of the CTO profile does not seem to be sharp enough compared to the CIO.

Interviewees during our research also mentioned additional tasks that had not been suggested by any of these prior studies (e.g. creating promising project teams, including the design of career development plans for successful technology project leaders, etc.). This task was so far only mentioned as a side note in a practioner paper by O'Neill and Bridenbaugh (1992).

Looking at our results regarding **trends** on the agenda of CTOs in Japanese electrical engineering firms, most items on the list were still ranked to be of major importance, despite the fact that the list for which we derived the items we tested by Thurlings, Bert et al. (1996) was already ten years old. Especially our top two ranked items ("The role and proper use of technology in order to develop a competitive strategy " and "Creating and implementing an efficient and effective innovation process") are ranked in a similar manner as in the list of Thurlings, Bert et al. (1996).

When finally comparing the **career developments** of our interviewees with issues mentioned in prior literature, we find most notably that besides two of our interviewees, who had done their PhD abroad, none of our interviewees had "real" international working experience. One might guess that this seems to be (still) a typical cultural issue in Japanese companies, however is contradictory to what Robb (1994) mentions in his paper. He particularly emphasises that a CTO in a large corporation should have carried out "an international assignment". Robb (1994) further emphasizes on the "Operations, marketing and/or general management experience" of CTOs, which actually was the case with two interview partners, although none of the ones with the official label "CTO". These two persons had worked for the "global marketing group" in the "marketing of the digital media network company" before being appointed to their current position (i.e. the CTO equivalent). Further, the other items on the list of Robb (1994) could not be verified or disproved with our research approach.

Additionally, it seems noteworthy that basically all of our interviewees had never worked for another company outside their corporation during their whole career. However, this issue had not yet been discussed yet in the literature, neither as being an advantage nore a disadvantage. As this career development ("seniority principle") is (still) typical for large Japanese corporations, we might not find the same pattern in European or US corporations.

6. Conclusions, limitations of research and implications for future work in this field

This paper has presented results from a literature review of papers discussing task-related issues of CTOs as well as their relations with other groups and functions within their firm. We have further discussed a number of questions, which had not yet been addressed by researchers and presented the results of an actual CTO survey conducted in eight large Japanese corporations from the electrical engineering industry. Based on this we have outlined 15 propositions that will be tested through a large empirical survey to be undertaken in the end of 2006 in Japan, Europe and the US.

We are fully aware of the fact that our small number of interviews carried out in Japan will not allow any fundamental conclusions reflecting the state-of-the-art. This was not the intention of our work. We hope that our explorative work has enriched the perspective on CTOs in general and asked some specific questions, which have either not been addressed by researchers in the past or not recently examined. We are further reasonably confident that our propositions cover many important questions concerning the role of a CTO and his tasks and duties from a theoretical as well as a practitioner's perspective.

As we believed that our work has contributed to a better understanding of what a CTO is or not, we did not touch many other aspects. For example we did not discuss if, and if so to which extent, a company having installed a CTO might be more competitive or successful. We further did not take a closer look at internal and external success factors which may have an influence on the work of the CTO and his organizational acceptance. We also did not discuss contextual factors on various levels which

might have an influence, as well. Similarly, we did not touch upon personal issues relating to CTOs skills and qualifications, although these were discussed in the literature by e.g. Robb (1994), D.P. Parker and Associates (2002). With our research approach it would have seem questionable if we would have obtained validate answers asking CTOs to self-assess their skills and qualifications.

Furthermore, we did not investigate the quality of the relationship between the CTO and CEO, or further with other stakeholders although this topic was mentioned in some papers, e.g. Smith (2003). To discuss all these related issues, would have been beyond our time and budget capabilities, nevertheless these and probably many other more detailed questions may encourage other researchers to investigate CTOs in the future.

Finally, with our findings we can support Smith (2003), in his criticism, that companies filled the CTO position with deeply ingrained technical people, same as the heads of R+D laboratories. From our perspective most of our interviewees might miss the education and experience to "translate technological capabilities into strategic business decisions".

References

Adler, P. S. and K. Ferdows (1990). "The Chief Technology Officer." California Management Review **32**(3): 55.

D.P. Parker and Associates (2002). The changing role of the Chief technology officer.

Fisher, S. E. (1999). "Web redefines Role of CTO." InfoWorld **21**(48): 100.

Fox, S. (2005). "Seeking CTO Stars." InfoWorld.

Giordan, J. C. K., Nir (2004). "It´s time to think differently about R&D assets and the CTO´s role." Research Technology Management **47**(1): 9.

Grochow, J. M. (2003). "Dot-com CTOs' new roles." eWeek **20**(19): 41.

Gwynne, P. (1996). "The CTO as a Line Manager." Research Technology Management **39**(2).

