The role and contribution of the Chief Technology Officer

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SUMMARY

The role of the Chief Technology Officer (CTO) came about because of new organisational demands on technology leaders in the 1980s. The initial research objective of this dissertation was to provide a clear scope of activities (a remit) for the CTO role. However, the analysis did not support a generic description for the role. Therefore, the approach taken explores CTO perspectives on technology management priorities when the technology context changes.

There is limited literature on the role and contribution of the CTO per se. The resulting gap in the knowledge about the role is amplified by a wide variety of research methods and academic perspectives. From a theoretical point of view, the existing research tends to focus in isolation on the work being done, the working context or the worker (i.e. the CTO). There are studies that consider how the working context is changing, and studies that consider the work of the CTO, for example, the technology management priorities. There are still other studies that consider the attributes of the CTO. In this dissertation, these three perspectives - the working context, the work and the worker - are investigated in an integrated way using a data collection technique called 'personal role mapping' that is based on cognitive mapping. The 'personal role mapping' approach has been developed as part of this work.

The evidence collected and analysed shows that the role of the CTO is highly idiosyncratic. This is because the CTO role changes as the organisation adapts in order to compete. Also, the role differs from one industry to another and between organisations within the same industry. To help deal with these variations, a CTO/Context Framework has been derived for use in conjunction with 'technology transition points'. The CTO/Context Framework has 20 sub-elements that support 6 primary elements including, 'technology management infrastructure', 'technology entry/exit points', 'technology business case & funding', 'operational improvement', 'people management' and 'technology business model & strategy'. The CTO can review each element with related sub-elements in anticipation or at the point of a 'technology transition'. This model for the CTO role is proposed as an alternative to a generic 'job description' (remit) for the CTO role. It is intended to be used as a platform for planning and decision-making.

Together, the framework and the research approach for mapping an individual's role are offered as a unique contribution to knowledge.

DECLARATION

This dissertation complies with the Department of Engineering Degree Committee word limit requirement (63746 / 65000 words) and the limit on the number of figures (50 figures and 56 tables / 150 figures). The work is my own. Concepts that are in common use are acknowledged where references are available. The work has not been done in collaboration with anyone else, nor has it been submitted for assessment as part of any other qualification at any other university.

Christopher van der Hoven

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1.1 Introduction

This research explores the role and contribution of the Chief Technology Officer (CTO). This introduction explains why the research was undertaken, provides an overview of the research objective and sets out the structure of the report. The terminology defined in Table 1 is used throughout this dissertation. Terminology that is more pertinent to specific chapters is set out in the introductory sections of those particular chapters.

Table 1: Terminology used in this research report

Term	Use
Chief Technology Officer (CTO) :	CTO is an abbreviation for Chief Technology Officer. Labels differ from business to business e.g. Technical or Technology Director, VP R&D, Chief Scientist, Chief Engineer and Innovation Director. Unless specifically indicated, references to the CTO are taken to mean the most senior technology executive in an organisation or strategic business unit (SBU).
Role perception:	Role perception refers to the personal lived experience of the role for the incumbent - the way it feels in the role. The perception of the role does not distinguish between the activities (i.e. the attributes of the work the CTO does), the role player (i.e. the attributes of the individual doing the work), and the context (i.e. the attributes of the environment within which the work takes place). In this research the role incorporates perceptions of the core purpose, related barriers and enablers to the purpose, and ongoing current and intended technology management actions. The role is viewed from the perspective of the CTO.
Context:	The context is the organisational and business environment within which the enactment of the CTO role occurs (from the CTO's frame of reference and perceived timeframe).
Role perspective:	Perspective is a function of where the CTO is, i.e. the position or context from which the role is 'seen'. It is also a function of 'who' the CTO is and 'when' the role is perceived. The assumption is that each CTO sees the role differently as a result of differing contexts, different personal attitudes and attributes, and different points in time.
Cognitive mapping:	An inductive process used to 'capture' the perception of the individual. The process output is a cognitive map that attempts to represent the interviewee's perspective. This process is recognized to be crude in that it can only ever approximate a mental model of the role.

Term	Use
Mental model:	The interviewee's perception of the way they do things and the way things happen around them. A set of constructs that emerge from the cognitive mapping process. In this research the mental model is also the output of an attempt to capture "…a snapshot in a stream of consciousness…" (Weick, 1995)
Construct:	A set of elements that the interviewee may represent or recognise as being related. These elements are the building blocks that ultimately make up the interviewee's 'constructed' view of the role.
Personal Role Map:	This type of 'map' was created for this research. It is based on four core elements: 1. A statement of core purpose of the role; 2. A metaphorical force-field with opposing forces (barriers and enablers to the stated purpose); 3. A cognitive mapping of constructs that build around barriers and enablers (drivers and actions); and 4. The interviewee's interpretation of the overall mapping of their role (i.e. the implications for practice).
Remit:	The scope or extent of the work carried out by the CTO. Remit is also used in relation to the broader scope and extent of work to be carried out by the technology team – as in the 'the technology remit'.

1.2 Research motivation

This thesis explores the changing nature of the role of the CTO over time. Also, an argument is offered to support the assertion that the role is becoming more complex. Furthermore, there are changes occurring during a period when the importance of technological advances is being recognised, but also while increasing pressure is being applied to use resources more effectively. The management of technology, and the leadership provided by the CTO is therefore of interest to organisations and practitioners.

The need for this research was further prompted by evidence of a lack of consensus regarding the core purpose of the CTO role. In 2004 and 2005 industrialists and academics attending seminars hosted by the European Institute for Technology and Innovation Management (EITIM) were surveyed[1]. Their responses were diverse and further discussion demonstrated a need for clarity on the CTO role. Delegates asserted that the CTO role was relatively understudied. This assertion was confirmed when the literature on the CTO proved to be sparse, and as is shown in this thesis, mostly anecdotal.

[1] See www.EITIM.org – Note this survey was brief and relatively informal. It captured 'core purpose' with related 'barriers' and 'enablers'. Also see Appendix 8 for summary of outputs (this is discussed in Chapter 4).

1.3 Research objective

A further motivation was the opportunity to research the role of the CTO from the perspective of the CTO. This allowed for the possibility to research the role without any formal *a priori* assumptions or hypotheses. This inductive approach is a basis for future theory testing in a deductive research mode. Additionally, CTO related research has tended to look separately at the attributes of the activities of the CTO, or attributes relating to the incumbent or those relating to the technology context. This research provides an opportunity to avoid approaches that isolate these attribute groups from each other because they are captured collectively in the CTO's perspective.

Specifically, the research objective was to provide a better understanding of the role from the perspective of the CTO. In particular to answer the following research questions:

1. What is the core purpose of the CTO role?
2. What are the barriers and enablers to achieving the purpose?
3. What are the causes of the barriers and enablers?
4. What actions do CTO's take to nurture enablers or mitigate barriers?
5. What are the implications for practice of the CTO role?

1.4 Dissertation structure

Figure 1 sets out the sequence and content of the chapters in this dissertation. The eight chapters are followed by a reference list and appendices.

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- Research objective
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- Theoretical perspective of benchmark CxO studies
- Dominant themes linked to the research objective
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- Limitations and future research
- Proposal for follow up research
- Summary

Figure 1: Chapter sequence and content overview

This thesis is structured into three broad elements covering literature and method and then the discussion, implications and conclusions.

The literature is discussed in two parts. The first is the CTO specific literature – i.e. literature that deals directly with the CTO or with other CxO roles. The studies of other roles are used to inform the way in which the CTO role should be researched. This is contained in Chapter 2. The second part of the literature is contained in Chapter 3 and deals with the "Technology Management Context". The literature used for the technology context is written up in a chronological sequence that tracks the way in which the authors have documented the evolution of the technology environment.

The literature is deliberately restricted to studies of the CTO and articles that shed light on the context of the CTO. This includes references to leadership, relationships, and management priorities, as well as references to the so-called "generations of R&D". References to existing management models are excluded because the research is inductive and thus deliberately avoids *a priori* technology management related theory (for example conceptual frameworks and models). Various adjacent fields such as innovation theory, culture, leadership theory and strategy are also excluded except where they relate directly to the perspective of the CTO. These fields are excluded because they are too broad and distract from the specifics of the role of the CTO.

Chapters 4 and 5 cover the method used and sets out the approach derived specifically for this work. Chapter 4 explains why certain methodological approaches are deemed inappropriate for this research. The limited amount of theory on the role of the CTO (and limited literature) and the need to create a platform for the study of the role, supports the use of an inductive study method. For this reason, a survey is ruled out as deductive hypothesis testing would have to presume to have insights into the purpose, barriers and enablers faced by CTOs. The same would be true of focus groups although a workshop format is used at various stages to check progress and understanding with knowledgeable practitioners and academics. The timeframe, resource limitations and confidentiality requirements removed the possibility for the use of ethnographic techniques.

Rather than eliminating various inductive research methods, the method used is a hybrid with elements from phenomenography, causal cognitive mapping and repertory grid technique. The research design is described in Chapter 4. The derived research method is called "Personal Role Mapping" and is set out in detail in Chapter 5.

Chapter 6 shows the outcome of the data collection and analysis in the form of a framework that is ‘grounded’ in the data. This framework is derived and then illustrated by cross referencing with the text taken from the interviews conducted. This chapter sets out the key contribution regarding the role and contribution of the CTO.

The “Discussion” Chapter (Chapter 7) is used to demonstrate how the framework might be used by future researchers. A graphical representation of the priorities of the CTO is created using an analysis of the text from interview transcriptions. While the technique used is not considered to be academically rigorous, it is included because it is only intended to demonstrate the possibilities for future research. The framework and the idea of technology transition points are explored and the possibilities related to planning and reacting to technology change are considered.

The chapter on “Implications for Practice” (Chapter 8) is unusual because although some ideas are inferred rather than directly grounded, the research approach includes a specific question on implications for practice. In other words, the interviewees are asked to declare what they think the implications are as part of the interview process. This provides additional data that is analysed and discussed. The analysis shows perception gaps in the ways that the interviewees interpret their role, and the inferences emerge from these gaps.

The final chapter summarises the conclusions from the literature and from the research. Also, the perceived contribution to knowledge is discussed, as are the research limitations. A proposal for follow up research is set out.

Chapter 2 follows with a review of the CTO specific literature.

2 CTO Literature

2.1 Introduction

The preceding chapter introduces the topic and defines related terminology. This chapter sets out existing CTO literature and links it to the research topic. The chapter begins with an overview of the empirical and conceptual articles on the role of the CTO. The literature is considered from the point of view of the purpose of the CTO role, barriers and enablers, management activity and implications. There is a review of a small number of benchmark studies and the implications for the theoretical perspective of this study. Finally there is a discussion of alternatives to the CTO role and alternative roles for the CTO.

2.2 Overview of articles on the technical leader

In this section the various CTO and technology leader related articles were considered. Articles were included if they specifically related to the CTO or technology leader, and were either empirically based or authored by experts[2]. Authors were considered to be experts where they were serving, or past, technical leaders, academics involved in technology management research, or senior consultants with technology focus. Articles reporting on or summarising research done by 3rd parties were excluded, unless these summaries added to the insights and conclusions drawn.

2.2.1 Description of empirical studies

In all 17 articles related to empirical studies, one article reported on a case study and one article was the author's review of two of his own studies. The studies are predominantly conducted by authors from the US, although studies focussed variously on Europe, Greece, Holland, Japan, Quebec in Canada, the United Kingdom, and the US. Six articles explicitly target the CTO although only three specifically refer to the CTO in the title of the article.

Overall, the studies[3] spanned the period from 1981 to 2007, with most of the CTO specific studies occurring in the 1990s and the late 2000s. One study (Roberts, 1995) was repeated

[2] An annotated list of articles in chronological order is included in Appendices 1, 2 and 3. These are included as a resource for further research.

[3] The date, title, number of pages, number of references and the source of knowledge / data per reference is summarised in Appendix 1.

(Roberts, 2001), and then subsequently reviewed (Roberts, 2004). This is the only source of potentially longitudinal data in the set of empirical studies conducted.

2.2.2 Description of articles by experts

In all 20 articles produced by experts are considered. Table 2 includes the titles of the industrially based contributors to give an indication of seniority and scope of responsibility.

Table 2: Credentials of industrially based contributors

Date	Name of author	Title(s) held
1988	Allen Heininger	VP Resource Planning at Monsanto President of the Industrial Research Institute (retired)
1992	Paul O'Neill	Chairman and CEO of Alcoa
	Peter Bridenbaugh	Executive VP – Science, Technology, Engineering, Environment, and Safety and Health at Alcoa
1994	Arthur Chester	Senior VP - Research and Technology at GM Hughes Electronics and Hughes Aircraft Company
	Walter Robb	Senior VP – Corporate R&D and on the Corporate Executive Council of GEC
1996	Charles Larson	Executive Director – Industrial Research Institute
1999	Frank Lederman	CTO – Alcoa
	Greg Smith	Director Technology Planning – Alcoa
2003	Roger Smith	Group CTO – Titan Corporation
2004	Dan Delmar	VP Strategy Planning – Carrier Corporation
	Judith Giordan Nir Kossovsky	Director – I/C/M/B Ocean Tomo (IP merchant bank). Previously VP Global R&D PepsiCola and VP R&D Henkel Corporation CEO - I/C/M/B Ocean Tomo
2005	Peter Cannon	VP Research and Chief Scientist – Rockwell International

Other authors included consultants (McKinseys or Arthur D. Little)[4], academics or science and technology writers[5]. The positions held by these expert authors are used as a proxy for their credentials. These credentials underpin the validity of their conceptual contributions.

2.2.3 Focus of empirical and expert articles

The literature suggests that the CTO role has attracted relatively little research attention (Herstatt et al., 2007; Smith, 2007). Furthermore, the literature tends to focus on the functional role of the technology leader. "The CTO literature emphasizes functional leadership and provides a good description of the knowledge and understanding that the CTO should have to carry out that role effectively." Medcof (2007, p.31) There is also a concern that generally the literature does not address the strategic leadership aspect of the role of the CTO (Medcof, 2008). These descriptions of the literature confirm the view that there is little research on the CTO.

On the other hand, while the accounts of industry experts are not empirical, collectively they are a credible source of anecdotal evidence. Finally, for the purposes of this research, the notable gap is the lack of research documenting the day-to-day experience of the CTO in their specific contextual role.

Table 3 brings together both the empirical and conceptual contributions made over a thirty year period. The broad focus of attention in each era is described under the column heading 'Focus'.

[4] See www.mckinsey.com and www.adl.com (accessed August 2010)

[5] The date, author(s), title, article length and source of knowledge are set out in Appendix 2.

Table 3: Focus of CTO related articles (1980s to 2000s)

	Date	Empirical	Experts	Focus
1980s	1981	Roberts and Fusfeld		These papers talk about the innovation team and the changes in leadership style required of the R&D manager.
	1988		Heininger	
1990s	1990	Adler and Ferdows	Lewis and Linden	These papers introduce the CTO role and the need to work across business units and coordinate new technology development. Also, positioning the CTO with arguments about credibility and relationships with key stakeholders (such as the CEO). There is recognition of the priority issues for the CTO and acknowledgement that these will differ depending on company context.
			Erickson, Magee, Roussel and Saad	
			Wolff	
	1991		Wolff	
	1992	Uttal, Kantrow, Linden and Stock	O'Neill	
			Bridenbaugh	
	1993		Erickson	
	1994		Chester	
	1995	Roberts		The first large empirical studies are conducted in the US, Europe and Japan. Issues are raised about locating the CTO on the board, and trends towards external alliances. Outsourcing is seen as a reason for the reduction in the R&D function and the increased need for the CTO to be a 'line manager' with profit and loss (P&L) responsibility. Findings reveal that context is more central to innovation than CEO personality.
	1996	Jonash	Gwynne	
		Thurlings and Debackere	Larson	
	1997	Lefebvre, Mason and Lefebvre		
	1998	Papadakis and Bourantas		
	1999		Smith, Lederman and Jonash	
2000s	2000		Fisher	A focus on CTO activity notes that strategic planning in the 60s and 70s declines in favour of quality and cost initiatives in the 80s. At the same time R&D and NPD is decentralised to business units to increase customer focus. Less central coordination of technology and less emphasis on longer term goals resulted. In this period a decline in the number of CTOs on boards is also noted in Europe and the USA. There is discussion about the boundaries of the firm and the need to 'leverage' R&D resources through better use of IP and access to capabilities via acquisitions and alliances.
	2001	Scott	Kwak	
		Roberts		
		Roberts and Liu		
	2002		Boer	
	2003		Smith	
			Delmar	
	2004	MacMillan and McGrath	Giordan and Kossovsky	
		Roberts		
	2005		Cannon	Findings from Japan point to high levels of strategic input from CTOs, but CEOs dominate technology strategy and external investment decision-making. In the US trends suggest increased R&D spend (with declines in spend on basic research), and continued growth in 'open innovation'. Studies on the CTO suggest 'patterns' of activity contingent on the 'type' of company, and key relationships.
	2007	Herstatt, Tietze, Nagahira, & Probert	Medcof	
		Scinta		
		Smith		
	2008		Medcof	
	2009		Probert and Tietze	

2.3 Benchmark CxO studies and theoretical perspective

The review of studies and conceptual papers in this section covers multiple points of view regarding the role of the technology leader. To elaborate on the perspectives of the CTO studies, articles looking at the Chief Information Officer (CIO) (Fisher, 2000 and Kwak, 2001) and the Chief Strategy Officer (CSO) (Delmar, 2003) are considered. Then, in order to get a benchmark of possible perspectives, two studies looking at the Chief Executive Officer (CEO) role are considered (Levebvre et al., 1996 and Papadakis and Bourantas, 1998).

Both Kwak (2001) and Fisher (2000) focus on the IT and internet industry. Kwak (2001) researches the technology background of CIOs and the impact of technical skills on successful tactics. The author implies that for the CIO, the "dual ladder" approach (Roberts and Fusfeld, 1981) i.e. that technical people progress along either a technology or a managerial track - will not work. The CIO needs to have both technical skills and people skills.

Fisher (2000) reinforces this view, but distinguishes between the functional and the strategic leadership roles. She suggests that the CIO is traditionally the technology leader, may be several layers away from the CEO, have a set salary, be focused on tactics and run a department which is seen as a cost centre. By contrast, she hails the introduction of the CTO, as a strategy oriented IT professional on the executive team with their compensation tied to performance. This individual considers long-term possibilities and treats their department as a profit centre.

To a large extent, these views (Fisher, 2000 and Kwak, 2001) are similar to the arguments being made outside of the IT and internet industry. In some ways the R&D Manager / CTO discussions mirror the CIO / CTO arguments made by these authors. For example, Smith (2007, p21) suggests that the R&D manager's role is to sponsor important research projects, whereas the CTO role is to match, "…research ideas with strategic plans of the company and capabilities to get new technologies to market."

Delmar (2003) points out that the CTO and the CIO only joined the CxO ranks in the 80s and 90s. Prior to that, the only executives labelled "Chief" were the CEO, the Chief Operating Officer (COO) and the Chief Finance Officer (CFO). The author describes the CSO role, and notes examples of the companies that have a CSO. With regard to "C-level" executives more broadly, the author suggests that they are distinguished by their dedicated focus on specific

activity domains within the business. The CSO is a senior executive put in place to compensate for the lack of dedicated attention provided by line managers to strategy. In the case of the CTO, the role is dedicated to the development and exploitation of technologies.

Delmar (2003) also notes that there is a cycle of centralisation and de-centralisation. In the 70s and 80s, strategy is centralised and given to a specific executive to lead. Then in the 90s, having become too bureaucratic and formulaic, strategy is moved back into the line functions. However, the author points out that experience shows that line managers typically focus on short-term financial / day-to-day responsibilities, and thus do not have the time to dedicate to strategy. Long-term and innovative thinking is thus sacrificed.

CEOs are also influential with regard to technology management. Levebvre et al. (1996) use a prism metaphor to explain the multiple ways that CEOs of SMEs interpret the same external environment. They suggest the need to understand the "cognitive schema" of CEOs and their effects on strategy and technology policy formulation. They then test a model that links the interpretation to company performance via the strategy and technology policy that the CEO advocates. This research also mentions the link between 'technocratization' and innovativeness on technology policy. Also, they assert that firms with a more "aggressive" technology policy are more likely to be innovative.

Another CEO study by Papadakis and Bourantas (1998) focuses on the role of the CEO in championing innovation. They point out two differing schools of thought regarding the influence of top management. In explaining the contradictory perspectives regarding the role of the CEO, Papadakis and Bourantas (1998) argue that there is a divide between proponents of the 'environmental determinism' perspective, and those of the 'strategic choice' perspective.

The 'environmental determinism' perspective suggests that the organisation adapts to the environment in order to succeed. Therefore, the threats and opportunities presented by the environment (such as dynamism, industry growth rate, competitiveness and concentration), and the characteristics of the organisation (such as size, structure and resource), determine the attitude towards innovation and strategy.

The 'strategic choice' perspective suggests that top decision makers determine the organisational processes and outcomes. They therefore expect their research to take account of the "idiosyncrasies" of decision makers. The focus of the various studies that they reviewed are summarised in Table 4.

Table 4: CEO studies reviewed by Papadakis and Bourantas (1998)

Date	Author	Title	Focus
1986	Miller and Toulouse	"Chief Executive personality and corporate strategy and structure in small firms"	In medium sized companies the influence of the CEO is greater.
1988	Meyer and Goes	"Organizational assimilation of innovations: A multilevel contextual analysis"	Weak relationship between leader's characteristics and innovation. But, innovation is likely to be assimilated if championed by the CEO.
1990	Lewin and Stephens	"CEO attitudes as determinants of organizational design: An integrated model"	Proposed an integrated model to link CEO characteristics (background, attitudes and demographics) to innovativeness, structures, culture and processes.
1990	Howell and Higgins	"Champions of technological innovation"	Personality characteristics influence the emergence of innovation champions.
1992	Marshall and Vredenburg	"An empirical study of factors influencing innovation implementation in industrial sales organizations"	Management support plays a critical role in innovation success.
1998	Papadakis and Bourantas (included for comparison)	"The Chief Executive Officer as a corporate champion of technological innovation: An empirical investigation"	CEO characteristics significantly influence technological innovation, but not as much as environmental context.

Papadakis and Bourantas (1998) find that research on innovation focuses largely on organisational and environmental factors, and that very little research has been done on "strategic leadership". The authors test a model of the relationship between the characteristics of the CEO and the context on the one hand, and technological innovation on the other. They conclude that while CEO characteristics do in fact influence technological innovation, the influence of the structural and environmental context is higher.

To link this back to the CTO research, in his study Roberts (2001) points out a correlation between performance and the degree to which the technology strategy is integrated with business strategy. This would seem to suggest that the influence of the CTO is a central requirement. However, Medcof (2008) cautions against the idea that more CTO influence in the organisation would mean better performance. He supports the argument put by Uttal et al.

(1992), and suggests that there should be a 'contingency' perspective to 'temper' expectations of the influence of the CTO.

In other words, different organisational circumstances will require different styles from the CTO. Scott (2001) states that, "…academic research that examines the top problem of strategic planning for technology outside of the context of other problems seems unlikely to be fully effective." (Scott, 2001, p.361) This suggests that as with the CEO studies, context needs to be taken into account in any research designed to understand the CTO role.

2.4 Dominant themes linked to research objective

The dominant themes that emerge or recur over the period from the 1950s onwards are captured in the various empirical studies and anecdotal references reviewed in this section. These are considered in terms of how they contribute to an understanding of the core purpose of the CTO role, the barriers and enablers to the role, the related management actions, and the implications.

2.4.1 New directions in 'Industrial Dynamics'

An early reflection on the need and importance for research into senior technology management is demonstrated by a review of "Industrial Dynamics" research at MIT. The review (Roberts, 1964) traces the history of "Industrial Dynamics" at MIT between 1957 and 1962. The author highlights the need to move the research agenda in industrial dynamics forward given the progress made to that point. He suggests two "new directions" i.e. "transient dynamics" and "intangibles and organizational policy".

"Transient dynamics" highlights the constant problem of a mismatch between technological opportunities and technological capabilities. In the review, a mismatch is described between the "order rate" (demand) and the amount of "professional effort" (staff) required at any time. The dynamic element refers to the flows of staff and market demand. The argument is that increased demand causes a need to increase staff. This is followed by a period during which increased complexity of managing the increased numbers jeopardizes performance. Demand then falls off and cutbacks are required. A lack of management skill in responding to the dynamics of demand and the related staffing is considered to be a persistent cause of company failure.