Lamparter, W. C. (2000). "Do you need a Chief Technology Officer?" Americanprinter.com.

Larson, C. F. (1996). "Critical success factors for R&D leaders." Research Technology Management **39**(6): 19.

Lorenzen, P., F. Tietze and C. Herstatt (2006). "Tasks and Responsibilities of the Chief Technology Officer - What companies are seeking and what experts say." Working Paper (Hamburg University of Technology).

Medcof, J. W. (2006). The Chief Technology Officer and Organizational Power and Influence. IAMOT 2006, Peking.

Melymuka, K. (2003). "So you want to be a CTO." Computerworld **37**(12): 42.

O'Neill, P. and P. R. Bridenbaugh (1992). "Credibility between CEO and CTO - A CEO's perspective." Research Technology Management **35**(6): 25.

Pala, O. (2006). "Do CTOs affect performance? A proposed model for assessing the CTO-performance relationship." Working Paper (Sabanci University).

Robb, W. L. (1994). "Selling Technology to your CEO." Research Technology Management **37**(5): 43.

Roberts, E. B. (2001). "Benchmarking Global Strategic Management of Technology." Research Technology Management **44**(2): 25.

Smith, R. (2004). Maximizing the CTO´s Contribution to Innovation and Growth.

Smith, R. D. (2003). "The Chief Technology Officer: Strategic Responsibilities and Relationships." Research Technology Management **46**(4): 28.

Spencer, B. and N. Cram (2004). "Your Hospital Needs a Chief Technology Officer." Journal of Clinical Engineering **29**(3): 138-143.

Takahashi, D. (2002). Intel's new chief technology officer has a mess to clean up. Red Herring.

Thurlings, Bert, Debackere and Koenraad (1996). "Trends in managing industrial innovation - First insights from a field survey." Research Technology Management **39**(4): 13.

Uttal, B., A. Kantrow, L. H. Linden and S. B. Stock (1992). "Building R&D Leadership and Credibility." Research Technology Management **35**(3): 15.

Zachary, T. (2000). "Chief Technology Officer: One Title fits All." Computerworld **34**(32).

Appendix – Survey questions

1. Personal career
1.1. For how many years have you been working for this company?
1.2. What was your last professional position before your current function?
1.3. Could you please briefly describe major milestones in your career development :
1.4. In your previous career, how many years did you spend working in the following areas: (a) R+D / Engineering, (b) Marketing / Sales, (c) Manufacturing / Production, (d) Information & Communication Technology (ICT), (e) Other functional areas
1.5. Have you extensive international experience (e.g. did you work for over one year outside of Japan) and if yes, in which countries and for how long?
1.6. Have you worked for another company outside your corporation before and if yes, in which industries?
1.7. What university degrees you have acquired?
1.8. What is the major of your education?

2. Responsibilities / Tasks
2.1. How important do you rate the following responsibilities in fulfilling your work? (a) monitoring new technologies and assessing their potential for new products/services for your company, (b) managing the selection of research projects to ensure that these have the potential to add value to the company (strategic innovation), (c) coordination among different business units and across functional areas, to ensure synergy and efficiency, (d) managing technology development teams/projects, (e) assessing potential M&As, alliances or cooperations from a technological and a business perspective, (f) consulting the CEO and the top management team in technology decisions, (g) representing the company, its products and technologies to the "external world" including the media, (h) participating in governmental, academic or industrial groups to promote the company, to capture valuable data and to support networking, and/or (i) other
2.2. Are you member of the *company's board* or *executive committee*?
2.3. How many employees are directly working for you?
2.4. What is the approximate share of people with (a) a business background, (b) a technical background
2.5. Are you linked to more than one division within your corporation and if yes, to which ones?
2.6. Do you have full or shared budget and approval authority over appointments of senior technology related positions in (a) business units, (b) R+D units, (c) the corporate R+D unit, and/or (d) others
2.7. How much do you need to involve your CEO or the board in the following issues: (a) technology strategy development, (b) overall R+D budget, (c) project selection/prioritization, (d) internal technology resource allocation, (e) selection of outside technology investments, and/or (f) other tasks?
2.8. How often do you personally meet your CEO to discuss issues on your agenda?
2.9. How much of your time (roughly in percentage) do you spend on personal relationships in networks inside and outside the firm?
2.10. What issues do you see as being highly relevant for your company over the next 3-5 years? (a) the role and proper use of technology in order to develop a competitive strategy, (b) creating and implementing an efficient and effective innovation process, (c) managing large and complex innovation projects, (d) managing interfunctional and divisional cooperation to significantly reduce product development cycles, (e) developing an Intellectual Property strategy, and/or (f) other projects