The reference to "intangibles and organizational policy" is recognition that historically, industrial dynamics has dealt with tangible flows in the organisation (e.g. financial resources). The review suggests that as top management research progresses, it needs to address company characteristics such as integrity and risk-taking propensity. These intangible aspects is less easily modelled, and, " … impossible to measure either accurately or in a non-controversial manner, but they are of vital importance to organizational behaviour." (Roberts, 1964, p.10)

Roberts then describes the need to consider these research problems by incorporating the psychological perspective on management behaviour. "Even the response of the individual manager is often an attempt to balance multiple and differentiated pressure sources within his own organisation." (Roberts, 1964, p.10)

He further suggests that solutions are to be found in appropriate policy i.e. the right organisational setup will provide the necessary context to ensure that the manager can succeed. An example of the type of 'policy' approach is the use of incentives and the effect that these have on managers.

The Roberts article suggests that the role of the manager (like the CTO) should fit the organisational setup (policy). Put another way, the system structure plays a role in creating organisation behaviour, suggesting that the individual and the role should follow the structure. This approach is reinforced when managers are recruited using a job description intended to achieve a 'fit' with the needs of the organisation. This practice has persisted over time.

Paradoxically, when considering the recruitment needs of innovative organisations, Roberts and Fusfeld (1981, p.23) point out that, "…Generally, the critical job functions are not specified within job descriptions, since they tend to fit neither the administrative nor technical hierarchies." This reference to technical and administrative hierarchies relates to organisations where innovation is taking place. The so-called non-specified "critical job functions" include idea generation, entrepreneuring or championing, project leading, gate keeping (collecting and using market, technology and manufacturing information), and sponsoring and coaching.

The authors state that an understanding of these "critical job functions" would help to avoid situations in which individuals are removed from innovation projects at inappropriate times. This sometimes occurs when individuals are moved to other roles based on their

qualifications or credentials (based on a job description), just as the project is in need of their particular (non-specified) critical skill. This problem can be compounded if the vacancy is then filled by replacing the 'technical specialism' without consideration for the critical role element needed to secure the success of the project. Roberts and Fusfeld compiled profiles of "several thousand" R&D and engineering staff and determined that the unique challenges of innovation required several types of role player. They go on to suggest that, "…Each type must be recruited, managed, and supported differently; offered different incentives; and supervised with different types of measures and controls." (Roberts and Fusfeld, 1981, p.24)

In terms of "manpower planning", the authors refer to the so-called "dual ladder" approach common at the time. That is, careers progress in either scientific or managerial steps. They suggest that where technical professionals are encouraged to actively take up the "critical job roles", they would in effect be progressing up multiple "ladders". This can be achieved by appropriate career management, appropriate goal setting and performance measurement, and related rewards.

These two earlier articles (i.e. Roberts, (1964) and Roberts and Fusfeld (1981)) suggest a shift from a focus on the organisation to the individual, and also from R&D to innovation. They also point to the beginnings of the debate about the way in which the future CTO profile might have to incorporate technology and general management / leadership.

2.4.2 The purpose of the CTO role

Multiple perspectives are reflected in the literature in terms of the purpose of the CTO role. Numerous aspects cause the purpose to differ. These include:

- the way in which the business is configured and how the configuration changes over time;
- whether there is a need for integration across divisions (horizontally) or between business and technology strategy (vertically);
- the manner in which key stakeholders, particularly the CEO need to be engaged;
- the way in which technology leadership is nurtured at an organisational level.

Adler and Ferdows (1990, p.60) suggest that the purpose of the CTO role may vary, " … depending on whether the business had a central R&D department." And in response to the question, "Why have a CTO?" there would broadly be two possibilities:

- Corporate R&D: Where the company has a central R&D function, they need a role that will ensure better "responsiveness" to BU requirements, and also improved "receptiveness" from BUs;
- Divisional R&D: Where R&D is located in the business units, the need is for someone to ensure "cross-fertilization" and to help "avoid duplication". Also, to ensure overall leadership to maintain the firm's technological base. This included the need to scan for technologies available outside of the company.

In both configurations, central and divisional, the technology leader would need to manage key stakeholders and integrate activity and best practice across the organisation.

With regard to the management of key stakeholders, various authors emphasise the importance of working closely with the CEO (Wolff, 1990, 1991; ONeill, 1992; Bridenbaugh, 1992; Robb, 1994). Wolff (1990), states that the onus is on the technology leader to work with functional managers to present an integrated view of the value of technology in supporting the corporate strategy. In particular, the technology leader must ensure that this view is "sold" to the CEO in the best way possible (Robb, 1994).

In working closely with functional managers and the CEO, the technology leader needs to integrate activity horizontally in the organisation (i.e. across functional units). The literature suggests that the technology leader needs to take opportunities to create synergies and economies of scale across business units (Adler and Ferdows, 1990). Another perspective is that the purpose of the CTO role is to integrate vertically between the business vision and mission of the organisation and the technology strategy. Lewis and Linden (1990), note a departure from the traditional functional R&D role to one of 'leadership'. They suggest that the purpose of the CTO leadership role is to be a spokesperson, a strategist and the director of corporate R&D.

Robb (1995) says that the CTO role is to defend technology when competing for funds against other functions. This is required to ensure long-term profitable growth. His view is that highly credible CTOs demonstrate excellent teamwork and performance and have an ability to take risks.

According to research conducted by Scott (2001), the most important integration activity is the need to align technology and business strategy (see also Smith, 2007). The importance of this point of view is further reinforced by a survey conducted by Roberts in 1999. He found

that firms that indicated a better integration between corporate and technology strategy also indicated better performance (Roberts, 2001).

However, research also shows that the dominance of key players in the integration activity is dynamic (i.e. the CTO is not automatically the dominant player). Smith et al. (1999), point out the trend in the 90s towards decentralisation of R&D activity. In a de-centralised configuration, the business unit manager is considered to be the most important linking role (Roberts, 2001).

During this decentralised phase, there is a concern that this domination results in an emphasis on shorter term goals. Business unit managers tend to prioritise customer's immediate needs and focus more on current year and following year products at the expense of funding longer term projects (Scott, 2001). These are very similar to the concerns raised by Delmar (2003) regarding the role of the Chief Strategy Officer. There the problem of the line manager mindset is seen as a threat to innovation and long-term thinking.

Scott (2001) defines the technology management role as including technology acquisition, product development and market launch. However, the point is made that the technology activity is sometimes separated into "functional smokestacks", such as R&D, engineering design, process design, manufacturing, ramp-up management, product introduction and technology "product family" activities.

Furthermore, the author states that strategic planning was a major component of coordinating in the 50s, 60s and 70s, and that from the mid 60s this started to flag. In the 80s the quality and cost focus caused a shift to manufacturing and operating efficiency. The tools used included JIT, Kan Ban, Quality Circles, TQM, down-sizing and re-engineering, etc. Parts of the strategic planning capacity were seen as unnecessary overhead and were cut back.

At the same time, R&D and product development was decentralised to line functions to increase the focus directly on customer needs and to reduce costs. This forced greater emphasis on short-term goals with immediate benefit to the business unit at the expense of longer-term research and development and more radical products. Additionally, while the proliferation of technologies and products in the market demanded more coordination within the firm, the decentralised configuration tended to be less coordinated.

Medcof (2008) sees the problem from a different perspective. He hypothesises a correlation between CTO influence on organisational strategy and the degree to which the organisation

relies on technology. Also, where technology is more important, influence is more likely to be gained through technical expertise. However, technical expertise and position in the business is not enough in contexts of high ambiguity and uncertainty.

It is thus suggested that the CTO build relationships with key stakeholders such as the CEO, form a strong network inside and outside of the firm, have expertise in non-technology areas of the business, and develop an ownership position in the business. The author states that the literature limits the role of the CTO to managing the technology function and advocating for technology in the company, and that technical expertise and organisational position are the most important bases of CTO influence. Medcof's summary of the purpose of the role of the CTO closely reflects the literature reviewed in this section. It also highlights the need to consider alternatives to the CTO role and alternative roles for the CTO.

2.4.3 Barriers and enablers to achieving the CTO role

In their review of the staffing requirements for innovative technology-based firms, Roberts and Fusfeld (1981) identify five so-called, "critical job roles". They find that to enable the innovative organisation, it is necessary to have each role represented. The critical job roles include 'idea generating', 'entrepreneuring or championing', 'project leading', 'gate keeping', and 'sponsoring or coaching'. However, while they declare it possible for single individuals to contribute across multiple roles, they also note certain barriers. Firstly, that the exact contribution of individuals enacting these roles is often not obvious. This may explain why changing a team member at a critical time in a project may result in unforeseen setbacks. The second barrier is that the ability to enact these roles may only become feasible over time. This is because of the need for experience, credibility and a strong network.

In terms of making sense of context, the technology leader may not be aware of the interactions between technology type, R&D programme type, relative competitive position etc. In their review Erickson et al. (1990) describe the implications of having various types of technology (termed base, key and pacing); and various types of R&D programme (termed incremental, radical and fundamental). They suggest that the role of "strategic technology management" is to support the business by underpinning sustainable cash flows that will grow.

The board members of an organisation are key stakeholders, who together with the shareholders, have an interest in cash flows and growth. Erickson et al. (1990) suggest that in

supporting sustainable cash flows, technology leaders are part of the drive to ensure investor support. They point out that the level of investment is a reflection of technological strength. This they characterise as – 1. Dominant; 2. Strong; 3. Favourable; 4. Tenable; 5. Weak. The authors suggest that in order to keep technology relevant (i.e. retain investor support), there are a number of principles to be applied:

- Keep R&D personnel in touch with potential customers and markets;
- Foster open communications between R&D, manufacturing and marketing;
- Hold to time commitments and schedules;
- Avoid fads;
- Understand the reason for outside linkages.

The work of keeping technology relevant is a central theme in articles considering the credibility of the technology leader. In a study conducted in 24 firms in the US, Uttal et al. (1992) found that where leadership gaps exist, this is generally an issue of credibility with the CEO. They suggest that the CTO needs to be a "technical businessman" to help close the credibility gap with the CEO (see also Wolff, 1991). Bridenbaugh (1992) has a slightly different perspective. His view is that credibility comes primarily from the ability to develop and lead the technical organisation to satisfy customer needs by applying scientific and engineering knowledge. He supports the "technical businessman" idea (uses the term "commercial savvy"), but adds that forming productive partnerships and having a global perspective are enablers to CTO credibility.

The customer centric approach is supported by O'Neill (1992), who was the Chairman and CEO of Alcoa in the US at the time of writing the article. He suggests that the role of the CEO is to facilitate the CTO in serving the customer. The author also says that the notion of having the CEO at the apex of a triangle, with customers and the CTO at the other points, is dated and is a barrier that, " … gets in the way of…" performance.

2.4.4 The CTO's management priorities

In order to understand 'what' CTOs do or what management and leadership 'action' they are engaged in, it is necessary to consider their topical issues. Chester (1994) suggests a meeting agenda which gives an insight into the topical issues for technology leadership. These issues include integrating strategy, getting technology staff closer to the customer, external relationships, researcher incentives, motivating staff transfers between research and product divisions, etc. He also notes the uniqueness of each company context, and that certain

processes are generic or need only minor adaptations. Unfortunately, the article does not focus much on 'how' these agenda items might be dealt with, or 'why' they occur.

In a broad based study Scott (2001) used a rigorous DELPHI approach to identify 24 technology management problems and put them in rank order - see Table 5 for 1st 11 problems.

Table 5: Ranked Technology Management Problems - Scott (2001, p364)

Rank	Management problem
1	Strategic planning for technology products
2	New product project selection
3	Organisational learning about technology
4	Technology core competencies
5	Cycle time reduction
6	Creating a conducive culture
7	Coordination and management of new product development teams
8	Technology trends and paradigm shifts
9	Involvement of marketing groups
10	Customer / supplier involvement
11	Senior managers' involvement in technology

He explains that the dominant issue is strategic planning for technology products (no. 1), and that the next 10 technology management issues i.e. from 2 to 11, all relate to the first. Also, a limitation noted in this research is that the numerous contextual features that might change these priorities are not taken into account. The other problems identified by Scott are included in Table 6.

Table 6: Technology management problems (cont.) - Scott (2001, p.364)

Rank	Management problem
12	Soft skills for technical personnel
13	Organisation structure for R&D
14	Alliances / partnerships between technology companies
15	Within-company technology diffusion and transfer
16	Using high-tech for competitive advantage
17	Involvement of manufacturing in new product development
18	Globalisation of product development processes
19	Resource allocations to high-tech activities
20	Establishing a 'technology vision'
21	Productivity of product development activities
22	Rewarding and educating technical staff
23	Project continuance / discontinuance
24	Oversight of high-tech activities

Overall, little specific research has been done on the responsibilities of the CTO, on methods of evaluating CTO performance, and on the skills that the CTO should bring to the role (Smith, 2007). Having conducted a literature search using, "Chief Technology Officer" and "CTO", Smith (2007) discovered "fewer than 20 published articles" in the 10 years prior to the search. It appears that, " … CTOs are not publishing their activities and few academics are researching the position." (Smith, 2007, p.18) He states that this is partly because the CTO title and role is relatively new and emerged in the 1980s from the role of the R&D laboratory director.

He finds that there are four drivers for the creation of the CTO role, i.e. that it is driven by unique business needs, by a process of evolution in the company, to mimic other companies, or as the result of a misunderstanding about the reasons for the role. His view is that the core purpose for having the CTO role is to leverage technology in products and service delivery. The author states that the position of the CTO fits into five possible patterns:

- Genius - examples are Steve Wosniak of Apple and Sergey Brin of Google – the genius CTO is important to emerging companies,
- Administrator - understands technical and commercial aspects of key relationships,
- Director - focuses on "leveraging" research and laboratory outputs into profitable products,
- Executive - large companies like GE Medical, Alcoa, IBM, Corning and ChevronTexaco – is noted for using CTO to guide strategic decisions and the innovation process;
- Advocate - often in retail and service businesses, this CTO works to understand/advocate for the customer.

Smith discusses the need to match the pattern of the CTO role with the needs of different types of company. He also hints at the need for a "Chief Innovation Officer" with a remit that extends beyond the technology field. However, there is no suggestion that these 'patterns' are either discrete or static. A case can presumably be made that based on the needs and attributes of specific events and specific individuals, the CTO may be characterised as belonging to two or more 'patterns' of activity simultaneously. Also, the pattern of activity will change over time, given the CTO's accumulation of experience.

2.5 Implications for the CTO role

The implications for the CTO role are considered in two ways. Firstly, are there alternatives to the CTO role? Secondly, after its introduction, has the role of the CTO changed over time?

2.5.1 Alternative CTO roles

Two decades ago, Heininger (1988) appealed to professional research managers – particularly the CEO, to broaden their scope and interact with stakeholders better. Prior to that, Roberts and Fusfeld (1981) discussed the need to recognise that technical professionals are able to fulfil different 'critical roles' as they gain experience. Their point was that newly appointed engineers are unlikely to be able to project lead or sponsor, nor to take up any gatekeeping or coaching roles. In the early stages of a career, the individual is likely to be focused on problem-solving in their specialist area. However, as their network grows and they gain credibility with key stakeholders, they are likely to be better placed to take up multiple critical roles.

More recently, Medcof (2007) agrees that in progressing their careers, CTOs need to build their credibility. But, he says that they need a record of good performance in the functional aspects of the role. Only then, can they be in a position to take on a higher level, more influential CTO role.

One apparent measure of influence is to ascertain whether the CTO sits on the main board or executive committee of the organisation. Roberts (1995 and 2001) looks at this in his benchmarking studies. However, he does not find a relationship between CTO board membership (… or the technical background of the CEO), and the strength of integration of technology (called "strength of linkage" in the study). His results are shown in Figure 2.

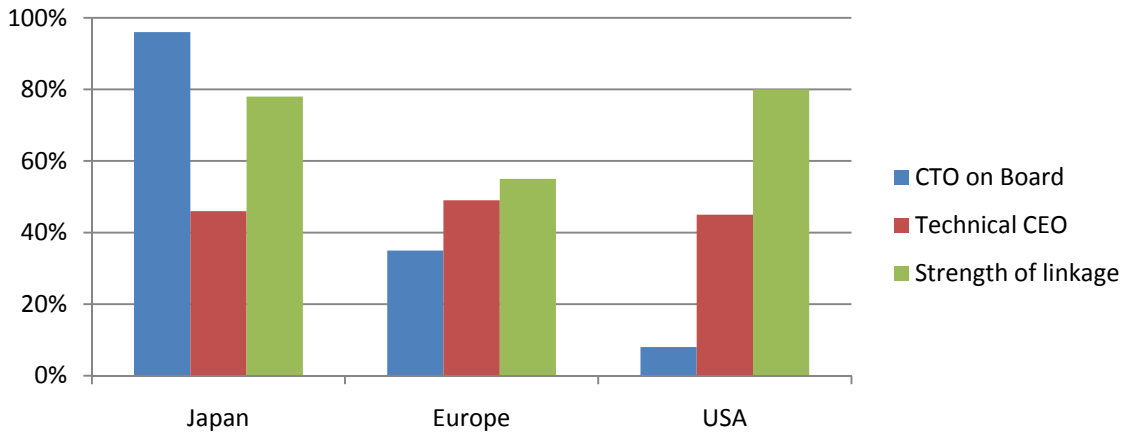

Figure 2: Comparison of board level CTOs and linkage strength (from Roberts 2001)

In another study, Gwynne (1996) suggests that there is a trend away from the leadership role of the CTO in companies in the US. He suggests that part of the problem is that over 5 years the trend toward outsourcing has caused a significant reduction in the size and function of R&D laboratories. He implies that a further cause is a lack of commercial focus from CTOs. His solution, based on six examples, is for CTOs to assume a dual role i.e. that of technology leader and line manager. The argument being that the P&L responsibility helps with the credibility of the CTO with peers in other line functions. The 'decentralisation' of technology and related changes in the focus for the CTO, mean that a CTO is more likely to be in a business unit.

Shifts between centralising and decentralising R&D over time are dealt with in detail in Chapter 3. However, it is worth noting here that these trends are also linked to the

macroeconomic context. Lean times exert pressure to be closer to the customer and to focus on short-term gains. The CTO is then more likely to be in or close to a line function / business unit, and less likely to be acting at a strategic level.

On the other hand, Jonash (1996) embraces the idea of a broader role, but suggests that the CTO and R&D manager roles diverge. He hails a "significant expansion" in the role of the CTO because few R&D managers are prepared to take on the burden of new relationships, processes and results that are difficult to control. He sets up the CTO as an interface across the boundaries of the firm and into the market for outsourced technologies like JVs, alliances, consortia, acquisitions, licensing, and a range of active and passive suppliers. This seems to suggest that the R&D manager will be in the line function, but that the CTO will act at a strategic level, looking at external relationships in particular.

A further emergent element of the CTO role relates to the value associated with the accumulation of intangible assets (whether from external or internal sources). The level of focus on the value of intangible assets differs across industries as is evident in Figure 3.

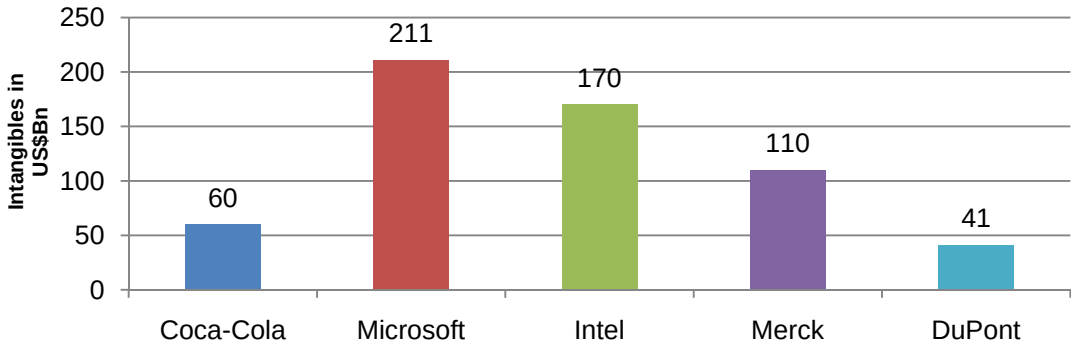

Figure 3: Value of intangible assets (Giordan and Kossovsky 2004, p.10)

Giordan and Kossovsky (2004) point out that a large business like DuPont seems to have a disproportionately low valuation of their intangible assets to that of companies such as Microsoft, Intel etc. They suggest that this is the result of a lack of focus, or the mismanagement of valuable intellectual property.

The authors further suggest that the CTO role may need to evolve to Chief Asset Officer with P&L responsibility and accountability for valuable R&D outputs. They state that intangible assets need to be managed in a portfolio as a particular asset class and accounted for in a way that properly recognises the market value. The authors use the US accounting convention of depreciating the value of R&D to zero (thus ignoring the future value), as an example of a practice that causes anomalies in management behaviour.

Cannon (2005) has concerns about the dangers of not actively managing intangible assets. He argues that CTOs should be stronger custodians of the value of R&D work. In particular they should monitor the impact of outsourcing. This includes the potential loss of IP in countries with weak intellectual property laws, and the loss of R&D skills offshore in exchange for lower cost short-term gains. The author recommends that the CTO should be looking for reciprocal relationships rather than having the procurement department seek the lowest cost option. He offers ten questions to test whether the CTO is, " … giving away the store."

Overall this literature suggests that in some organisations the CTO role is essentially similar to the R&D manager role, but with a remit to interface with the top of the business. The purpose of this interface is to improve the understanding and buy-in to technology initiatives, and to ensure that these are focused on valuable outputs. However, where there are attempts to leverage external technologies and / or internal intellectual property, the CTO role looks entirely different. This is particularly important where the value of intangible assets is high as a proportion of the value of the business. Either way, the change in remit for the CTO is significant.

2.5.2 Alternatives to the CTO role

This section is included because a review of the CTO literature excludes the technology leadership practices of businesses that do not have a CTO - either by default or by deliberate choice. One situation in which a CTO may be absent in a business, occurs when technology is led by the CEO. Another possibility is the use of technology committees such as Technology Management Review Boards (sometimes in conjunction with the CTO role). Also, this section notes alternative roles for the CTO.

Smith et al. (1999) focus on new CTO responsibilities resulting from the introduction at Alcoa of Technology Management Review Boards (TMRB). These boards are set up via the Alcoa Technology Board. The Technology Review Board includes the CEO, CTO and

business unit presidents, while the TMRBs included marketing, manufacturing, business leaders, etc. and are set up around common technologies. The objective is to get technology closer to the business units.

While the TRMBs were successful in getting closer to the business units, they are criticised for being too inwardly focused. As a result, the remit has changed to encourage global networking and targets to close specific innovation gaps. The authors describe the overall shift as being from a traditional, central laboratory, to a global, 'virtual' technology organisation. Whereas the CTO was previously the department head of the central laboratory, the new role is that of a global facilitator, ensuring technology capabilities across geographies and technologies, and across business unit and functional domains.

In a more refined perspective on the CTO role, MacMillan and McGrath (2004) set out nine processes – three at each level (venture, champion and "heatshield"), related to "opportunity pipeline", "market entry" and "takeoff". They suggest that the technology manager needs to carry out these processes in order to achieve success in technology development. They claim that this " … new type of technology development management" seeks speed to profitable commercialisation. The focus is " … on the challenges facing the technology program manager who is responsible for the innovation program as a whole."

The authors also state the need to consider competitors' reactions and the entire supply chain i.e. to take account of resources within and outside of the boundaries of the firm. They conclude that to succeed, firms need technology programs focused on business-building rather than R&D. They suggest that this role should be called the "Technology Development Manager".

The apparent need to redefine the CTO role using TMRBs or to suggest alternatives such as the 'Technology Development Manager' are not unusual. These can be added to the Giordan and Kossovsky (2004) suggestion to have a 'Chief Asset Officer', or the option to have a 'Chief Innovation Officer' (Smith 2007). The lack of alignment about the role of the CTO in the literature echoes the outcome of the initial survey conducted for this research[6]. Opinion leaders had difficulty reaching consensus on the scope and focus of the CTO role.

[6] With the European Institute for Technology and Innovation management (EITIM). See Appendix 8.

2.6 Implications for researching the CTO role

In this review of the CTO and related literature, it is evident that very few empirical studies have focused on the role of the CTO. However, collectively the conceptual articles written by authors holding senior posts and having a lot of technology leadership experience do need to be taken seriously.

Together, the contributions of the authors suggest that technology management has evolved significantly. A number of articles are reviewed for insights into their perspectives and approaches regarding studies of the roles of other CxOs e.g. the CEO and CIO. The majority of authors either explicitly or indirectly support the need to capture context in any investigation of the role of the technology leader.

There are also various themes that recur. These include the credibility of the technology leader; the need to nurture key relationships; the need to ensure that technology and business strategy are integrated; and the need to consider the customer.

Consideration of alternatives to the CTO role, and of alternative roles for the CTO reveal various insights. For example because of the prominence of intangible assets—increasing value of IP as a proportion of company value—and because of the impact of centralising and de-centralising R&D i.e. on whether the CTO is positioned on the board or not.

There is discussion on the need for careful management of intangible assets, particularly when trends are towards an increase in externally sourced technologies. This aspect of the innovation process requires specific high level leadership abilities. These abilities are not a natural progression of technological skill development, and need to be included in the training of future technology leaders.

More generally, the literature is considered in terms of the core purpose of the CTO role, the related barriers and enablers that CTOs encounter, and what management activity they engage in. In summary, the view is that very little is written specifically on barriers and enablers. Also, that where management action is discussed, it is causally isolated from the barriers and enablers it is addressing. Furthermore, the diversity of opinion on the role suggests that seeking a generic characterisation of the role is problematic. Regular reference is made to the need to consider the context when looking at the role of the CTO. Chapter 3 extends the review of the literature by looking at the technology management context.

3 Technology Management Context

3.1 Introduction

This chapter looks at literature that focuses on the technology management context. In particular, consideration is given to the perspective that the R&D management context is continually evolving. The six generations of R&D and innovation processes set out in the literature are discussed. The assumption for this work is that each generation represents a stage in the evolution, and thus potentially different technology management contexts.

Another perspective (Phelps et al. 2007) challenges long held views about the applicability of life-cycle metaphors related to context. A framework depicting different organisational "states" is reviewed. In considering an alternative framework, Phelps et al. (2007) critique existing life-cycle perspectives on organisational growth. While their study is based on literature that focuses on small, fast growing and high-tech firms, it is considered here as a counter-argument to the 'evolving context' view.

Evidence is discussed regarding the relationship between context and the role of the CTO. The key assumption to be reviewed, is that certain technology management priorities are self evident for a given context. The appeal of looking at context is that if a typology of contexts can be identified, then characterising the role of the CTO could be based on patterns of priorities matched to each context.

3.2 The management context

However, it is useful to first locate the discussion about technology management in the broader context of management. Hamel (2007) makes the point that (the technology of …) management has not changed much since the 1930's. He says that, " … most of the essential tools and techniques of modern management were invented by individuals born in the 19th century … ". He goes on to point out, that by 1930 they, " … had also designed the basic architecture of the multidivisional organization … " (Hamel, 2007, pp.6-7). These are set out in Table 7.

Table 7: Modern management principles (Hamel, 2007, p.151)

Principle	Management attention	Goal
Standardization	Minimize variances from standards around inputs, outputs, and work methods.	Cultivate economies of scale, manufacturing efficiency, reliability, and quality.
Specialization (of tasks and functions)	Group like activities together in modular organizational units.	Reduce complexity and accelerate learning.
Goal alignment	Establish clear objectives through a cascade of subsidiary goals and supporting metrics.	Ensure that individual efforts are congruent with top-down goals.
Hierarchy	Create a pyramid of authority based on a limited span of control.	Maintain control over a broad scope of operations.
Planning and control	Forecast demand, budget resources, and schedule tasks, then track and correct deviations from plan.	Establish regularity and predictability in operations; conformance to plans.
Extrinsic rewards	Provide financial rewards to individuals and teams for achieving specified outcomes.	Motivate effort and ensure compliance with policies and standards.

It is for this reason that Hamel (2007, p.21) suggests that it is time to review management practice itself. He is targeting what he calls, " … the recipes and routines that determine how the work of management gets carried out … "

He includes:

- Strategic planning
- Capital budgeting
- Project management
- Hiring and promotion
- Training and development
- Internal communications
- Knowledge management
- Periodic business reviews
- Employee assessment and compensation

He notes that while these processes need to be reviewed, there are a number of businesses that have applied them in ways that have resulted in durable competitive advantage. He cites General Electric's approach to managing science, DuPont's capital allocation approach, Procter & Gamble's management of intangible assets, Toyota's methods for capturing the " wisdom of every employee… " and, the way in which Visa uses a global consortium and operates as a "virtual company" (Hamel, 2007, pp.23-24).

However, Hamel (2007) also points out the paradox that while shifts to new technology, global economy and new political and socio-economic states have happened, management has stayed essentially the same. He cites numerous business failures and failures of management and leadership. The implication is that it is incorrect to assume a steady state in the environment within which R&D and innovation occur. The environment (the context) is changing; however, the role of management is not adapting appropriately.

Context is defined as, " … the set of circumstances or facts that surround a particular event, situation, etc." (Dictionary.com, 2010) It also denotes, " … frame of reference, background, framework, relation, connection…" (Collins Thesaurus, 1987). For this study, related to the technology management context, it is necessary to include the stakeholders. That is, context would include competitors, suppliers, customers, trade unions and shareholders, within a particular economic situation. Additionally, this would include organisational structures and processes created and monitored by managers. The context of an organisation is also based on the products and markets they serve, sources of labour, sources of funding, geographical footprint, and where the organisation is in time.

The technology management context incorporates any or all of these elements, taken specifically from the point of view of the technology executive. The next section considers how R&D has evolved over time.

3.3 The technology management context: R&D

3.3.1 First generation R&D

Roussel et. al. (1991) state that the R&D approach of the 50s and early 60s should be called "first generation R&D". 1st generation R&D is characterised by an absence of the linkage between technology / R&D and strategy. They declare that with regard to the operations of R&D, "…General management possesses scant insight and provides little guidance." Future technology options are selected by R&D in isolation from the rest of the business. They state

that " … business people" think that R&D people don't understand business and are "uncontrollable". R&D people think that, " … targeting stifles motivation". Erickson (1993) adds that 1st generation R&D involved setting scientists up in attractive premises and locations and leaving them to intuitively deliver the technology requirements.

The macro context of the time is described by Rothwell (1994) as having been when leading economies saw rapid growth rates and increases in employment. New industries emerged including – semiconductors, computing, pharmaceuticals and synthetic and composite materials. Existing industries were boosted by technology driven improvements affecting agricultural production, textiles, and steel. A consumer boom fuelled growth in consumer white goods, electronics and automobiles.

Generally, scientific and industrial innovations were seen as a way to solve many social problems. As a result, national policy was to support science and technology particularly on the supply side i.e. by funding universities and government laboratories. The assumption was that more R&D input would lead to more successful products at the output end. Furthermore, the assumption for this technology-push view was that the process was linear starting with scientific discovery, through technology development to the market.

3.3.2 Second generation R&D

The next stage, 2nd generation R&D, is characterised by the collaboration between R&D and business in the selection of projects. This stage marks the beginnings of "purposeful" R&D activity (rather than intuitive), broadly within a strategic framework (Roussel et al. 1991). There is no discussion about management taking account of the benefit of synergy across business units or businesses.

Erickson (1993) says that 2nd generation occurs because of pressure from shareholders to abandon the "wait and see" approach of the 1st generation. This stage is described as adversarial with decisions based on a more quantitative approach.

Rothwell (1994) suggests that from the mid 1960s to the early 1970s, this 2nd generation innovation process occurs against the backdrop of an increased focus on marketing. The process is characterised as being "market-pull" or "need-pull" oriented. Manufacturing productivity is the focus and so the emphasis moves from product innovation to production innovation. This period is also marked by industrial consolidation, an emphasis on organic growth, as well as diversification via acquisitions.

The public policy response (in the USA) results in a distortion of the importance of demand side factors (e.g. through public procurement policy). The intention is to stimulate innovation. The overall impact of the policy response and the general corporate approach is intensified competition, an eroding technology base (in pursuit of short-term gains), and that R&D is relegated to a somewhat reactive role.

3.3.3 Third generation R&D

The strategic corporate perspective is introduced in the 3rd generation R&D perspective. This includes a portfolio approach towards projects (i.e. a set of projects defined and managed for the overall benefit of the corporation) - (Roussel et al., 1991). Third generation R&D requires a holistic strategic framework, a partnership between key functions and R&D, a breakdown in the isolation of R&D, and integrated technology and business strategies at a corporate level.

Roussel et al. (1991) also distinguish between a management and strategic context on the one hand, and operating principles on the other. The operating principles focus on the approach to funding, resource allocation, targeting (goals defined and consistent with business and technology), priority setting, measuring results and evaluating progress.

Rothwell (1994) describes the 3rd generation innovation process as a series of sequential activities conducted in independent, yet interdependent functional areas. These activities incorporate feedback loops not envisaged in 1st and 2nd generation innovation processes. He also points out that by this stage, evidence has highlighted that the "technology-push" and "market-pull" models are "atypical" extremes.

The shift to the 3rd generation occurred against the backdrop of the oil crises of the 1970s. The period was characterised by high inflation, and supply outstripping manufacturing demand. The result was higher levels of rationalisation and cost control. The emphasis of scale and experience benefits was accompanied by higher levels of scrutiny of the business cases for innovation projects. These factors all contributed to the need for what Rothwell (1994) calls the 3rd generation "coupling" model of innovation.

In reviewing the evidence regarding innovation processes, Rothwell (1994, pp.10-11) identifies two sets of factors that might differ depending on the sector being considered. The two groupings are to do with execution (project management) and corporate level factors.

"Project execution factors:

- Good internal and external communications: accessing external know-how.
- Treating innovation as a corporate wide task: effective inter-functional coordination; good balance of functions.
- Implementing careful planning and project control procedures: high quality upfront analysis.
- Efficiency in development work and high quality production.
- Strong marketing orientation: emphasis on satisfying user needs: development emphasis on creating user value.
- Providing a good technical and spares service to customers: effective user education.
- Effective product champions and technological gatekeepers.
- High quality, open-minded management: commitment to the development of human capital.
- Attaining cross-project synergies and inter-project learning.

Corporate level factors:

- Top management commitment and visible support for innovation.
- Long-term corporate strategy with associated technology strategy.
- Long-term commitment to major projects (patient money).
- Corporate flexibility and responsiveness to change.
- Top management acceptance of risk.
- Innovation-accepting, entrepreneurship-accommodating culture."

Erickson (1993) views the 3rd generation approach as a means for technologists to explain why, where, when and how technology is important to the business. In her prescriptions for improving performance in the 3rd generation, she makes six key points: 1. Increase communications; 2. Encourage frequent employee interaction; 3. Minimize the fear of failure;

4. Create a flexible organisation capable of making tough choices; 5. Maintain a sense of urgency; 6. Put all your cards on the table.

The 1st to 3rd generations tend to refer to R&D. The generations that follow in the literature include a mixture of references to R&D and 'innovation' generations.

3.4 The technology management context: Innovation process

The literature dealing with the 4th generation to the 6th, refers to 'innovation process' rather than 'R&D'.

3.4.1 Fourth generation

The fourth generation occurs in the period between the early 1980s and the early 1990s, and is characterised by a higher emphasis on technology strategy. Firms have engaged in global projects and there is a rapid increase in the number of trans-border alliances. Rothwell (1994) suggests that in this period a new awareness grows about the value of the approach being used by Japanese firms. This is particularly so because of shortening product life-cycles and thus the need for rapid development processes. The Japanese approach is to take activities that were previously run sequentially, and execute them simultaneously. They focus on "design for manufacturability" and use intensive "information exchange" between departments. The process is also known as "parallel development".

3.4.2 Fifth generation

Rothwell (1994) suggests that by the early 1990s, the world economy had faltered. Once again, this precipitates resource constraints and a much closer look at product development speed. This is particularly necessary where technology change is high and product life-cycles are short. The major issue related to development speed remains the trade-off in terms of development cost. As a consequence technology strategy is central – particularly where higher development speed (with related higher costs) means development portfolio rationalisations.

Better understanding of the output of development projects is also key. This is because an important variable in the decision process is the impact on overall revenue and profit of getting to market first (Reiner, 1989; Rogers, 2003).

The 5th generation process is called, "lean innovation" by Rothwell (1994). He suggests that the 5th generation approach requires four "primary enabling features" (Rothwell, 1994, p.23):

- Organisation and systems integration
- Parallel and integrated development process – cross functional
- Early supplier involvement
- Lead user involvement
- Horizontal technological collaboration
- Flat, flexible structure for quick decisions
- Empowered managers at lower levels
- Empowered champions and project leaders
- Fully developed internal databases
- Data sharing systems
- Expert systems, metrics and heuristics
- 3D-CAD systems and simulation modelling
- Enhanced manufacturability and development flexibility from linked CAE/CAD systems
- External data links
- Link to suppliers with CAD for co-development
- CAD use when customer facing
- Links with R&D collaborators.

Rothwell (1994, p.27) points out that informal information exchange is another feature of 5th generation. Notably, the former is most successfully deployed by Japanese firms. He says that the use of informal information exchange is slightly less useful in science based process oriented sectors, such as chemicals and pharmaceuticals. It is most useful in complex assembly-type environments such as aerospace, automobiles, and electronics. The former sectors tend to innovate internally and have less input variety, while the latter have many actors and a high diversity of components.

3.4.3 Sixth generation

The sixth generation approach is described by Nobelius (2004, p.374) as a return to the research orientation of 1st generation R&D. This approach has similar motivations in that radical innovations are possible. However, the approach has changed significantly, because in place of the corporate research laboratories, he envisages an, " … arena for collaboration and sharing of ideas … " The considerations for the 6th generation approach are, " … multi-technology base for high-tech products and a more distributed technology-sourcing structure." Examples of the technology-sourcing approaches that may be selected, depending on specific sector and project need, include internal R&D, joint ventures, intellectual property acquisitions, corporate venturing, technology company acquisitions, corporate venture capital and independent research groups and networks.

The author cites two examples of this way of working. One is Linux (an alternative to the Windows operating system) which was developed by an unaffiliated interest group who share the code freely. The second, is the development of Bluetooth, which was driven by Intel and Eriksson, and involved around 1600 companies. In the Bluetooth project, Eriksson gave up important intellectual property rights (to the special interest group) in order to ensure that Bluetooth would become the *de facto* standard.

3.4.4 Linking generations to technology management priorities

In each description of the stage of the evolution of R&D, the "generation" includes elements of the macro context, in some cases the policy responses, and the type of activity being led by the technology executive. In other words, each generation is characterised by a discrete context that forms a backdrop to the purpose, barriers, enablers and management actions undertaken by the CTO. A useful summary and an example of the way that context is related to management priorities is provided by Nobelius (2001) – see Figure 4.

In a similar attempt to link context and management priorities, Roberts and Liu (2001) use an example of successful companies embracing the use of external technology. Their approach is to track the external transactions of the Microsoft Corporation between 1975 and 1999 (using a Technology Life-cycle framework based on the work of Utterback, 1994). The authors suggest the need for technology executives to understand where their products are in the technology life-cycle, in order to make informed decisions about whether to use alliances or acquisitions.

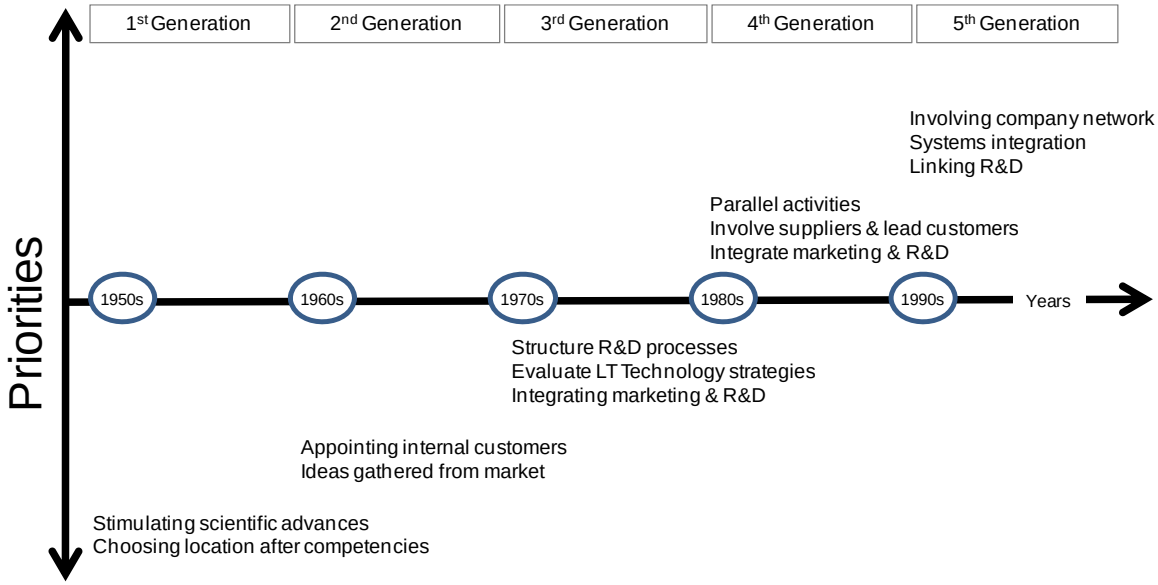

Figure 4: Technology management priorities (based on Nobelius, 2001)

They summarise the activities undertaken by these executives under each of the four phases from "fluid" to "discontinuous" - see Table 8. They describe how there is a change in emphasis from product to process innovation towards the mature phase of the technology life-cycle. The need for faster development is cited as a reason for external collaboration, given the relatively higher cost of process innovations. The authors also point out that acquisitions may be better where exclusive rights to technologies and the development of core competencies are required.

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Table 8: Characteristics of the four technology phases (Roberts and Lui, 2001, p.29)

	Fluid phase	Transitional phase	Mature phase	Discontinuous phase
Dynamics of the phase	Uncertainty in products and markets High rate of product innovation and degree of process flexibility Fast-growing demand; low total volume Greater importance of product functionality than brand names Little direct competition	Appearance of dominant design Increased clarity about customer needs Increased process innovation Importance of complementary assets Competition based on quality and availability	Strong pressure on profit margin More similarities than differences in final products Convergence of product and process innovations	Invasion of new technologies Increasing obsolescence of incumbents' assets Lowered barriers to entry; new competition Convergence of some markets as new technologies emerge
Priorities	Development and preservation of technology (with a focus on product development and aggressive patenting) Promotion of proprietary technology as industry standard	Realignment of technological capabilities with dominant design Continued exploration of technological opportunities Pursuit of growth strategy (through aggressive capacity building or by establishing a close relationship with suppliers and customers)	Cost control throughout the value chain Strong customer focus Lean and efficient organisation	A need for incumbents to identify new technologies and realign core competencies An option for incumbents to exit the market Attackers' need to gain market recognition Attackers' need to focus on product development

	Fluid phase	Transitional phase	Mature phase	Discontinuous phase
Strategic alliances	Formation of alliances to promote technology as the industry standard Adoption of licensing strategies (say, open-source licensing or aggressive licensing to users) Formation of key marketing alliances (with key players of the supply chain or one industry leader) Formation of technology alliances with established companies, often coupled with equity investments	Winners' aggressive licensing to customers and to companies that lost the dominant design battle Formation of joint R&D ventures with companies in the market Formation of marketing alliances; signing of supply agreements to guarantee consistent quality, price and availability	Formation of joint R&D ventures to share risks and costs of technology development Formation of marketing alliances to attack latent markets or lure customers away from competitors Manufacturing alliances to ensure availability of essential products Open alliances with suppliers and customers	Attackers' formation of marketing alliances to gain market recognition Attacker agreements to supply technology leaders Incumbents' acquisition of disruptive technology through license agreements
Mergers and acquisitions	Acquisitions of start-ups by well-established technology companies from more mature high-tech industry Corporate equity investment by well-established high-tech companies	Acquisitions of competitors by the winners in the dominant technology battle Acquisitions by established technology companies entering the market	Horizontal mergers between companies with complementary products and services Divestiture of manufacturing capabilities that are essential Acquisition of technology start-ups making products that would be difficult to develop in-house	Possible equity financing for attacker from established technology companies Established companies' move into new markets through acquisition of niche technology companies Established companies' acquisition of enterprises that have related product capabilities Divestiture of companies as priorities shift with market convergence

This particular example of a case that links management priorities to the technology management context is of interest because it differs from the 'generations' perspective.

The generations assume that the dynamics of the context are a function of time and related economic circumstances. The Roberts and Lui (2001) example assumes that the dynamics of the context are linked to the maturity (in life-cycle terms) of the technology. Also, it is worth noting that Utterback (1994) added his 'discontinuous phase' some time after his original three phase technology life-cycle. By comparison with the original life-cycle metaphor, the additional phase seems to be added to cope with random changes that do not fit with a life-cycle progression. The 'discontinuities' are of the type that would be hard to predict except where the CTO or the business had planned them in advance.

This life-cycle perspective is considered in more detail in Section 3.5.

3.5 Technology management context: Life-cycle stages

Generally, the appeal of life-cycle models is the possibility of being able to attribute particular management priorities to each life-cycle stage (Kazanjian and Drazin 1990). An example is the 'technology life-cycle' discussed and summarised in Table 8 (Roberts and Lui, 2001). The application of the life-cycle metaphor to 'organisational' growth is considered in this section. In particular the life-cycle metaphor is considered as it applies to the growth of technology firms.

In their systematic review, Phelps et al. (2007) identified thirty three life-cycle based studies published between 1967 and 2003[7]. These studies propose anything from 2 to 10 life-cycle stages. The models they review characterise each stage as a set of contextual dimensions such as size, age, and rate of growth, or structural dimensions (e.g. formalization, centralization and vertical integration). Their approach applies pattern recognition to the sets of problems encountered by managers. As an aid to sensemaking these patterns are packaged into proposed life-cycle stages, with related prescriptions. The prescriptions take the form of suggesting that in order to manage *x* stage, deploy *y* set of management actions. In other words, for each stage there is a packaged solution.

The difficulty is however, that, " … there is little consistency either in the number of elements that define these models or in their constitutive components, and that they suffer

[7] Phelps et al. (2007) have a tabulation of these studies in their Appendix 1 – p.23

from being linear, unidirectional, sequenced and deterministic." (Phelps et al., 2007, p.17). These authors state in their review that they would expect a higher level of convergence of patterns that relate management problem sets to specific stages. Their concern is that this lack of convergence challenges both the explanatory and predictive validity of the life-cycle idea.

However, a number of variations to a sequential, life-cycle type view may exist. The life-cycle view assumes that a series of discrete (predictable) stages or states follow in a sequence. An example might be the growth from early start-up to an early manufacturing concern. The life-cycle metaphor follows the idea of the birth, development, decline and demise of a living organism. The assumption of progression in an incremental and predictable manner does not necessarily translate to the reality of business growth.

However, each stage or state may occur at different times in different sectors, in a discrete way. Each stage may be akin to a specific context, with specific problem sets and management responses. It may therefore be useful to know what circumstances, or conditions, or events, transform the context from one state to another. Gladwell (2000) describes the occurrence of dramatic events that appear to change a situation from one state to a radically different state very quickly. He calls these events, "tipping points". "Tipping points" are defined more formally as, " … the culmination of a build-up of small changes that effects a big change." (Dictionary.com, 2010)

He uses numerous social anecdotes to support his ideas (such as the dramatic reduction in crime in New York from the 80s to the 90s, fashion changes, book launches, religious memberships and the impact of television on learning). The proposition is that certain events precipitate "social epidemics" that spread rapidly. The author uses the epidemic metaphor and suggests that dramatic changes occur because three agents of change are in place i.e. the environment in which an infectious agent is operating, the infection itself, and the involvement of people to transmit the infection.

The example cited by Nobelius (2004, p.373) of Bluetooth might be an example of such a rapid change. Bluetooth launched in the market in 2001 with ten million units. By the end of 2002, nearly 35 million devices were in the market. Bluetooth has since become ubiquitous. In the Bluetooth case, the industry context (the environment) was amenable to the collaborative development of the Bluetooth standard, the solution was needed and very attractive (the potential virus) and both Eriksson and Intel were motivated to convene and activate the process (the people).

While Phelps et al. (2007) suggest that the life-cycle metaphor is inappropriate; they do consider the 'tipping point' perspective to be valid. The metaphors used, i.e. the life-cycle and the epidemic, are dealing with slightly different aspects of changes in context. The life-cycle is suggesting some degree of predictability, while the epidemic is addressing the speed at which things change.

Based on their systematic review of the literature and the their concerns about existing theories, Phelps et al. (2007) derived a framework to show how managers can 'navigate' between contexts by addressing 6 elements. The elements are affected when a business changes from one context to another. They are labelled market entry, strategy, formal systems, obtaining finance, people management and operational improvement. Each element is described as follows:

Market entry – entails a permutation of new and/or existing products and markets with the requirement to be able to adapt the business model and execute the appropriate marketing approach.

Strategy – involves the strategic orientation. This may involve simply adopting a strategic plan for the first time, or may entail a change in an existing orientation. An example cited is the move away from opportunistic and reactive working to targeting specific opportunities in a formal manner.

Formal systems – entails the shift from ad hoc processes and policies to increased control and coordination. This typically occurs in response to growth of the organisation, in particular to the entry of larger competitors or the demands of expansion into new markets. " … Formalization enables smaller firms to focus limited resources and to concentrate efforts … " (Phelps et al., 2007, p.10)

Obtaining finance – funding for start-ups is most often provided by the founders. If they succeed and begin to grow, the funding source typically shifts from internal to external. When this occurs the type of problem encountered is to do with the way in which risk is presented and in particular the quality of business plans.

People management – this type of encounter occurs when a firm is growing fast, needs to reduce the number of staff (such as when the economy falters), needs to implement delegation, recruitment, training, and performance management. An example might be when

a start-up can no longer be managed by the founders and professional management is required. This may also entail issues to do with communications in an organisation.

Operational improvement – this represents an area where significant barriers to improvement may occur. Growing firms may feel pressure to adopt improved operations e.g. from key customers or competitors, but lack the motivation. The barriers may include cost, lack of information and indecision. These improvements may become apparent due to efficiency gaps and errors, and yet, Phelps et al. (2007) cite evidence that there is a reluctance to resolve the problems faced.

Finally, in their study Phelps et al. (2007) suggest a mechanism to address the speed of change. They state that the navigation process between contexts is based on the ability to learn. The ability to learn is a function of absorptive capacity. Absorptive capacity is the ability to use networks and information to transition from ignorance to awareness, then to knowledge and finally on to implementation. Both the 6 elements and the learning stages are shown in Figure 5.

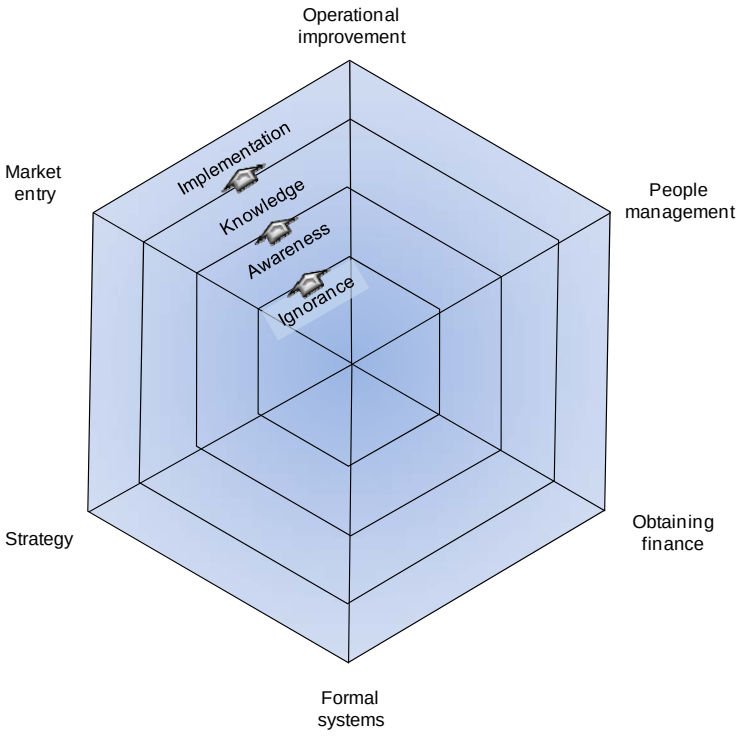


Figure 5: Absorptive capacity framework (Phelps et. al., 2007, p.13)

The contribution of the absorptive capacity framework is that it suggests a practical way to manage the process by which change occurs by focusing attention on each of the absorptive capacity stages. When used in conjunction with the six elements in Figure 5, both the priorities and the goals of management attention are addressed.

3.6 Implications for researching the CTO role

In Chapter 3, perspectives on context are considered. One perspective is that R&D has evolved over time from 1st to 6th generation. Another argues for a move away from a life-cycle view of growing firms to one of firms facing both expected and random change. The latter perspective is based on the notion that the stages in the growth of a business are not sequential or predictable.

In the literature about the R&D context, there is a recognition that it is more appropriate to think of the generations as depicting overlapping and interchangeable approaches. Nobelius (2004) summarises these managerial approaches as they relate to each generation. This summary (Table 9) indicates how the change in technology management context is perceived to be linked to the management approaches. For the purposes of this research, this suggests that the CTO might serve a different purpose depending on what generation of R&D characterises the organisation.

The recognition that the CTO role is changing is referred to by Larson (1996). He specifically discusses the way the R&D leader role has evolved during the various generations. His view is that the R&D leader role has been changing over 40 years. For the Research Director in the 50s and 60s, the focus was on getting good people, building “beautiful” laboratories away from HQ, and producing information that may or may not be useful. In the 70s and 80s the VP of R&D attempted to link R&D to the corporate strategy, but was not part of the board.

Table 9: Managerial actions based on Nobelius (2002, p.372)

R&D Generations	Company response	Managerial priorities
5th generation	Cross-boundary alliances	Involving company network Focusing integration of systems Separating / linking R and D
4th generation	Cross-functional projects	Parallelizing activities Involving suppliers & lead customers Integrating R&D and marketing
3rd generation	R&D projects	Structuring R&D processes Evaluating long-term technology strategies Integrating R&D and marketing
2nd generation	Business unit development	Appointing internal customers Ideas gathered from market
1st generation	Corporate research labs	Stimulating scientific advances Choosing location after competencies

However, since the contexts are sector specific and are not necessarily representative of each business, it is inappropriate to generalise using this perspective. It may be necessary for the CTO to deploy a configuration of different management approaches that are drawn from multiple R&D generations simultaneously. Furthermore, the configuration may change depending on significant events in each particular business (the so-called "tipping points").

This idea is taken up in the perspective that businesses move from one "state" to another, rather than from one "stage" to another, as suggested by the life-cycle growth model. These "states" may still be discrete, but may regress or progress in a non-sequential manner.

The framework proposed by Phelps et al. (2007) is based on literature that mostly applies to smaller fast growing, high-tech firms in the US (Phelps, 2007, p.13). However, there is a possibility that this framework may be suitable for use in larger technology specific organisations provided certain rigidities are taken into account (see Aislabie, 1992).

The two perspectives of context used, also appear to converge in the views of 5th and 6th generation R&D / innovation processes (Nobelius, 2004), and the Absorptive capacity / tipping point framework (Phelps et al., 2007). Both emphasise the shift to integration and the use of networks and learning.

As noted in the CTO literature in Chapters 2, various authors support the idea that the CTO be part of the strategic planning team with leadership of the innovation process (Larson, 1996; Uttal et al., 1992; Adler and Ferdows, 1990 and Heininger, 1988). However, what their purpose might be, what barriers and enablers they encounter and what management actions they should undertake will both impact and be informed by, the technology management context. To some extent, it is possible to locate the sector types of the interviewees broadly within the 6 generations view of context. However, it seems more useful to attempt to identify technology management specific "discontinuities" (Roberts and Lui 2001) and "tipping points" (Phelps et al., 2007).

A final implication related to this study of the role of the CTO is highlighted by Garreau (2005, pp.10-13). He talks about 'inflection points' and reminds his readers that, " … culture and values lag technology." By this he means that technological innovation only becomes visible and useful when society engages and deploys it. This reinforces the idea of 'tipping points', and suggests the need for CTOs to be at least as aware of the broader context as they are of the technologies they are managing. Any framework that would support the CTO at 'tipping' or 'inflection' points needs to take account of the balance between social and technological priorities.

In Chapter 4 the 'CTO' and 'Technology Context' literature set out in Chapters 2 and 3 is used as the basis for finalising the research purpose and specific research questions. The choice of method is based on alignment between the purpose, the research design and the theoretical perspective.

4 Methodology

4.1 Introduction

The preceding chapters have introduced the research topic, set out the literature used for this work, and defined the related terminology. This chapter has four sections, the first of which focuses on the derivation of the research questions. Links are made between existing literature and the research topic with a view to establishing a basis for the research questions that are framed.

The next section covers the choice of research method[8], including the purpose, research questions, theoretical perspective and the research design. Consideration is given to the options available for researching the topic, and justification is offered for a new research approach i.e. personal role mapping.

4.2 Derivation of the research questions

The sparseness of CTO specific literature and the diversity of research approaches may be partly because of the variety of roles taken on by CTOs. Attempts at generalising the role of the CTO are continually undermined by alternative perspectives. Each alternative perspective is based on specific assumptions regarding the particular technology management context. Overall the conclusion from the literature is that the role of the CTO is highly idiosyncratic.

The literature shows that the topic is still in an explorative phase relative to more established research domains. Also evident, is the variety of research approaches that have been taken in the investigations published to date.

A comprehensive database search in 2006 returned thirty seven articles specifically focused on the CTO (Herstatt et al., 2007). The earliest of these, dates back to the 1990's. It is reported that very few of these articles are empirically based because in most cases only small samples are used. The authors also confirm that few studies look at the role in terms of personal background, tasks, responsibilities, authority and the relationships between key stakeholders. A number of conceptual papers focused on the characteristics of the CTO.

[8] See Appendix 4 for checklist of research design considerations (Hart, 2001)

In Chapter 3 the 'technology management context' literature is considered. Researchers have attempted to describe technology management priorities based on assumptions about patterns in stages of development of the technology management context. This perspective is found to be problematic and there is evidence that change is not linear or predictable.

Whether empirical or conceptual, the CTO literature is broadly restricted to a view of the role of the CTO through two lenses. The first is the attributes of the task – i.e. What is it that needs to be done by the CTO? The second is to do with the attributes of the person undertaking the role – What type of person is best suited to the CTO role?

The technology management context is a further lens through which to consider the CTO role. In the literature reviewed for this research, the 'generations of R&D' perspective and the 'life-cycle' of growth perspective are used as a way to think about the technology management context. This is because these views suggest associations between certain contexts and technology management priorities.

The emergent opportunity given the existing literature is thus to bring together the "task attributes" view, the "personal attributes" view, and the "technology management context" view in a single perspective. This can be achieved by researching the role from the CTO's point of view. In other words, to look at the way in which the CTO experiences the role. The CTO does the work, embodies the personal attributes and operates in the context, and so can be investigated as a way to take account of all three perspectives in a single study. Future research can build on this research by triangulating the CTO perspective with that of the CxOs in each business (i.e. peers and superiors).

So, this research investigates the role and contribution of the CTO by asking the central question:

"How do CTOs perceive their role and contribution?"

More specifically:

"What do they consider to be their core purpose in the role?"
"What barriers and enablers do they encounter?"
"Why are these barriers and enablers to the declared purpose?"
"What actions do they take to nurture or mitigate these barriers and enablers?"

What follows is a section that covers the purpose of the research, the research questions revisited from the perspective of the method, the theoretical perspective, and the research design.

4.3 The research process elements

The choice of research method is based in part on the need to align the research process elements - see Figure 6. Also, the choice is based on a consideration of alternative approaches. Given the limited literature and related theories about the role of the CTO, the initial assumption is that this research should not be based on any particular prior theory i.e. it is theory building rather than theory verifying.

Partington (2002) emphasises that the way in which theory is generated, is central to the adequacy of that theory. In his view, adequacy stems from alignment between four key research process elements – see Figure 6. These are the research purpose, the theoretical perspective, the research questions, and the research design. He states that these four key elements relate to each other, that they evolve, and that they should be reviewed constantly.

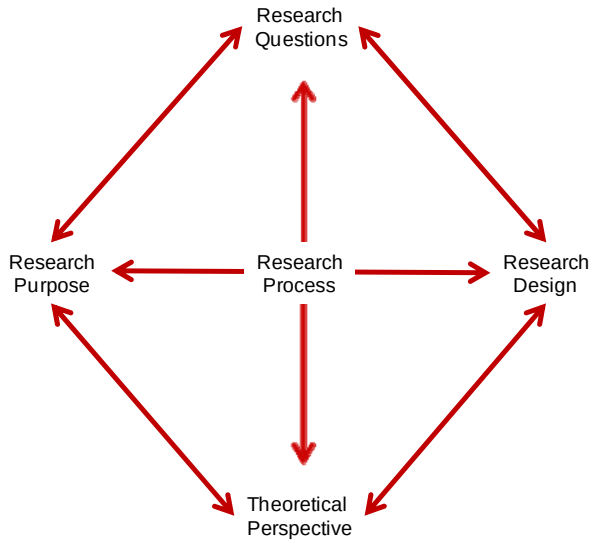


Figure 6: The research process: alignment elements (Partington 2002, p.139)

Each element, as related to this research, is considered in turn in the following sections.

4.3.1 The research purpose

This research explores the role and contribution of the CTO. As expected, the purpose of the research evolved over the course of the study (this is predicted by Partington, 2002). The initial purpose, 'to investigate the role and contribution of the CTO', changed to a focus on the role and contribution from the perspective of the CTO. This evolution of the purpose potentially makes any theory developed substantive (i.e. localised to a particular perspective), even though the research is undertaken across numerous industries and types of companies. However, it does address a specific gap in the literature, and is necessary to simultaneously investigate the work, the role player and the context (as discussed in Section 4.2).

A secondary purpose for this research is the opportunity for the author to meet face-to-face with senior technology executives and to engage with them in a meaningful learning process.

4.3.2 Research questions

The first discussion of the research questions above relates to the way in which the research questions respond to gaps in the literature and an understanding of the role of the CTO. What remains is to establish the manner in which these questions can be answered and analysed. In order to do this, it is necessary to briefly revisit the literature. Firstly, the empirical and then the conceptual papers are considered.

Herstatt et al. (2007) found only five empirical CTO related studies. The approaches taken included 25 telephone interviews in Fortune 100 companies based in the US (Adler and Ferdows, 1990); 24 interviews of CTOs in large US companies (Uttal et al., 1992); 25 semi-structured interviews with corporate CTOs and 22 academics (Thurlings et al., 1996); 209 survey questionnaires in Japan, the US and Europe (Roberts, 2001); and 18 interviews of German based head-hunters and analysis of 34 CTO job advertisements (Tietze et al., 2006).

In all Herstatt et al. (2007) reviewed 6 out of 14 conceptual articles (the balance were not considered to be sufficiently substantial). These deal with issues such as the mechanisms by which CTOs can build credibility (O'Neill and Bridenbaugh, 1992); the case for CTOs having profit and loss responsibility (Gwynne, 1996); and the link between future credibility and short-term vs long-term value creation (Larson, 1996). Certain of the conceptual articles are based on the author's credible personal CTO experience (as in the case of Smith, 2003 and 2004). And finally, Medcof (2006) sets out various propositions relating the CTOs activity to the level of strategic involvement and/or power in the organisation.

The conceptual papers offer a broad scope of topics with prescriptions and hypotheses, but may not be sufficiently grounded in data. Of the empirical papers, only three are specifically targeted at the CTO and as Herstatt et al. (2007) point out, " … the perception of the tasks and responsibilities of the CTO have not yet been closely studied." An approach is thus required that is a combination of the credible personal experience of the CTO role (eliciting emergent concepts such as those derived in the conceptual papers), while simultaneously being rigorous and grounded (similar to the empirical studies). This could be achieved by using interviews with CTOs, provided the interview design allows them to explore their experience of the role in depth.

The other consideration regarding the manner in which the research questions are answered, is that the exploration simultaneously takes account of the work, the worker and the context.

In studies of the competence of engine optimisers at Volvo in Sweden, Sandberg (2000) uses phenomenography - see Table 10.

Table 10: Research approaches considered

	Approach	Issues
Phenomenography:	Uses conceptions of individuals in a role as the unit of analysis. Seeks to elicit and codify a hierarchy of conceptions of the role against emergent attribute clusters.	Applied in a single context with many role players in the same role. No precedent for application across multiple sectors. The author conducted an interview and attempted to analyse the results to test this approach.
Repertory Grid:	Largely used in market research to identify polar extremes of constructs elicited from users' views of consumer products.	This technique was trialled by the author as part of another piece of research and found to be extremely cumbersome (from the point of view of the interviewee).
Cognitive Mapping:	Based on the theory of personal constructs. Uses a visual mapping and sequentially reveals constructs and shows associations using arrows to link nodes.	No direct precedent for investigation of an individual's role. However, this approach appears to be more flexible than Repertory Grid. Also, allows interviewees to interpret their own outcomes. A pilot was conducted using this approach (see Section 4.3.4.2.).

His approach has the advantage in that it is simultaneously able to explore the work attributes, the worker attributes and the working context. The approach is applied by Partington et al. (2005) in their study of programme managers. In both studies the unit of analysis is the conception of the role. In the Sandberg (2000) study, each engine optimiser fulfils a similar role in the same context. In the latter study, clusters of programme managers are located in the same business, but the studies are conducted in five different UK based firms.

The concern about the use of the phenomenographic approach for the study of the CTO was that each CTO is located in a different business context and in different businesses. However, the idea of finding an approach that simultaneously captures the work attributes, the worker attributes and the context remains a key objective.

Another way in which these questions could be answered, is to consider using the Repertory Grid technique. This approach could be used for investigating the relationships between colleagues in a working context (as in the example given by Goffin cited in Partington 2002, p.199). The Repertory Grid method was based on Kelly's 'Theory of Personal Constructs' (1955), and as Goffin (2002, p.223) points out it is valuable as a way to, " … uncover interviewees' understanding of complex issues." However, as with any method there are limitations and in particular problems with interpretation (see Goffin, 2002, p.219 for nine specific limitations of this technique). Also, there is no clear precedent of a design for an investigation of a senior management role.

Yet another option is to use a cognitive mapping approach (see for example Ackermann and Eden, 2005). This technique has the advantage that for the research questions chosen, it allows interviewees to retain a visual connection between their different ideas (this is discussed in detail in Section 4.3.4 Research Design). Furthermore, since the CTO prepares the map, their experience of the role is explored in depth. The approach accounts simultaneously for the work, the worker and the context attributes, and interpretation can be done by the interviewee rather than the researcher. However, to do this a further question must be added (underlined for emphasis):

1. "What do they consider to be their core purpose in the role?"
2. "What barriers and enablers do they encounter?"
3. "Why are these barriers and enablers to the declared purpose?"
4. "What actions do they take to nurture or mitigate?"
5. "<u>What are their views of the implications for practice (i.e. of exploring these questions)</u>?"

The last question is essentially asking the interviewee to interpret their own map. This provides a set of interpretations directly from the interviewee and removes one key step that might be detrimental to the validity of the research i.e. the interpretation of the researcher. These interpretations are captured in Chapter 8 “Implications for practice”.

4.3.3 Theoretical perspective

The appropriateness of the method selected is also a function of the theoretical perspective adopted for the research. In this case, this is because an analytical approach is needed to interpret in-depth data that represents the perspective of the CTO about the role. Also, given the scarcity of existing theory, the approach is seeking to build theory in a manner which is empirically grounded. One mechanism to improve theory building is to consider elements of the Grounded Theory approach first articulated by Glaser and Strauss in 1967. To understand the value of this approach it is necessary to briefly review their perspective.

Strauss and Corbin (1998, p.3) defined ‘methodology’ as, “ ... a way of thinking about and studying social reality.” Their definition is drawn from their involvement in the qualitative research tradition for generating theory (or theory building). Glaser and Strauss state that, “Generating a theory involves a process of research.” (2006, p.6) The focus on a process of research is partly driven by the historical criticism of sociological research, i.e. that it lacks scientific rigour.

In response Glaser and Strauss (2006, p.3) suggest that a theory of social research should:

predict and explain behaviour;

- “ … be useful in theoretical advance of sociology;”
- “ … be usable in practical applications – prediction and explanation should be able to give the practitioner understanding and some control of situations;”
- “ … provide a perspective on behaviour – a stance to be taken towards data;” and
- “ … guide and provide a style for research on particular areas of behaviour.”

Overall, their response to concerns about social research results in an approach called “Grounded Theory”. Glaser and Strauss articulated the theory and the process in 1967 and Strauss and Corbin (1998) further codified the techniques and procedures.

Generally, researchers make a distinction between "theory building" and "theory testing" – also referred to as "theory generation" and "theory verification". Grounded theorists build theory by 'grounding' the theories generated in the data used, as opposed to an approach which works from a set of *a priori* assumptions i.e. the so-called logico-deductive approach. Furthermore, when they have assessed their relative merits, they have, " … taken the position that the adequacy of a theory for sociology today cannot be divorced from the process by which it is generated." (Glaser and Strauss, 2006, p.5).

As stated in Section 4.3.2 - Research Questions, in this research the desire is to use a grounded approach. The aim is to predict and explain behaviour in a manner that provides understanding and control to the practitioner. The theory building approach itself is required to ground the outcomes in the data.

Christensen (2006) argues that theory building is part of a wider process that provides hypotheses to be tested i.e. theory testing. The theory building phase is thus fundamental to being able to ask the 'right questions'. Christensen (2006) compares what he calls descriptive and normative theory. He suggests that the Glaser and Strauss (1967) references to substantive theory and formal theory, match his attribute based categorisation of descriptive theory and the circumstance based categorisation of normative theory (Christensen, 2006, p.42). The difference is shown in the comparison in Table 11.

Table 11: Comparison of Normative and Descriptive Theory (Christensen, 2006)

	Descriptive theory	**Normative theory**
Basis of the theory:	Statements of association (Models)	Statement of causality
Analytical process:	Categorisation based on attributes of phenomena (frameworks & typologies)	Categorisation of the circumstances in which we might find ourselves
Research activity:	Observe, describe, and measure phenomena (Constructs)	Observe, describe, and measure phenomena
Data:	Often historical	Field-based

The relevance of the distinction between descriptive and normative theory is that for the study of the CTO role, 'constructs' will need to be 'observed, described and measured'. A framework (model) depicting the role of the CTO is required as a basis for 'asking the right questions' in future research. This recognises that for completeness, an inductive data collection phase and derived hypotheses will ultimately be deductively tested. The scope of this research covers the inductive phase of this approach.

The next section will look at the Research Design.

4.3.4 Research design

Figure 7 summarises the research process elements of purpose, theoretical perspective, and research questions discussed in the methodology section to this point. The research design section explains the background to the research design, reports on the outcome of a pilot interview, and discusses the use of cognitive mapping.

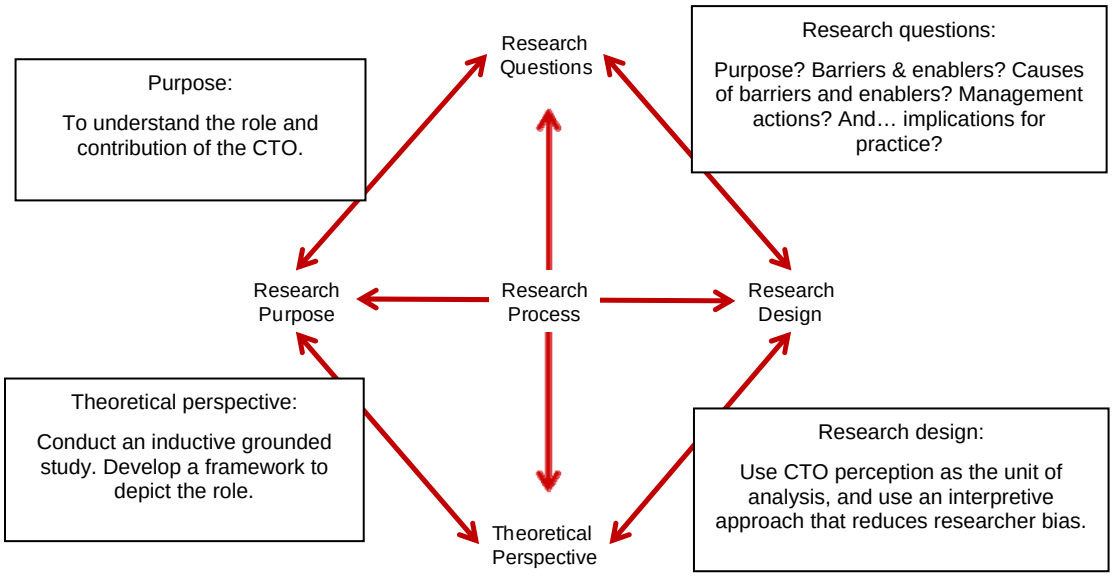


Figure 7: Summary of the research process - based on Partington (2002)

4.3.4.1 Background to the research design

The first part of the research involved asking a group of industrial partners in the European Institute for Technology and Innovation Management (EITIM) about their views on the role

of the CTO, and the need to research the role further. At an annual forum, workshop time was set aside and participants completed a brief survey in which they were asked for their views on the core purpose, and barriers and enablers to that purpose for the CTO role. Small groups then convened to discuss the outcome of the surveys and further discussion occurred in a follow-up plenary discussion.

The outcome of the survey and the discussions revealed that there was very little alignment on the role and contribution of the CTO. It also emerged that it was necessary to understand the reasons for the diversity of views and the implications for practice. In particular the industrial partners present agreed that further research would be useful.

Apart from the central research questions (that is, "What is the core purpose?", and "What are the main barriers and enablers to the core purpose?"), no other questions were formulated at the time of the forum. A decision was then taken to test a very open interview process in a pilot interview with a senior technology executive.

4.3.4.2 Outcomes from a pilot interview

The pilot interview took approximately two hours and was recorded and transcribed. The interviewee was briefed that the session was intended to explore the role and contribution of the CTO. Otherwise, no specific research agenda and interview protocol was formulated. A free-hand cognitive map[9] was used to test a cognitive mapping approach, and the interviewee was encouraged to explore themes as they emerged. The interviewee was prompted to think about and discuss examples from his own experience. The examples tended to surface additional thoughts which could be added to the cognitive mapping.

The output from the pilot interview includes an attempt to define preliminary levels of conception of a range of attributes (along the lines of the analytical process used by Sandberg, 2000 and Partington et al., 2005). The analysis of the interview and sample outputs are summarised in Table 12, Table 13 and Table 14. The analysis involved categorising phrases and expressions as they relate to the work (Table 12), the worker (Table 13) and the context (Table 14). Certain further categories emerge and are noted as column headers in the tables.

[9] See Table 16 for definitions of 'cognitive map' and 'cognitive mapping'.

Table 12: Attributes of CTO work

Manage Customers	Manage Competition	Manage Teams	Manage Technology
Build commercial partnerships	Scan competitor behaviour and operations	Clarify roles	Create commercially viable structures
Keep a customer focus	Benchmark externally	Identify and keep key people Manage expectations Sponsor projects Set standards Reward good performance	Seek alternative applications Seek competitive technologies

Table 13: Attributes of the CTO

Customers	Competition	Teams	Technology
Market savvy Creative	Seeks a challenge Seeks intellectual stimulation	Have a team perspective Trust your teams	Commercially aware Business culture aware
Customer orientated	Good relationships	Provide critical sponsorship	Portfolio perspective
Alliance seeking	Enthusiastic and driven Focused Patient and creative	Set strategic priorities Delegate effectively	Analytical Risk taking Future perspective

Table 14: Context attributes

The organisation	Performance	The market
Deals made Structures Distributed channels Service channels Reporting lines Processes	Measurement Rewards Trends	Key players Market size Market structure Trends

A positive outcome of the pilot interview was that a large amount of data was generated relatively quickly. Also, the data could be captured into attributes of the role that related to the work, the worker and the context, with relative ease. However, analysing the data for levels of conception (that is, using a phenomenographic approach) proved to be difficult. Further interviews and data were needed. Defending the process and explaining the initial outputs also proved difficult.

Finally (and crucially), when the interviewee was asked post interview to reflect on the process, he reported discomfort with the lack of structure. The interviewee agreed to be re-interviewed once a more structured approach was established. The second interview provided a result that seemed to satisfy the interviewee and was the structure used in subsequent interviews. The original transcript of the pilot interview was retained to inform the mapping, generated in the second interview.

A protocol for a semi-structured interview was then developed for subsequent face-to-face interviews. The first version of this protocol had too much detail - for example a lot of biographical detail and questions to do with why certain elements might be prioritised. As a result, the two hours set aside for each interview did not leave enough time to focus on the central questions. The interview protocol evolved to version six over the course of three pilot interviews and the initial live interviews. To show the content of the interview protocol and to demonstrate some of the changes, sample versions are included in Appendices 5 and 6.

4.3.4.3 Using a cognitive mapping approach

A cognitive mapping approach is the basis for what is called "Personal Role Mapping" in this research design. "Personal Role Mapping" is a technique that has been developed specifically for this research. The 'personal role mapping' process as applied to the CTO role is explored in more detail in Chapter 5 because the process of data collection, collaborative interpretation (i.e. with the interviewees) and analysis is considered to be a contribution to knowledge.

There are many applications of cognitive mapping and the use of mental models to explore decision making. Examples include using cognitive mapping to improve decisions in water management (Kolkman, Kok and van der Veen, 2005), as a means to study perceptions of competition (Daniels, Johnson and de Chernatony, 1994), as a way to understand person-organisation fit (Billsberry, Ambrosini, Moss-Jones and Marsh, 2005), and to improve understanding in the area of stakeholder dynamics (Van Huy, 2002).

There are also studies focusing specifically on the development of cognitive mapping as a research approach (see for example Tschetter, 1999, Van Huy, 2002 and Hodgkinson, Maule and Bown, 2004). The most relevant study for the purposes of this research was from Hodgkinson and Maule, (2002, pp.196-219). This study focuses specifically on the application of behavioural decision research and cognitive mapping applied to the individual in the strategy process.

Finally, Swan (1997) adds a useful caveat by pointing out that it is incorrect to refer to the output of cognitive mapping as being a cognitive map. This is because in psychology a cognitive map is an internal mental schema which is incapable of external replication (presumably because of the complexity and the inability to access sub-conscious belief structures). This is why in this research the output of the cognitive mapping process is called a 'personal role map'.

4.3.4.4 Key cognitive mapping sources and definitions

The key sources and definitions that are helpful to this research method are noted in this section. In thinking about the research design, it is appropriate to consider the combination of data collection and analytical techniques that will overcome some of the theoretical and practical barriers encountered in previous research. Table 15 is a summary of six references with an explanation of why these build the case for the use of cognitive mapping.

Table 15: Key cognitive mapping sources

Date	Author(s)	Title	Appropriate to this research design because…
1955	Kelly	"A theory of personality"	—focuses on the 'construed' nature of experience and the interpretation of experience. Provides a basis for the use of cognitive maps;
1992	Eden, Ackermann & Cropper	"The analysis of cause maps"	—links the purpose of the research to the method of data collection and the related coding approach. Explains the characteristics of cognitive maps and ways to analyse them;
1995	Weick	"Sensemaking in organisations"	—focuses on the selectivity of consciousness, organisational routines, ambiguity in interpretation, and social construction. Introduces benefits and limitations of cognitive mapping;
1997	Swan	"Using cognitive mapping in management research: Decisions about technical innovation"	—makes the link between cognitive mapping and decision-making in the technology field. Continues the review and motivation of cognitive mapping as an approach;
2004	Hodgkinson & Maule	"Causal cognitive mapping in the organisational strategy field: a comparison of alternative elicitation procedures"	—looks at the implications of choice of elicitation procedures (e.g. compares pair-wise and freehand methods);
2007	Hodgkinson & Healey	"Cognition in organisations"	—brings the cognitive mapping discussion up to date.

Additionally, Fiol and Huff (1992, p.268) point out that in their use of cognitive maps (for strategic decision-making), they are less interested in the maps as representations of thought itself and more interested in them as " … representations of thought that can be related to decision-making." The following table gathers further sources and some of the key phrases used in discussions of cognitive mapping. A key definition is that of the cognitive map (see Table 16).

Table 16: Definitions of terms and phrases used

Term	Definition	Reference
Cognitions	Refers to both cognitive structures (mentally represented concepts and relationships) and cognitive processes. Dynamic – i.e. ways of constructing and utilizing knowledge.	Swan (1997, p.184)
Perception	More than a "retinal code". A cognitive, mental activity where the brain interprets incoming stimuli in the light of prior knowledge. Attending to stimuli and shaping mental models.	Swan (1997, p.185)
Mental models	Cognitions or belief systems. Shape unconscious attention.	Swan (1997, p.184)
Cognitive mapping	An attempt to try to display subjective beliefs and to display these externally. Process to reveal cognitive maps. Not the same as mapping underlying (internal) psychological schema.	Fiol and Huff (1992) Swan (1997, p.185)
Cognitive map	A graphic representation; a frame of reference for what is known and believed; depicts a world view; helps to assess current position – relationships among key actors and events – and the possibility of improved position; locates people in relation to their information environment; they exhibit the reasoning behind purposeful actions. Strip map: Sequence of clear choice points. A simple map that could be committed to memory and invites efficient behaviour and avoids distractions. Gives no detail about the setting within which the choice points exist, so that deviations that cause a blockage may lead to failure in reaching a particular outcome. (p.272) Context map: Strip maps with details of the surroundings added in. More complicated and providing a sense of the setting. Requires graphic and language skills to transmit between individuals. Allows users to exercise judgement if progress in the desired sequence is blocked because of the availability of details about the surrounding features. Cause map: Graphic representations depicting nodes and causal links. Created in the form, A causes B causes C; or D has positive causal link to E which has a negative link to F, etc.	Fiol and Huff (1992)

Term	Definition	Reference
Aggregate map	A merged map based on the idiosyncratic maps of individuals.	Bougon (1992)
	1. Merges or overlays all labels with great care to denote similar concepts.	Eden et al. (1983) Eden (1989)
	2. Merges all labels that are the same with vigilance for similarity of meaning.	
	3. Links all labels in the merged maps that denote concepts that should have been linked.	
Congregate map	This is drawn from individuals' full cognitive maps connected only and exclusively by labels drawn from a social system map.	Bougon (1992, p.371)
Node	Nodes on a map should be referred to as labels.	Bougon (1992)
Variable	A block of narrative which represents key aspects of organisation. May be linked causally with other variables.	Bougon et al (1977)
Concept	Concepts reside in the mind of the individual. They are a unit of meaning sometimes invoked by specific "labels". Private inner tags sometimes labelled by the individual with public labels to aid communication. They are private, idiosyncratic and subjective. A concept isolates one meaning for one person.	Bougon (1983, 1992)
Label	Words strung together, metaphors, euphemisms, logos, cartoons, images. Labels are public, verbatim and objective. A label evokes several meanings for several people or several meanings for one person.	Bougon (1992)
Link	Depicts a relationship between nodes, variables or concepts depicted in a spacial layout. Arrowheads (may) show direction of causality.	Swan (1997, p.189)

4.3.4.5 Benefits and drawbacks of using cognitive mapping

Cognitive mapping applications have various benefits and drawbacks. The mapping process has the benefit of building detail around a central idea (node), or key thoughts – see Figure 8.

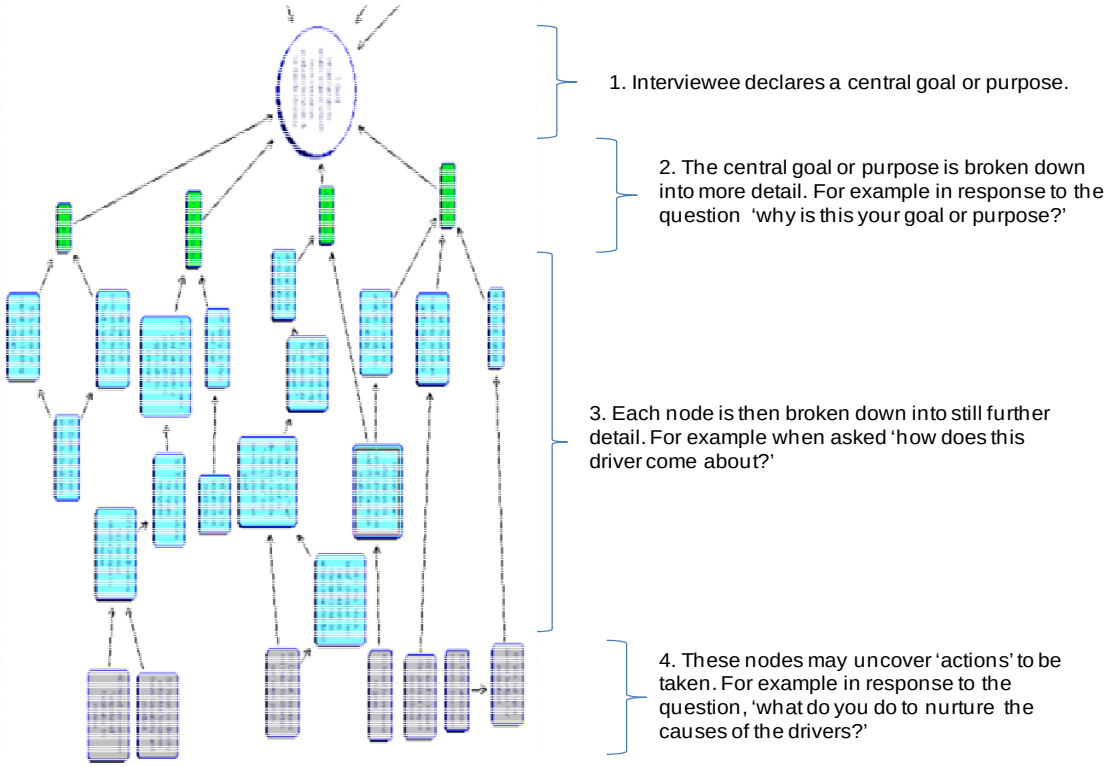


Figure 8: Sample mapping with emerging nodes and links

In succession, each node is "attended to" by the interviewee and related nodes and their relationships (links) are elaborated and captured. In this way, the picture literally grows as the detail is added and new connections emerge. The piecemeal unravelling of the nodes and links is facilitated by the researcher through a questioning process that helps the interviewee to explore the ideas. Because subjects tend to categorise or abstract their views in order to make them manageable (cognitive simplification – Simon, 1957), this process provides access to the detail required. More particularly, the maps have a number of direct impacts – these are called 'direct operations' in Table 17.

Table 17: Map functions (Fiol and Huff (1992, p.275)

Direct operation		Decision making function
Focuses attention Triggers memory		Issue structuring
Reveals gaps		Issue closure
Highlights key factors Supplies missing information		Creative problem solving

For each of these, there is a related "decision making function". Maps help to trigger memory and focus attention, and thus help the interviewee to structure issues. They reveal gaps and therefore help with "issue closure". They highlight key factors and supply missing information and thus help in the area of "creative problem solving."

Inevitably, there are also drawbacks related to the maps. These centre around four key areas – focus, memory, closure and agreement. Table 18 summarises the downsides of extremes in each of these four areas. With regard to focus, the extremes are characterised by "splattervision" (too little focus) on the one extreme, and "tunnel vision" (too much focus) on the other. The drawback of these extremes may be amplified because of the possibility that an inappropriate focus is attended to in the first instance. This may occur because the interviewee will draw on their own experience when selecting the starting point and level of focus required.

The, "over-use of past experience" (Fiol and Huff, 1992, p.276) may be problematic because managers may draw on inappropriate analogies. This may occur because of the illusion of control bias and availability bias (Schwenk, 1988). The outcome at the extremes, is that problem solving takes too long (inefficient access to similar past experience) on the one hand, or that managers repeat inappropriate behaviours (access the wrong experience) mechanistically on the other.

Table 18: Function trade-offs (Fiol and Huff, 1992, p.276)

Too little		Too much
Splattervision	Focus	Tunnel vision
Inefficiency	Memory	Mechanistic behaviour
Analysis paralysis	Closure	Inflexibility
Fragmentation	Agreement	Group think

In seeking to deal with gaps revealed by the mapping process (i.e. getting "closure"), an approach that is too rigid (inflexible) may detract from the need for reanalysis. On the other hand, too little attention to closure may simply cause the process to deteriorate into "analysis paralysis".

With regard to "agreement", the risk at one extreme is the phenomenon known as "groupthink" (Janis, 1972). "Groupthink" has the disadvantage that a diversity of views is not incorporated into the solution or is present in the agreement. This has the effect of making a solution suboptimal, and also (since by definition it ignores contrary evidence) may not have take-up outside of the decision group. Of course the opposite extreme is the inability to reach agreement (fragmentation).

4.4 Summary

Chapter 4 sets out and explains the derivation of the research questions. A research process framework (Partington, 2007) is then used as a checklist to cover four key aspects of the research process. The first is the purpose of the research, then the research questions, followed by the theoretical perspective and finally the research design. The objective of this approach to setting out the research process is to seek alignment between the four elements of the framework.

Given the research purpose and the theoretical perspective, an inductive process involving face-to-face interviews, will be used to provide a perspective on the research questions. The research design is based on a variation of cognitive mapping called 'personal role mapping'. This is discussed in Chapter 5.

5 Personal Role Mapping for the CTO

In this section the developmental stages of the research are covered and the use of cognitive mapping, Decision Explorer™, and NVivo™ is explained. The concluding paragraphs explain the process for eliciting the emergent constructs used in deriving a new framework to support the CTO's priority setting, and also as a basis for further research. This comprises two phases; the data capture phase (see Figure 9) and the data analysis phase (see Figure 18).

5.1 The data capture phase

The data capture phase comprises four stages that are set out in Figure 9. There are references to Decision Explorer™ and NVivo™ in Figure 9. These are explained below. Each of the stages is discussed in sequence below, starting with Stage 1 – the interview process.

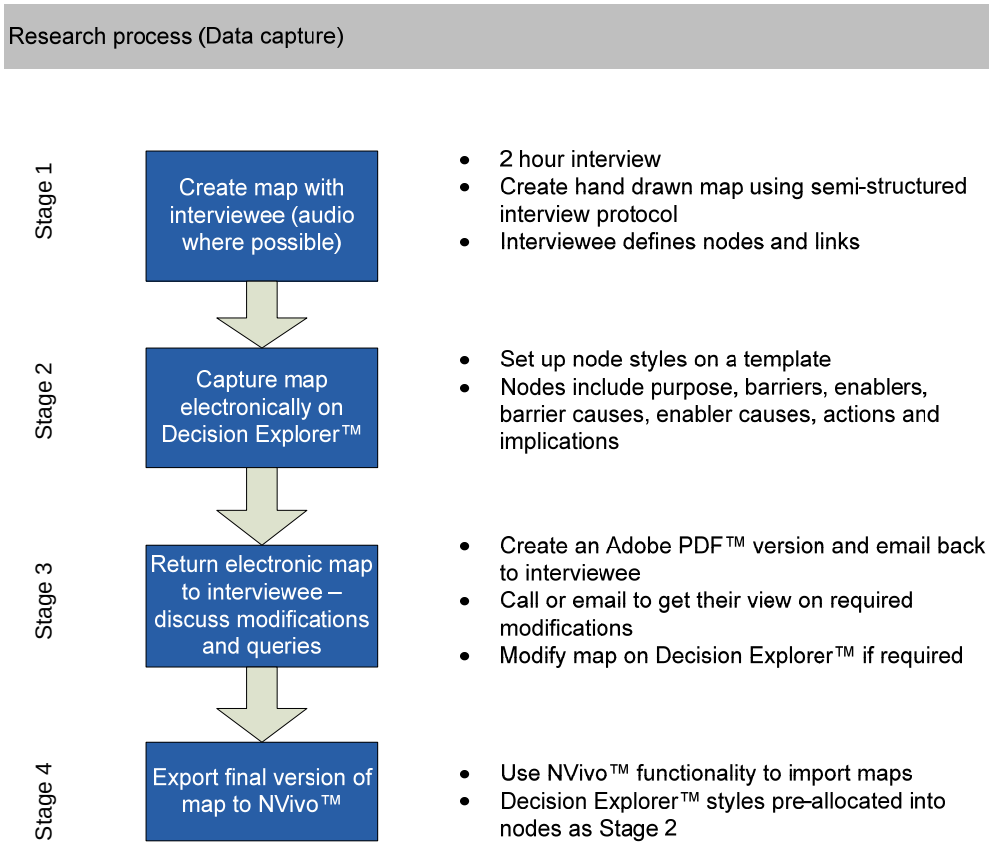


Figure 9: The research process (Data capture)

Stage 1: The interview process

Each interviewee was asked to set aside 2 hours and was sent a copy of a project briefing note (see Appendix 7). A quiet meeting room (in case audio recording was permitted by the interviewees) with clear wall space (to allow A1 size interview poster to be mounted on the wall), was requested. At the interview the A1 size mapping poster was put up on the wall or laid flat on a table. The interviewee was given the option to write directly onto the map or to dictate and have the interviewer write. The template used for the poster is shown in Figure 10.

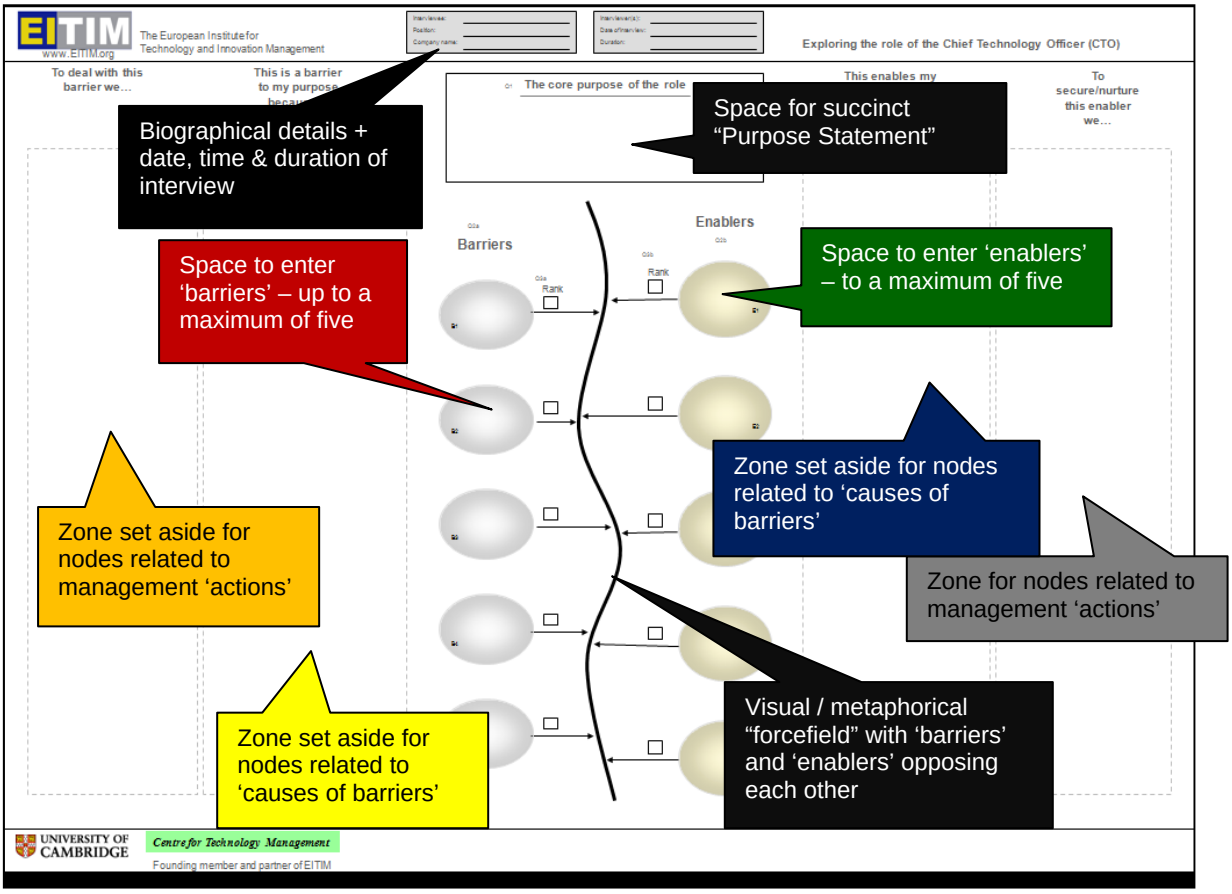


Figure 10: Blank interview map - version 7 (printed size A1)

The questions and the typical sequence are shown in Figure 11. The sequence of questioning is somewhat hierarchical. In other words, subsequent questions build on questions that came before. So, for example, the question about the 'core purpose' (see Figure 11) would need to have been answered before progressing to questions about related barriers (to that purpose) or

related enablers etc. However, the interviewee was told that they could return and modify a previous answer if subsequent questions clarified their thoughts.

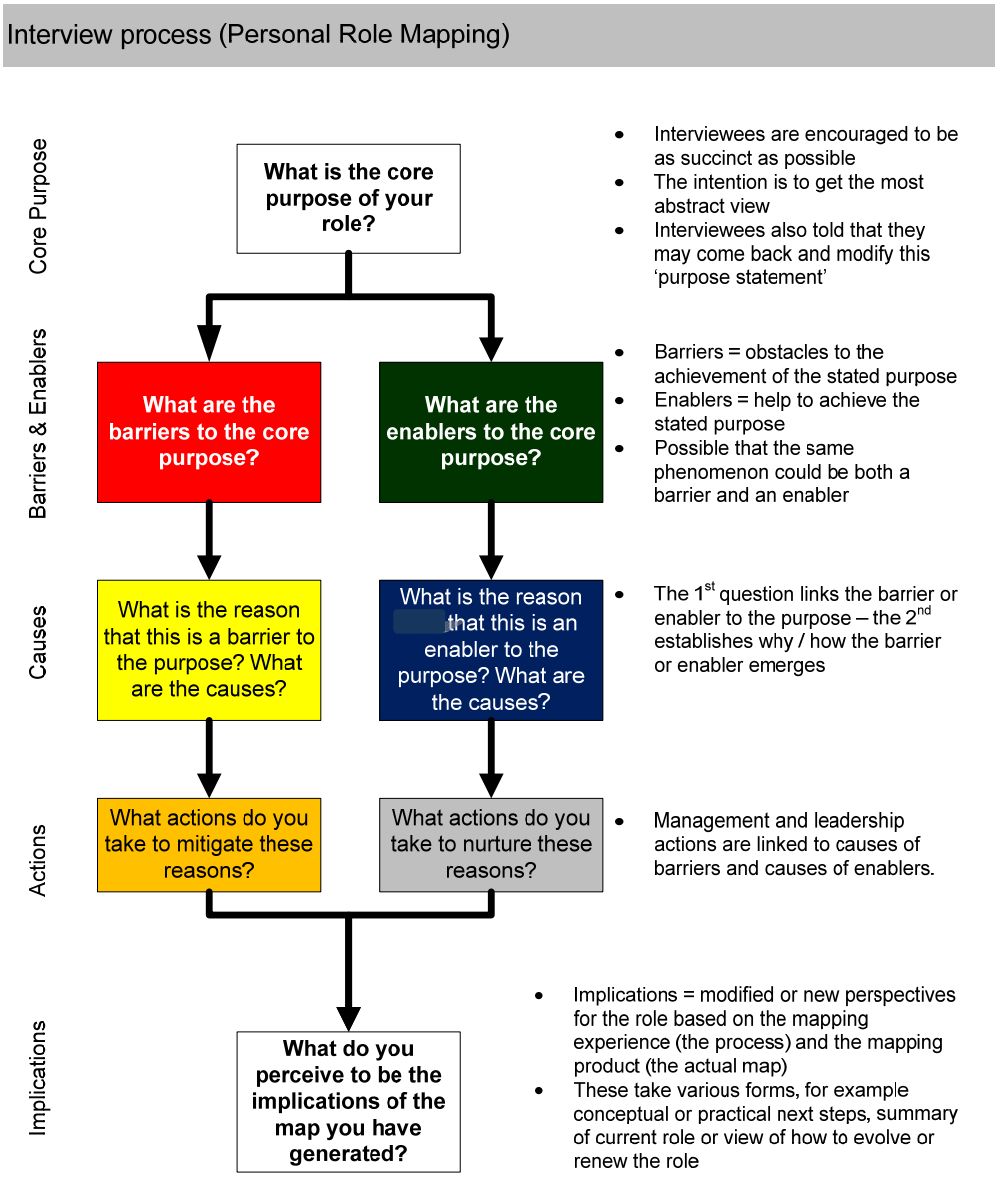


Figure 11: Interview process (Personal Role Mapping)

Examples of the outputs of two of these interview sessions are shown in Figure 12, Figure 13, Figure 14 and Figure 15. The detailed content in these maps is deliberately small to avoid any concerns from interviewees regarding confidentiality.

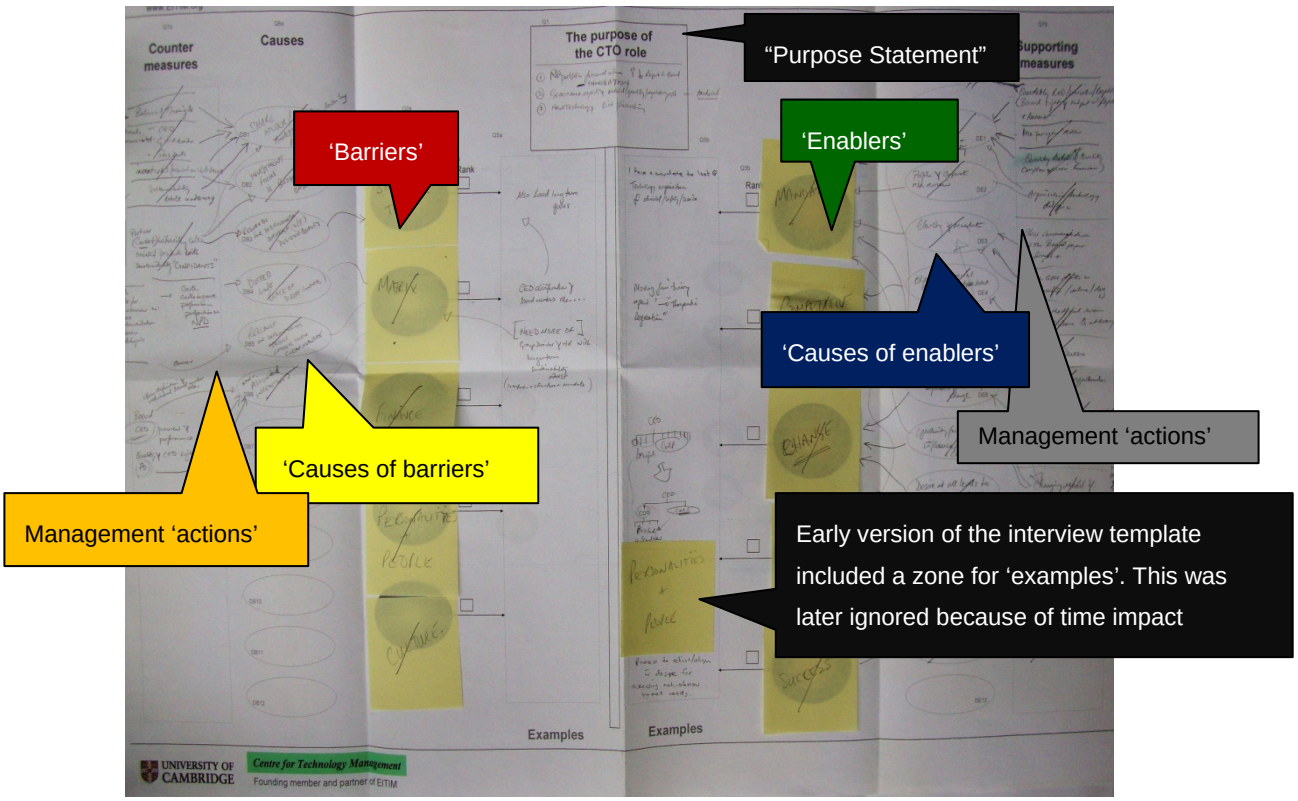


Figure 12: Interview output [Interviewee 25]

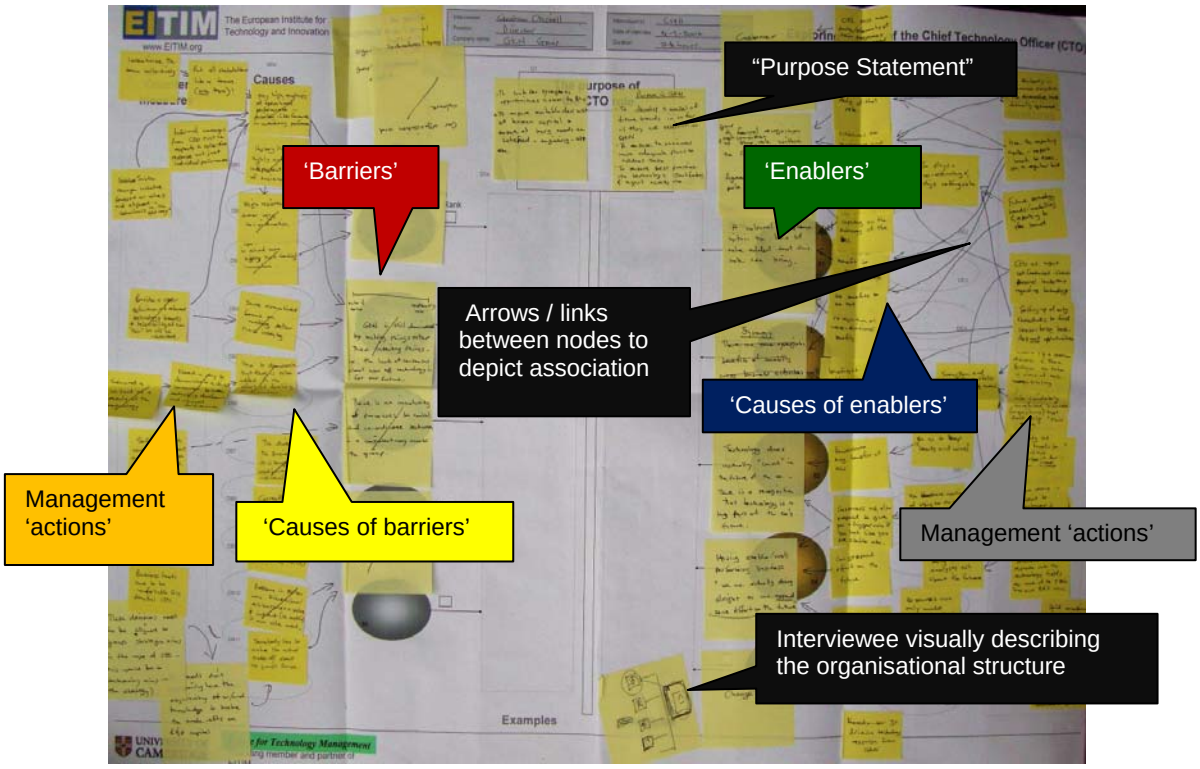


Figure 13 Example of interview output [Interviewee 12]

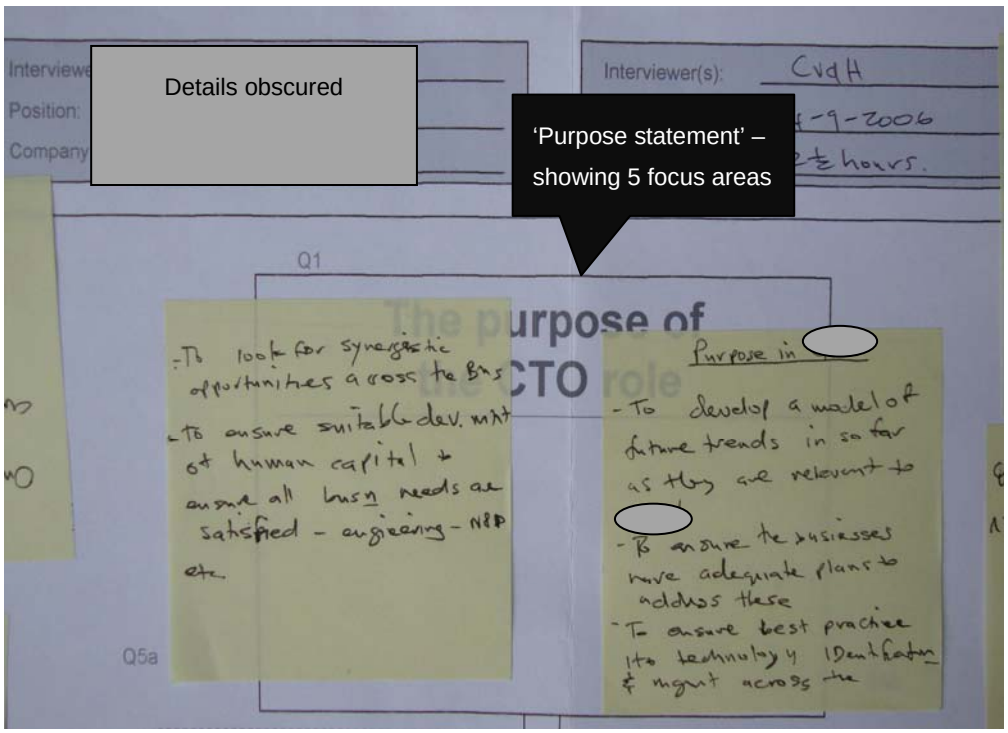


Figure 14: Close up of question 1 - i.e. purpose of the role

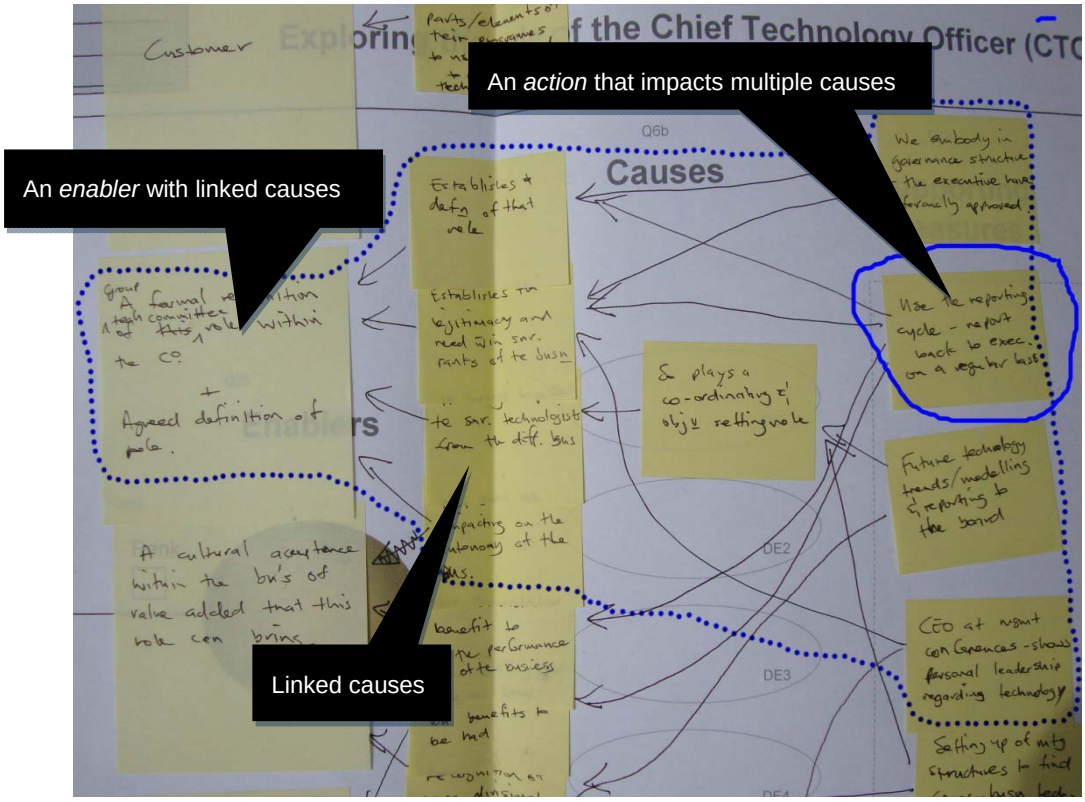


Figure 15: Construct within an interview map showing links

Figure 14 and Figure 15 show how the interview detail is captured at the top of the map, and also how the mapping produces clusters of nodes that are linked together with arrows. The nodes in Figure 15 have been elaborated and built on, from left to right starting with an 'enabler' which has four related 'causes', these causes in turn have four related 'actions'. These are all shown within the dotted line. The node in the solid outline is of particular interest because it seems to indicate a response that is appropriate to multiple 'causes'. Also, it is simultaneously a management 'action' in response to the 'enabler' within the dotted demarcation, and also to three 'causes' of a neighbouring 'enabler'. This shows part of the value of this process, in that this action can be prioritised by the interviewee once its prominence becomes visually evident.

Stage 2: Capturing maps on Decision Explorer™

This stage involves using a proprietary software package[10] called Decision Explorer™ to capture the manual output of the interviews. An example of the finished product is shown in Figure 16. The software has various advantages that support the research process. These include the ability to colour code like nodes – for example all barriers in red and all enablers in green. A key is created on the map output once "styles" are set up in the software – these are visible at the bottom left hand corner of Figure 16. Also, the software is specifically designed to capture nodes and links as they would be generated in a cognitive mapping process.

Capturing the hand drawn maps is helpful because it allows a digital image to be returned to the interviewee. Also, the node content can be transferred directly into NVivo™ (this is discussed in Stage 4).

Stage 3: Verify map with interviewee

Once the map is captured in Decisions Explorer™ it can be converted into an Adobe™ PDF document. This makes it possible to email the map to the interviewee. In each case the interviewee was asked to consider the nodes and the links to verify the accuracy of the data capture and to fill in any blanks. In some cases this follow-up resulted in a further interview session, and in others the map was completed over the phone.

[10] For more detail on Decision Explorer™ see www.Banxia.com

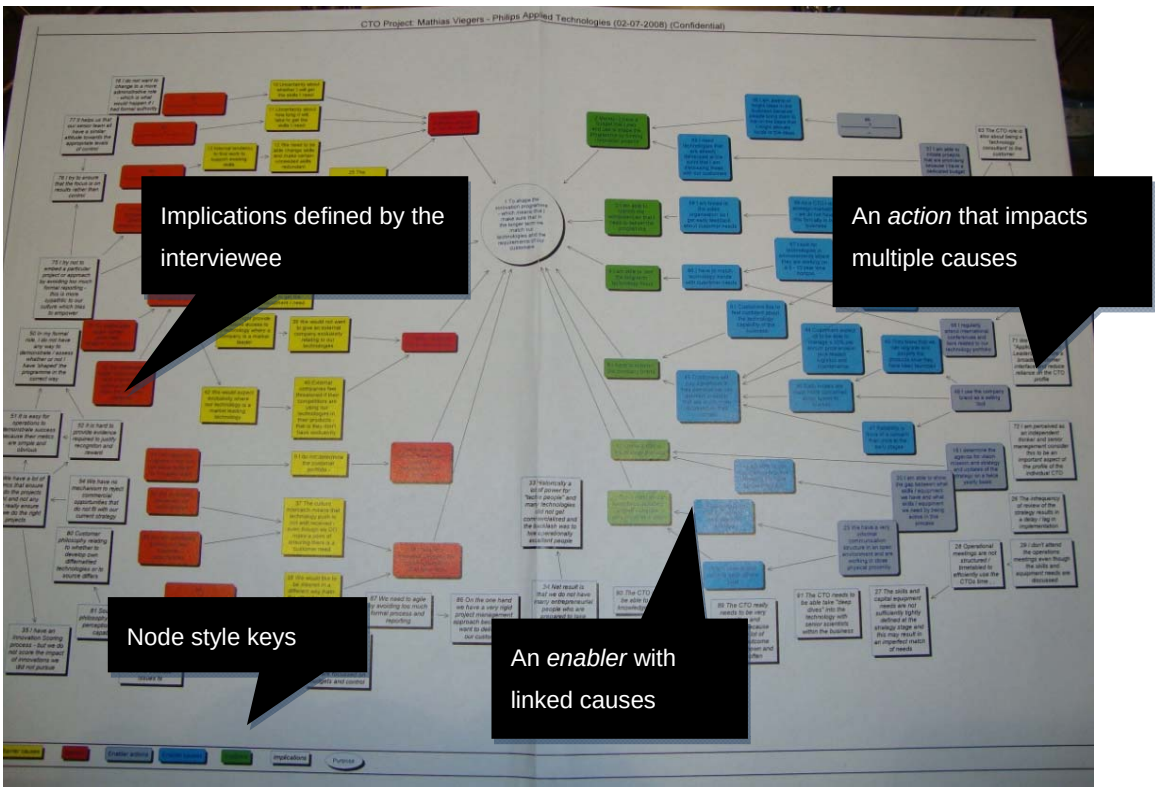


Figure 16: "Personal Role Map" captured electronically post interview

Stage 4: Export the data to NVivo™

This software[11] is used by researchers for qualitative analysis. It has an import facility which makes it possible to capture the data from Decision Explorer™ directly. The process is imperfect, but avoided the need to re-type every node from every map. Once the audio was transcribed, the transcribed interviews were added into NVivo™. Once the data is captured in NVivo™, it can be analysed. An example of a coded transcript is shown in Figure 17.

These four stages result in the generation of multiple maps. Before continuing to describe the analytical process, the extent of the data collected is described.

[11] For more detail on NVivo™ see www.qsrInternational.com

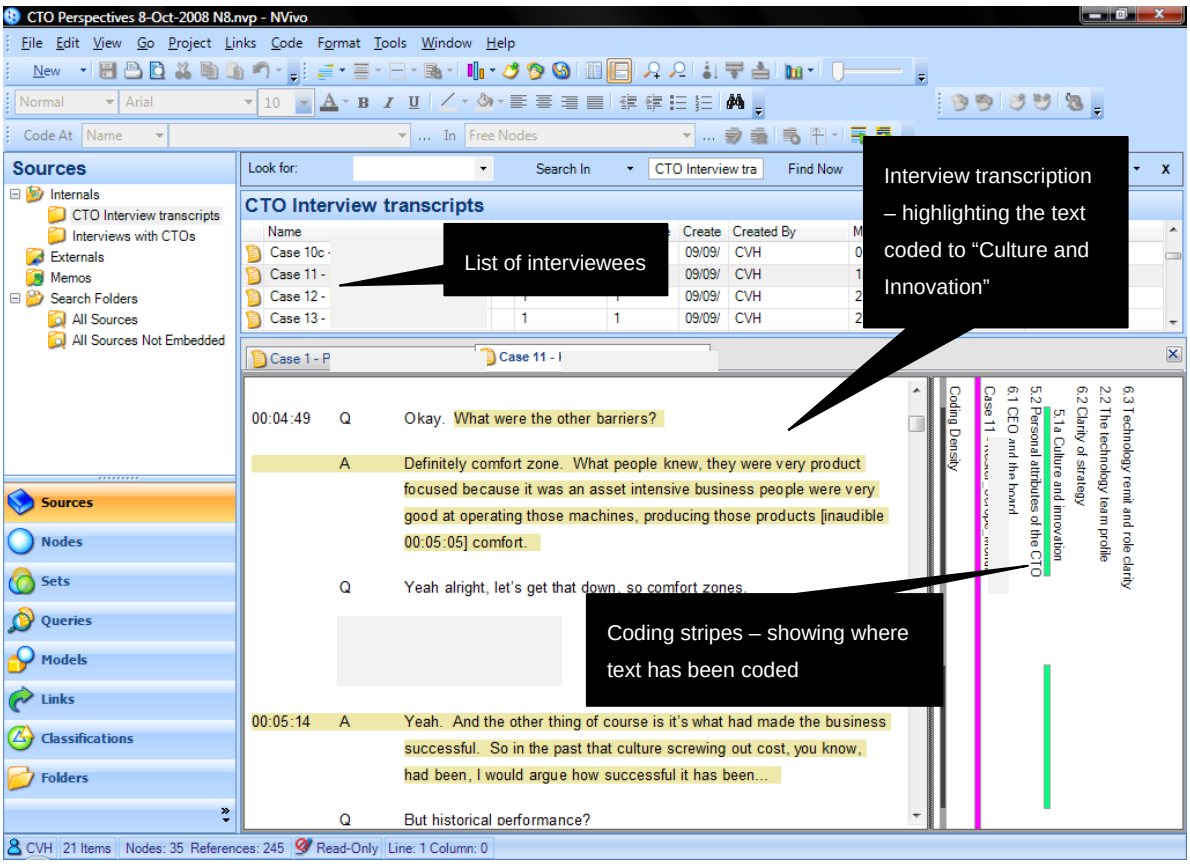


Figure 17: Screen shot of NVivo™ software

5.2 Scope and reach of data collection

Here the data is described to give a sense of the scope and depth of the information captured. This covers the number and duration of interviews, as well as giving a sense of the variety of settings in which the interviewees operate. Additionally, a breakdown of the elements (nodes categorised by type) within each interview is provided.

In total, the interviewee organisations that submit financial accounts in the UK represented 38 UK Standard Industry Codes (SICs). Three of the businesses that submit accounts in Europe are represented by a further 6 US SICs. Although SICs do not directly indicate the variety of technologies that the CTO would encounter in an organisation, they do give an idea of the diversity of disciplines required for the overall technology portfolio (See Table 19). Each organisation is typically listed with a primary SIC indicating the main line of business, and secondary SICs indicating other lines of business (See Appendix 10 for listing per business).

In total interviewee organisations employed over 1 million staff between them, with the smallest employing 136 staff directly[12] and the largest employing 330 000 staff. Revenues range from zero (for a start up company) to approximately GBP 150 Bn.

Table 19: List of UK Standard Industry Codes for interviewee businesses

SIC	UK SIC (2003) descriptions
1110	Extraction of crude petroleum and natural gas
1533	Processing and preserving of fruit and vegetables not elsewhere classified
2121	Manufacture of corrugated paperboard and of containers of paper and paperboard
2222	Printing not elsewhere classified
2225	Other activities related to printing
2320	Manufacture of refined petroleum products
2441	Manufacture of basic pharmaceutical products
2442	Manufacture of pharmaceutical preparations
2452	Manufacture of perfumes and toilet preparations
2466	Manufacture of other chemical products not elsewhere classified
2522	Manufacture of plastic packing goods
2615	Manufacture and processing of other glass including technical glassware
2872	Manufacture of light metal packaging
2924	Manufacture of other general purpose machinery not elsewhere classified
2956	Manufacture of other special purpose machinery not elsewhere classified
2960	Manufacture of weapons and ammunition
3162	Manufacture of other electrical equipment not elsewhere classified
3210	Manufacture of electronic valves and tubes and other electronic components
3310	Manufacture of medical and surgical equipment and orthopaedic appliances
3320	Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment
3410	Manufacture of motor vehicles
3430	Manufacture of parts and accessories for motor vehicles and their engines
3511	Building and repairing of ships
3530	Manufacture of aircraft and spacecraft
3663	Other manufacturing not elsewhere classified
5151	Wholesale of solid, liquid and gaseous fuels and related products
5186	Wholesale of other electronic parts and equipment
5190	Other wholesale
5212	Other retail sale in non-specialised stores
5242	Retail sale of clothing
5243	Retail sale of footwear and leather goods
6340	Activities of other transport agencies
6420	Telecommunications
7222	Other software consultancy and supply
7310	Research and experimental development on natural sciences and engineering
7412	Accounting, book-keeping and auditing activities; tax consultancy
7415	Holding companies including head Offices
7487	Other business activities not elsewhere classified

[12] Note: However, this particular organisation uses approximately 25 000 contract staff at any one time.

Interviews are numbered from 1 to 31. All interviews were conducted face to face, apart from one that was conducted telephonically. Twelve interviews were either not recorded, or were, but could not be used for technical reasons such as interviews conducted in public settings with high levels of ambient noise. The total transcribed audio time was 2301 minutes (38 hours and 21 minutes). On average these interviews took 120 minutes, which resulted in an overall total of 62 hours and 21 minutes of interviews. The shortest interview took 50 minutes, and the longest was 5 hours and 48 minutes (conducted over 2 days).

In total 2271 nodes are mapped and captured electronically. A breakdown per interview is shown in Table 20.

Table 20: Breakdown of interview information

Interviewee No.	Interview Recorded	Audio Duration (minutes)	No. of nodes mapped	Interview location (Business HQ)
1	Yes	75	91	London (UK)
2	No	-	58	Cambridge (Holland)
3	Yes	-	86	Bedford (UK/France)
4	Yes	128	88	Cambridge (UK)
5	Yes	72	20	Cambridge (UK)
6	Yes	160	173	London (UK)
7	Yes	130	81	Harrow (UK)
8	No	-	38	Germany
9	No	-	41	Bedford (India)
10	Yes	93	38	Northampton (UK)
11	No	-	92	Dublin (Ireland)
12	No	-	77	London (UK / US)
13	No	-	52	London (Japan)
14	Yes	105	108	London (UK)
15	Yes	240	119	Lymington (UK)
16	Yes	50	21	Telephone interview (UK)
17	Yes	124	74	Bedford (UK)
18	Yes	97	62	London (UK)
19	Yes	133	139	London (UK / Monaco)
20	No	-	73	London (UK)
21	Yes	150	96	Eindhoven (Holland)
22	Yes	348	102	Peterborough (UK)

Interviewee No.	Interview Recorded	Audio Duration (minutes)	No. of nodes mapped	Interview location (Business HQ)
23	Yes	-	48	Bristol (UK)
24	Yes	103	102	Bedford (UK)
25	No	-	56	Leeds (UK)
26	Yes	120	54	Zurich (Switzerland)
27	No	-	27	Germany
28	No	-	37	Germany
29	Yes	120	61	Bedford (UK)
30	Yes	98	72	Cambridge (UK)
31	Yes	75	85	London (UK)

A summary of the number of nodes per type is shown in Table 21, with examples of the content / narrative that appears in these nodes. The audio recordings were not captured for the initial interviews. This oversight was rectified when it became obvious that the recordings were important to the analytical process. However, some interviewees did not want the interview recorded, and some recordings were incapable of being transcribed due to technical issues.

Table 21: Nodes generated summarized per node type

Node type	Number of nodes	Examples taken from interviews
The Purpose of the role	33	"The core role of the technologist is to specify products"
The barriers to the stated purpose	149	"Access to people and expertise on emerging issues"
The enablers to the stated purpose	166	"Demonstrating that we are delivering value"
Reasons why the barriers occur	442	"Have to adapt and get new technology skills"
Reasons why the enablers occur	453	"Protecting our brand"
Management actions to mitigate barrier reasons	229	"Have a clear understanding of emerging talent needs"
Management actions to nurture enabler reasons	450	"Supplier management – auditing etc of quality, and independent product testing"
Implications for practice	190	"We will have to change our supply base to achieve our goals"

A weakness in the early interviews was pointed out in a discussion with an experienced researcher[13]. She reviewed a sample interview map and noted that the nodes were written verbatim rather than capturing the intended meaning of the interviewee. This occurred because of the incorrect assumption that capturing the meaning would involve a degree of interpretation and thus potentially introduce researcher bias[14]. Once the problem was identified the narrative in each node became more comprehensible and less cryptic. However, the transcripts are a good way to deal with maps that have a less clear narrative.

5.3 The data analysis process

The overall analysis process is described in Figure 18.

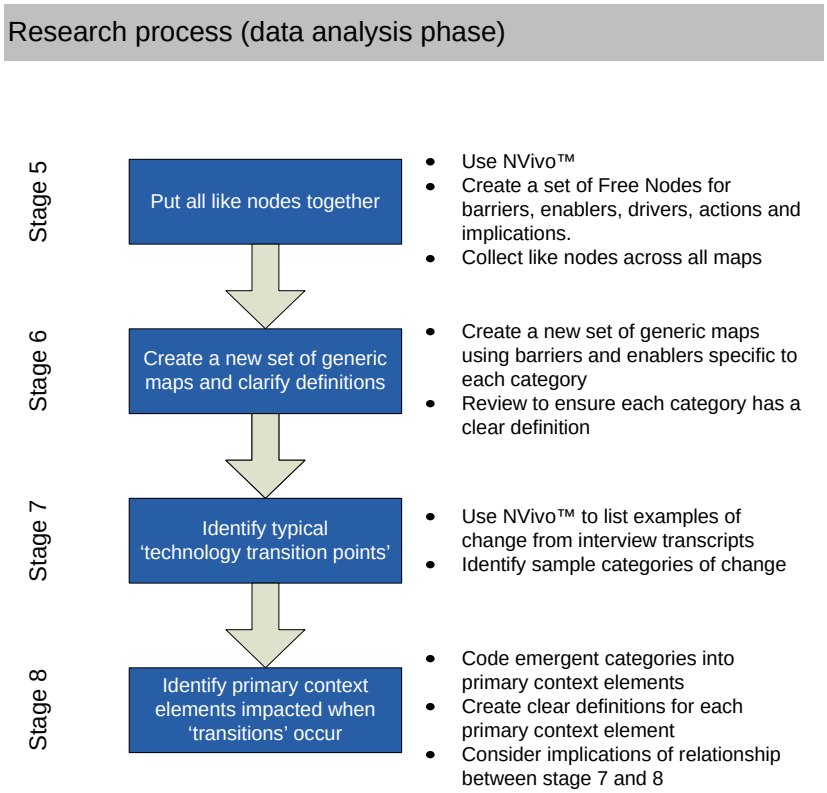


Figure 18: Research process – data analysis phase

Stages 5 to 8 of the research process are discussed in more detail.

[13] Professor Fran Ackerman of Strathclyde Business School

[14] This is not a problem if the interviewee is present to verify that the node accurately reflects the intended meaning.

Stage 5: Collecting like nodes

This stage involves going through the data on the cognitive maps and capturing (coding) similar strips of narrative into categories (nodes)[15]. Selecting the initial categories involved an iterative process where the first node was used as a category, and then all related nodes were added to it. The category was redefined as soon as it became evident that a more useful label for the category was emerging. This process ran simultaneously for a number of categories until no new categories emerged.

In order to do this, the first pass at the analysis was done manually using cards. Each card had the node content typed onto it. To keep track of the cards coded to each category, a unique reference number was allocated to each card.

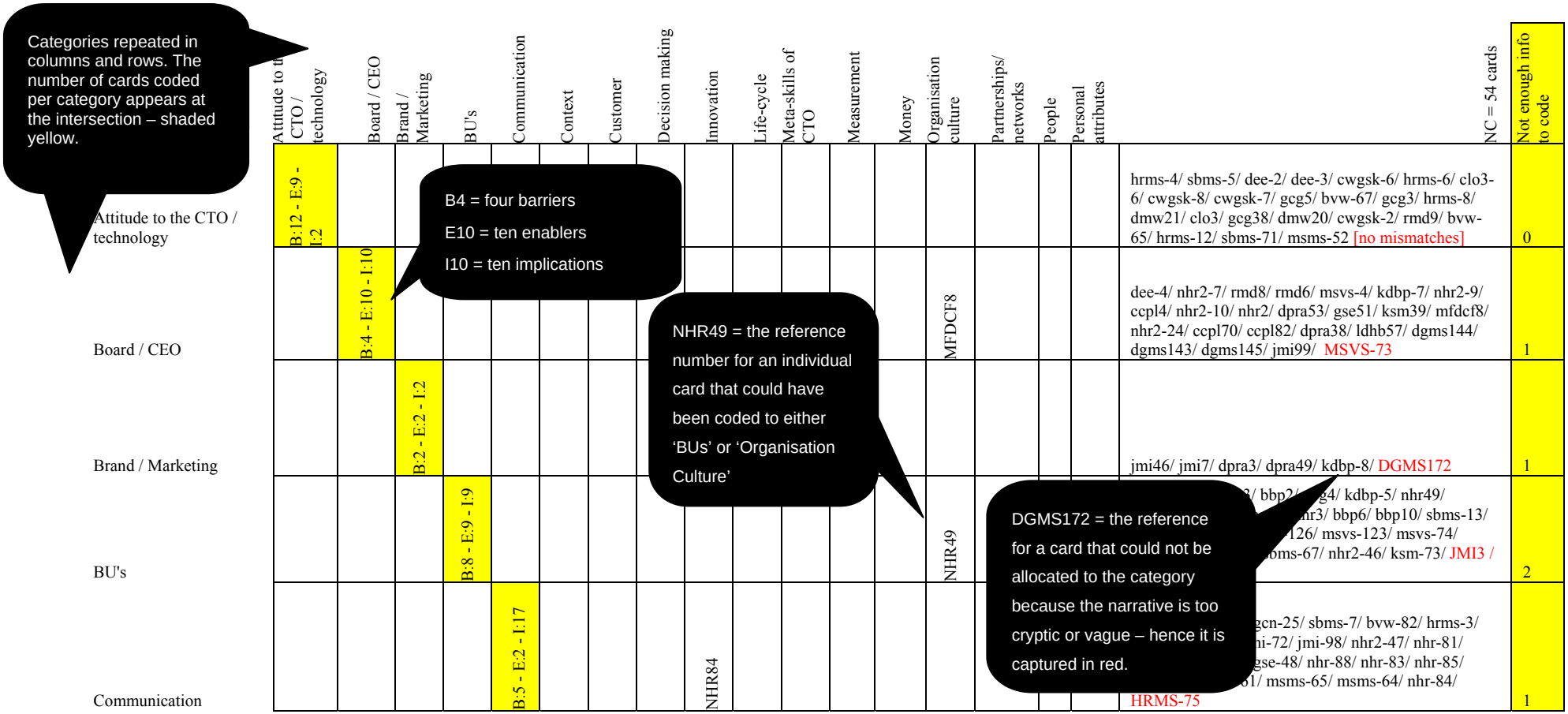
Once the cards were sorted into categories, a table was created in MS Excel (see Table 22). On this table, the column and row headings are the categories that emerged from the first sort - for example "Attitude to the CTO/technology", then "Board / CEO" etc. The total number of cards coded to each category was counted up and appears at the top of each row. This count was broken down into the number of 'enablers', 'barriers' and 'implications' per category (these are the figures shown at the intersection – for example, B9 - E12 - I3).

In order to test the consistency of the categories used, two other researchers allocated all the cards to the named categories. Various issues emerged from this process. Firstly, in some cases the node content causes some nodes to be allocated to more than one category. Secondly, certain node content is too vague so that it cannot be allocated at all. These nodes are monitored by capturing them in the right hand column of Table 22 in red ("mismatches").

Overall, when the reliability of the allocation was first checked, there was a 60% match between the author and the two other researchers. This suggested the need for a number of modifications and improvements. The categories needed to be defined more clearly. Some categories were obscure and insubstantial, and should have been removed. Still others were too broad. And finally, where information on nodes was too cryptic, the node should either have been ignored, re-written (using transcripts of interviews where available) or re-written with consideration of the context of the relevant personal role map.

[15] Both NVivo™ and Decision Explorer™ use the term "node". In NVivo™ a node is a receptacle into which like strips of narrative are coded (allocated). In Decision Explorer™ a node is the 'strip of narrative' – i.e. a block of narrative text.

Table 22: Sample of 1st pass card sort in MS Excel™



	Atttude to the CTO / technology	Board / CEO	Brand / Marketing	BU's	Communication	Context	Customer	Decision making	Innovation	Life-cycle	Meta-skills of CTO	Measurement	Money	Organisation culture	Partnerships/ networks	People	Personal attributes	NC = 54 cards	Not enough info to code
Context						B:1 - E:5 - I:2												gse-49/ cwgsk-3/ mfdcf-7/ pasn-25/ dgms-42/ ldhb-59/ DEE-17/ ACMS-2	2
Customer							B:8 - E:9 - I:6			MFDCF5*			MFDCF5*			JMI97		dee-13/ dmw-22/ gcg-33/ gse-55/ pta-3/ clo-5/ rwb-9/ mfdcf-5/ bbp-4/ gce-3/ dgms-2/ mfdcf-11/ rwb-3/ rwb-4/ rwb-2/ ldhb-58/ mfdcf-51/ mfdcf-52/ rwb-30/ jmi-97/ KDBP-3/ GSE54/ GSE90	3
Decision making								B:4 - E:4 - I:5										pevw-119/ msvs-91/ msms-54/ sbms-76/ sbms-75/ kdbp-13/ kdbp-16/ pta-32/ HRMS-5/ ACMS-54/ ACMS-50/ ACMS-53/ SBMS-72	5
Innovation									B:8 - E:6 - I:13							KSM68		msvs-3/ sbms-11/ pevw-115/ dee-11/ kdbp-11[illegible]p-18/ nhr-48/ bvw-77/ kdbp-4/ kdbp-2/ kdb[illegible]bp-14/ msvs-7/ ksm-68/ mfdcf-48/ jmi-[illegible]/ ksm-70/ mfdcf-47/ [illegible]4/ mvp-35/ MSV[illegible] NHR87	5
Life-cycle										B:4 - E:1 - I:4								ccpl-6/ ccpl-40/ ccpl41/ clo-37/ clo-39/ ccpl-86/ ccpl-73/ dgms-173/ ccpl-79	

Red numbers in yellow shaded column indicate the number of cards that could not be allocated.

This process was replicated in NVivo™ to make the data manipulation and subsequent presentation more practical. When the cognitive maps are captured in Decision Explorer™, a coding system can be applied that uses different colours to indicate node 'styles'. The import function within NVivo™ is capable of capturing these node styles directly. Unfortunately, they are only displayed as a label at the end of each strip of narrative, and so while the actual codes are already labelled, they still need to be manually allocated in NVivo™.

The actual allocation is done using the Free Node capability of NVivo™ and has the benefit of cross-referencing all coded data back to the original data source. Once the data is allocated in this way, it can be described (this was done in Section 5.2.).

The final output from Stage 5 is 20 categories. Although Table 22 shows 17 categories from the first pass card sort, subsequent refinement reconfigured these categories in the way set out in Chapter 6. The refinement occurs as the definitions—in the form of 'priorities' and a 'goal'—take account of additional data from each interview.

Stage 6: Create new generic maps

Stage 6 involves creating a new set of maps in NVivo™ using only the barriers and enablers imported from Decision Explorer™. Figure 19 is an example. For the purpose of explanation, the new generic 'map' for 'CEO and the Board' is used. All barriers and enablers related to 'CEO and the Board' are re-drawn onto a metaphorical forcefield for 'CEO and the Board'. In Figure 19 the 'generic map' is overlaid with 6 different interview maps that represent the 'grounded' source of the data used (i.e. the original interview maps).

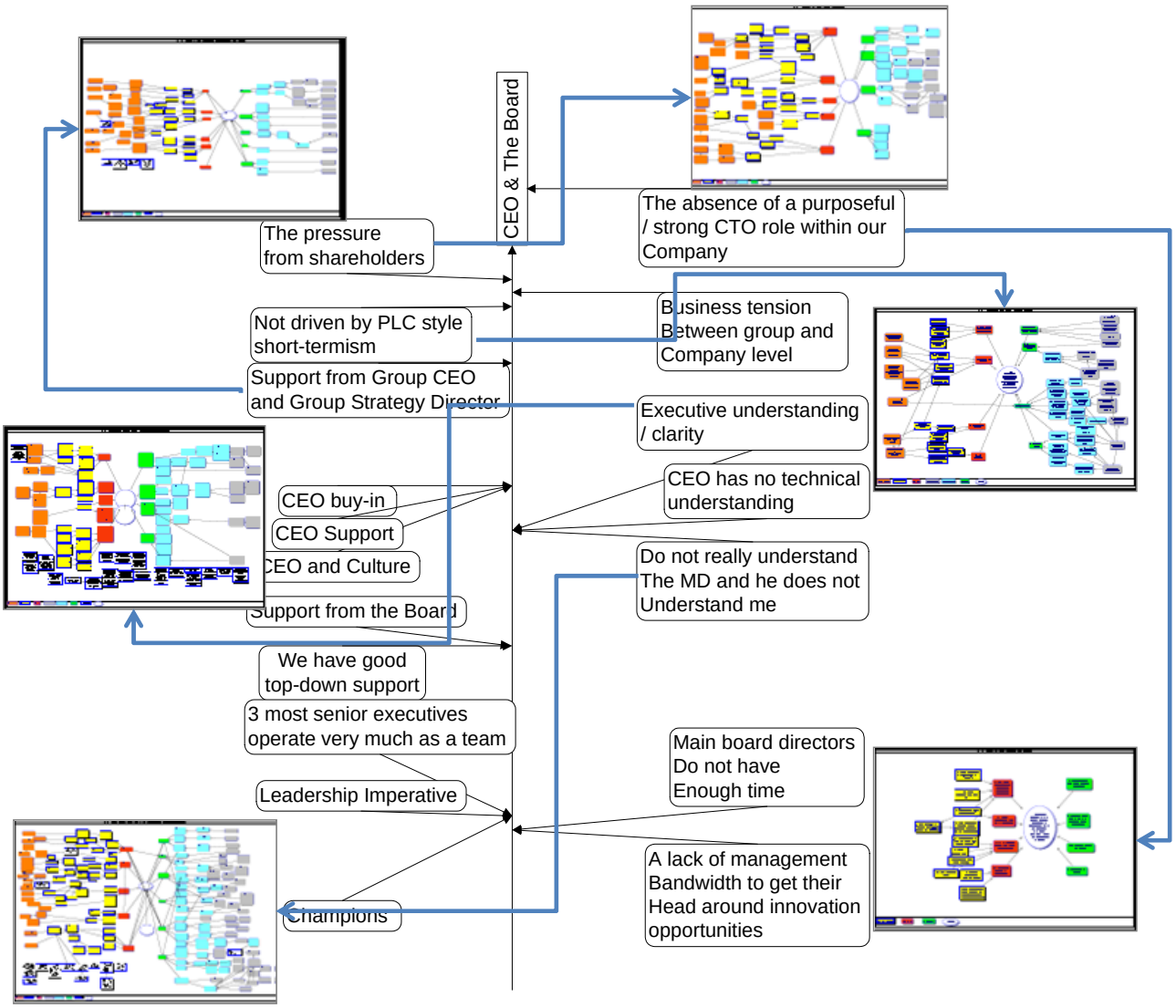


Figure 19: Generic map for the 'CEO and the Board'

Other examples are included in Appendix 9 and an overview of the 1st pass view of 19 of these clusterings is shown in Figure 20. While these barriers and enablers clustered around central themes are of interest, to some extent they are a replication of the research approach in the studies reviewed in this research. The problem is that they are generic and remove the context. They describe a scope of activity, but give no indication of the implications for practice.

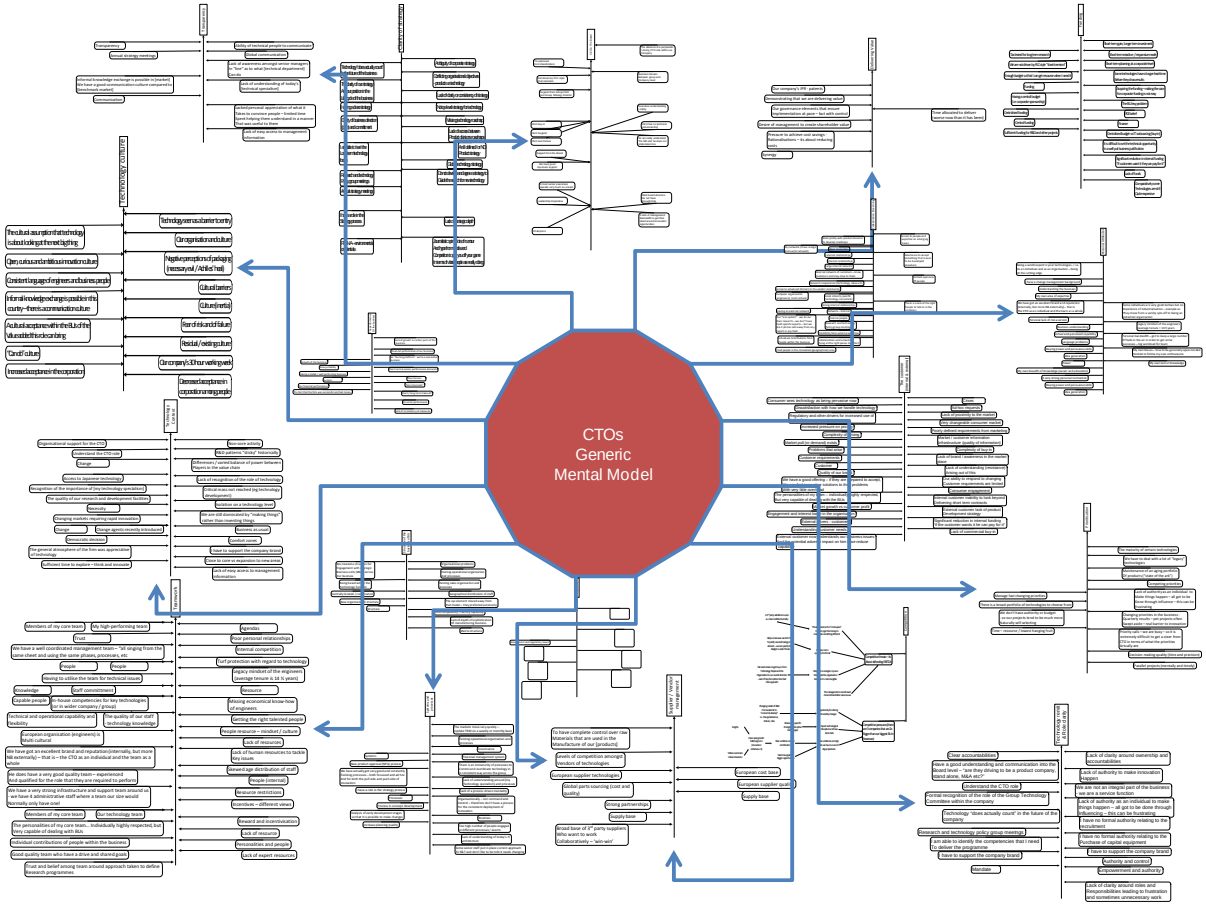


Figure 20: A 1st pass generic 'mental model' for the CTO[16]

However, the categories that emerged remain of interest for the CTO as a way to identify focal points.

Stage 7: Identify 'technology transition points'

The outputs of stage 6 and a cross-checking with the literature help to highlight the static nature of the analysis to this point. The role of the CTO is dynamic. The implication for the research analysis is that there is a need to take account of the 'tipping points' (Gladwell, 2000) or 'discontinuities'

[16] Note: Subsequent passes and refinements resulted in a total of 20 maps that were used for the CTO/Context Framework.

(Roberts and Lui, 2001) or 'inflection points' (Garreau, 2005). These are points in time at which the CTO intervenes. In this research these events are called "technology transition points".

The process of identifying technology transition points differs from the process used in stage 5 in that the data set is the transcripts of the interviews - not the maps. Furthermore, this aspect of the analysis does not require the rigour deployed in Stage 5 because it is sufficient to simply identify examples of change. More specifically, these examples suffice for 2 reasons. Firstly, it is self evident that the technology context changes over time. Secondly, any single type of change clearly demonstrates the application of the CTO/Context Framework in a change situation.

Nevertheless, the transcripts are captured in NVivo™ and then on an iterative basis the texts are screened and indications of 'change' are set up as category nodes. The output of this process can be seen in Chapter 7.

The relationship between the scope of the work of the CTO and the 'technology transition points' is important. The proposition that emerges is that the CTO's priorities (Scott, 2001) vary depending on the transition point. The scope of work thus changes when a 'technology transition point' causes the CTO to move from one 'context' to another, and thus re-prioritise. However, a change in the CTO's scope of work can also cause a technology transition to occur. In other words, the relationship is dynamic.

Stage 8: Identify primary context elements

By this stage it is clear that the context as represented by the scope of activities (barriers and enablers) needs to be considered in relation to the technology transition points. For this reason it is helpful to derive a framework that captures the scope of activity of the CTO. This approach would result in a CTO centric, grounded variation of the Absorptive Capacity/Tipping Point Framework suggested by Phelps et. al (2007) – see Figure 5 on Page 65. This involves a two step process (again using NVivo™).

The first step is to use the data from the maps as configured in stage 5 and to provide a definition for each of the categories. In effect 21 'categories' from the coding process are used as 'context sub-elements'. These are then summarised into 6 'context elements'. In order to relate the context element definitions to the transition points, the definitions need to take the form of a 'priority' and a 'goal', as in Table 23.

Table 23: Definition of 'context elements' in terms of priorities and goals

Context element	Priority	Goal
1. Technology management infrastructure	CTO attending to the need to review and replace systems, processes, policies, governance and organisational structures.	To secure appropriate, accurate and timely information and decisions.
2. Technology management entry /exit points	CTO attending to technological shifts and changes in customer needs.	To ensure the alignment of technology capabilities with market opportunities.
3. Technology business case & funding	CTO attending to changes in the technology business case.	To balance the technology contribution to volume, profit, leverage and sustainability. In order to motivate external investors and secure internal budget.
4. Operational improvement	CTO attending to the need to create and sustain learning, collaboration and change.	To ensure appropriate technology scope and eliminate errors and efficiency gaps.
5. People management	CTO attending to changes in the technological capabilities requirement.	To refresh skills, attitudes and the working context.
6. Technology business model and strategy	CTO attending to shifts in organisational strategic priorities.	To provide clarity to CEO, the board and organisation regarding technology value, focus, role and remit. To ensure engagement and support.

The second step in the analysis involves cross-referencing the definitions with so-called 'exemplary statements' from the interview transcripts. This is demonstrated in detail in Chapter 6.

6 Deriving and Verifying a CTO/Context Framework

6.1 Introduction

In this chapter the elements and sub-elements of a derived framework are cross-referenced using statements taken from interview transcripts. The derivation of the framework based on the output of the coding process discussed in Chapter 5 is summarised and set out in Section 6.2 and Table 24. The 6 elements (numbered 1 to 6) and 20 associated sub-elements (numbered 1.1 to 6.4) have been derived using the barriers and enablers from 31 personal role maps (see Figure 21 and Table 24).

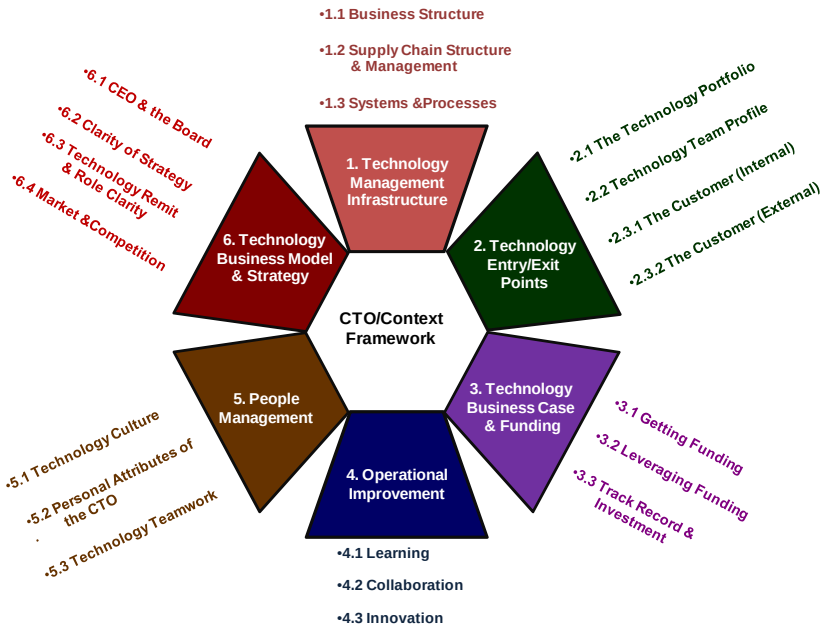


Figure 21: Overview of CTO/Context Framework[17]

Then in Section 6.3 the definitions of the context elements and sub-elements are broken down into more basic components (target phenomena), and 'cross-referenced' with interviewee statements. Transcripts of interviews have been used to more accurately identify appropriate cross references. The final section in this chapter summarises the process and the outcome.

[17] Note for comparison Absorptive Capacity/Tipping Point Framework in Figure 5 Page 64.

6.2 Deriving the CTO/Context Framework

This section is included to demonstrate that the derived CTO/Context Framework is grounded in the data from the 'personal role maps' of the interviewees. Table 24 shows how each 'Context element' is defined and derived from a set of sub-element definitions, which in turn are based on the barriers and enablers from the 'personal role maps'. The coding process using NVivo™ has been described in Chapter 5.

Table 24: Framework elements linked to barriers and enablers

Barriers and enablers used in coding (taken from 'personal role maps')	Sub-element definitions (based on coding)	Element definition	Context element
1.1 Business structure – Structures that facilitate internal technology links; Standalone technology structures; Central v decentralised; Changes in structure – impact on technology / business; Rigidity of structures; Sales, Manufacturing and operations structures; Geographic distribution of staff; Structure as a reflection of technology knowledge domains; Matrix / functional / project team structures.	**1.1 Business structure** – Configurations that locate technology people geographically, hierarchically and in groupings that facilitate technology linkages.	CTO attending to the need to review and replace systems, processes, policies, governance and organisational structures.	1. Technology management infrastructure / organisation
1.2 Supply chain structure and management – Level of control of materials for manufacture; Level of competition between technology vendors; Geographic source of technologies; Costs and quality of supply; Strength of supplier partnerships; Supply base; Attitude of vendors to collaborative working.	**1.2 Supply chain structure and management** – Configurations of people and structures that secure availability of technology knowledge and materials inputs.	To secure appropriate, accurate and timely information and decisions.	
1.3 Systems and processes – New product development process; New product approval process; Degree of flexibility of processes; Extent of review and revision / elimination of legacy processes; CTO involvement in processes; Ability of technology staff to intervene early in development; Quality of processes (planning); Speed and diligence in updating to market changes / trends (e.g. TRMs); Governance; Financial systems; Systems and processes to consistently control and coordinate technology across business; Awareness and understanding of technology processes; Type of processes – command and control v ad hoc; Routines; Involvement levels i.e. number of people involved in processes. Support for processes, systems, routines etc. (e.g. via IT infrastructure and integration).	**1.3 Systems and processes** Codified frameworks and sequences that attract information and support decision-making.		

Barriers and enablers used in coding (taken from 'personal role maps')	Sub-element definitions (based on coding)	Element definition	Context element
2.1 The technology portfolio – Delivery time-frames; Managing fast changing priorities; Attitude and impact of cost focus; Synergy; Shareholder value; Demonstrating value delivery; Broad portfolio of technologies to draw from; Projects 'self-selecting v owned'; Attitude to easy project (low hanging fruit); Maturity of certain technologies; Matching technology portfolio to product portfolio (legacy, current, emerging); Attitude to 'pet projects'; Attitude towards innovation projects; Timing the insertion of technology projects; Impact of roadmaps and strategy; Decision making quality (time and precision).	**2.1 The technology portfolio** – The management act that efficiently allocates technology resources so as to maximise technology contribution, to align technology and business strategy, and to balance the need for short-term value with the need for a pipeline of technologies.	CTO attending to technological shifts and changes in customer needs. To ensure the alignment of technology capabilities with market opportunities.	2. Technology entry / exit points
2.2 The technology team profile - Core tech team; Ability to convert knowledge into value; Team to deal with technical issues; In-house competencies for key technologies; Reputation; Experience of technology team; Business skills of tech team; Availability of expert technology talent; Age distribution of technology staff and tenure with business.	**2.2 The technology team profile** – The capabilities embodied in the technology team.		
2.3.1 The customer (external) – Price pressures; Pricing complexity; Regulatory and other drivers for increased use of technology; Market pull – demand; Customer awareness of brand; Brand quality; Customer needs; Crises; Ad hoc requests; Proximity to market; Changeability of consumer market; Availability and quality of customer and market information; Consumer engagement; External customer approach to development strategy; Customer attitude to funding co-development; **2.3.2 The customer (internal)** – Dissatisfaction with approach to technology; Problems that arise; Ability to understand and translate customer needs (e.g. from marketing); Organisation orientation i.e. growth in market share v profit; Engagement and interest at lower levels in organisation; Personalities of technology team members – ability to deal with BUs; Complexity of buy-in; Attitude of internal customer to time frames and longer v short-term targets; Priorities for use of funds; Commercial buy-in to technology opportunities.	**2.3 The customer** – The market participants that value technologies and the outputs of technology management.		

Barriers and enablers used in coding (taken from 'personal role maps')	Sub-element definitions (based on coding)	Element definition	Context element
3.1 Getting funding – Tax levied for long-term research; PLC v private ownership (sources of funds and attitudes of investors); Central / dedicated / owned budget for technology; Amount of funding for R&D; Short-term v long-term; Funding for reactive / responsive mode; Lead times of certain technologies (attitude towards payback); Making the business case; Attitude to BU levy; Attitude towards ROI; Attitude of finance entity in the business; Impact of lack of funds; Changes in cost of certain technologies over time.	**3.1 Getting funding** – Management approaches and arguments that facilitate availability, access and use of funding for technology initiatives.	CTO attending to changes in the technology business case. To balance the technology contribution to volume, profit, leverage and sustainability. In order to motivate external investors and secure internal budget.	3. Technology business case & funding
3.2 Leveraging funding – Government funding for innovation; Using BU funds for technology; Funds from Customers; Outsourcing innovation to supply chain.	**3.2 Leveraging funding** – Deliberate management interventions to ensure that technology resources return higher multiples of value than expected from the use of cash alone.		
3.3 Track record and investment – Growth; Performance stability; Successes; Availability of money; Differentials of growth in different parts of the business; "Burning platforms"; Time horizons; Trade-offs between short and long-term; Consistency of measures; Trade-offs between sales – profit – sustainability; Attitude of shareholders; Uncertainty of R&D process; Awareness and experience of market analysts; Impact of technology or CTO on investment behaviour.	**3.3 Track record and investment** – The historical contribution of technology to value / growth and the recent performance of the organisation in influencing decision makers about investing in the technology pipeline.		

Barriers and enablers used in coding (taken from 'personal role maps')	Sub-element definitions (based on coding)	Element definition	Context element
4.1 Learning – Transparency; Ability of CTO and technology team to instil understanding; Availability of time for learning and collaboration; Access to supportive management information infrastructure; Customer networks – stay close to customers; Access advanced thinkers in vendor environment; Attitude toward make v buy for research; Proximity to key thinkers; Attitude towards external contributions / ideas; Degree of openness; IPR and patents.	**4.1 Learning** – Sourcing and use of information (including feedback loops) that improve operations by reducing errors and eliminating efficiency gaps.	CTO attending to the need to create and sustain learning, collaboration and change. To ensure appropriate technology scope and eliminate errors and efficiency gaps.	4. Operational improvement in Technology & Innovation management
4.2 Collaboration - Ability of technology people to communicate; Global communications; Awareness amongst senior managers of technology capabilities; Awareness of decision makers of pipeline of opportunities; Jointly develop product maps with divisions; Research cooperation; Knowledge exchange – informal and formal – in and outside firm boundaries; Create and utilise networks (internal and external – e.g. via partnerships); Availability of people with whom to share ideas.	**4.2 Collaboration** – Use of networks to harness the best contributions across technology and business domains, both internally and external to the organisation.		
4.3 Innovation – Attitude and approach to innovation; Can do - ambition - curiosity - openness; Inertia - business attitude to technology risk; Attitude to failure; Need for technology in the business; Availability of time for exploration, thought and innovation in technology; Stickiness of R&D patterns; Scope of activity (including non-core to technology); Critical mass of technology activity; Close to core v expansion into new areas; Reward systems and incentives e.g. BU performance measures.	**4.3 Innovation** – The social and organisational view of the review of existing technologies and/or introduction of alternative technologies and approaches.		

Barriers and enablers used in coding (taken from 'personal role maps')	Sub-element definitions (based on coding)	Element definition	Context element
5.1 Technology culture - Cultural assumptions re role of technology; Consistency of language used re technology; Attitude of BUs to technology's role and staff; Impact of legacy culture; Reward systems and incentives; Working environment in technology area; Organisation support for CTO; Organisation understanding of CTO role; Quality of R&D facilities; Decision process within technology domain; Attitude of organisation towards technology; Degree of integration of technology within the business; Technology role in brand profile; Access to management information; value shop – value chain – value network.	**5.1 Technology culture** – The feel of the working environment within the technology domain and the attitude towards technology more broadly in the organisation.	CTO attending to changes in the technological capabilities requirement. To refresh skills, attitudes and the working context.	5. People management
5.2 Personal attributes of the CTO - World standing as a technologist; Change management background; Business experience and understanding; Personal brand and reputation; CTO attitude to risk; Language skills; Determination and influencing skills; Creative - idea generator; Breadth of knowledge, experience and education; Personal motivation; Power attitude; Experience of business transition; Personal bandwidth; Personal biases awareness.	**5.2 Personal attributes of the CTO** – Leadership, management and technology related attributes of the technology executive.		
5.3 Technology teamwork - Attitude of tech team - flexible v rigid; Trust - belief - motivation of tech team re goals; Mentality of staff / attitude towards process; Tech team forward looking v legacy; Infrastructure to support tech team; Personal relationships, internal competition and turf protection, Personalities, Composition / diversity of technical team; Attitude towards the rest of the business.	**5.3 Technology teamwork –** The attitude of the technology team.		

Barriers and enablers used in coding (taken from 'personal role maps')	Sub-element definitions (based on coding)	Element definition	Context element
6.1 CEO and the board - Shareholder attitude to technology; CEO attitude to technology; Attitude of the board; Management time/availability; CTO on board or not; Relationships between key board level people.	**6.1 CEO and the board –** The attitude of owners and their agents to technology and the CTO and the related contributions and relationships.	CTO attending to shifts in organisational strategic priorities. To provide clarity to CEO, the board and organisation regarding technology value, focus, role and remit. To ensure engagement and support.	6. Technology business model & strategy
6.2 Clarity of strategy - Technology strategy in corporate strategy; Conflicts products vs technologies; Consistency of strategy; A view of the future - a roadmap; Visibility / access between divisions and vertically in corporation; clarity on how to guide search for technology; Awareness of life-cycle stage / tipping point status.	**6.2 Clarity of strategy** – The manner in which strategy provides heuristics across the organisation for the current deployment and future search for technologies.		
6.3 Technology remit and role clarity - Clarity of accountabilities and ownership; CTO role is understood; What is CTO role; Recognition of role of group level technology forums; View of technology contribution to future of company; It is clear what competencies will be needed; CTO mandate; Innovation roles clear; Formal or informal authority; value shop – value chain – value network.	**6.3 Technology remit and role clarity** – Organisational mandate with delegated authority for the CTO to secure and deploy technology resources to enhance the business strategy.		
6.4 Market and competition – Competitive threats (e.g. get technology budget because EBITDA is at risk); Competitive pressures (e.g. disruptions, contributes to business case for technology); M&A activity; Need for competition; Industry trends (e.g. open innovation); Impact of market analysts (representing shareholders in PLCs); Industry / market structure and channels; Matching of market orientation of internal BUs; Volatility of markets; Regulatory environment; Government policy; Trade blocks - tariffs; Balance of power between value chain players.	**6.4 Market and competition** – The context (and related variables) within which the organisation and technology executives identify opportunities that are valued by customers and the mapping against existing and required technology capabilities.		

6.3 Verifying the CTO/Context Framework

In keeping with a 'cross-referencing' approach demonstrated by Plowman et al. (2007), "exemplary quotations" (narrative extracts) from the transcribed interviews are used to illustrate definitions used in the CTO/Context Framework (as set out in Table 24). Each definition is broken down into component parts called 'target phenomena'. Only one or two substantiating statements are required for each 'target phenomena' (hence statements that are 'exemplary').

References that infringe on the confidentiality of interviewees are replaced by generic terms in square brackets. The interviewee number is also referenced to retain the link to the original interview transcript. The framework graphic is used in order to navigate the elements, with the 6 elements numbered from 1 to 6, and the 19 sub-elements numbered to keep the relationship with each primary element (see Figure 22).

6.3.1 Technology management infrastructure

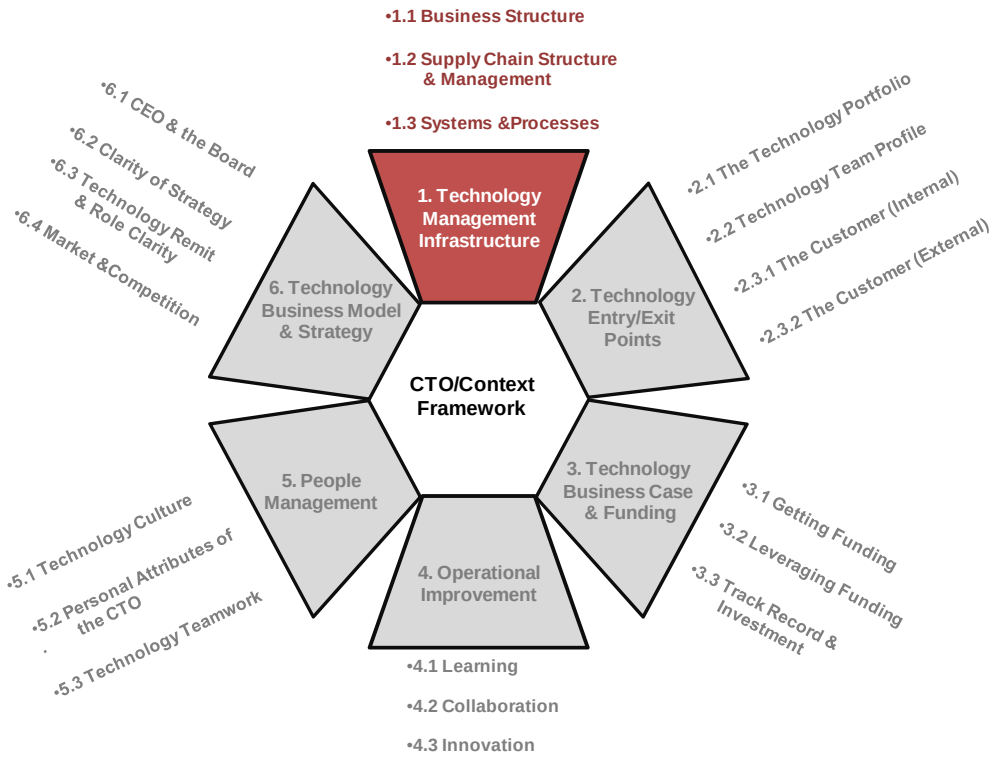


Figure 22: Technology management infrastructure

Definition for Technology Management Infrastructure:

- The CTO attending to the need to review and replace systems, processes, policies, governance and organisational structures;
- In order to secure appropriate, accurate and timely information and decisions.

This dimension consists of three sub-elements – i.e. Business Structure, Supply Chain Structure & Management, and Systems and Processes. The definitions and related exemplary statements are found in Table 25, Table 26, and Table 27 respectively.

Table 25: Evidence in support of 'business structure' definition

Definition	Target phenomenon	Exemplary Quotations
1.1 Business structure: Configurations that locate technology people geographically, hierarchically and in groupings that facilitate technology linkages and / or focus on specific goals.	…locate geographically	"…specifically, we have an organisation that is divisional as well as regional. Certainly we manage the technology on a global level, whilst still trying to keep a network with the regions." [Interviewee 1]
	…locate hierarchically	"…We have the research reporting directly to me. So, I look after anything in research from beginning to end, so to say." [Interviewee 1]
	…locate in groupings	"…The research is split between fundamental and applied research in some way." [Interviewee 1]
		"…we're seeing an increasing number of cross-company forums." [Interviewee 5]
	…facilitating technology linkages	"…we can create that interconnectivity between all the different functions within [the business] and the SBUs." [Interviewee 2]
		"…you need to have the structures in place so that the information does get shared in the right way with the day-to-day management team..." [Interviewee 3]
	…focusing on specific goals	"…when I joined [the business] I had responsibility for innovation and global product development." "…we decided to split them out so that so now we've got a dedicated [service] innovation team which focuses on this stuff..." [Interviewee 2]
		"…[The business] being a very large corporate giant has actually turned itself into …" - "…a group of smaller companies, sold off a lot of its basic core competencies, and now just concentrating on [portfolio x] and [portfolio y]." [Interviewee 3]

Table 26: Evidence in support of 'supply chain' definition

Definition	Target phenomenon	Exemplary Quotations
1.2 Supply chain structure and management: Configurations of people and structures that secure availability of technology knowledge and materials inputs.	…people and structures	"…everybody talked about fully outsourcing R&D some years ago and you were only in the network and they do the innovation for you." [Interviewee 1] "…our business is very much about integrating stuff, we're integrators of stuff, and therefore our innovated contribution is innovating stuff together, rather than doing fundamental science and development, and that comes really up through the supply chain, as it were. And so we're large-scale integrators." [Interviewee 7]
	…securing technology knowledge	"…they'll pull on a number of consultancies who are also good experts in this space." [Interviewee 2] "If you look at that model today, suddenly outside technology, as well as buying access to technology, is suddenly quite expensive. So, the make option is more attractive…" [Interviewee 1]
	…securing materials inputs	"…gives our supply base confidence to invest in our ideas. We have a supply base of around four hundred and fifty suppliers and every one of those, either they're either privately owned or they might be a venture capital owned business, or they might be a public company, but every one of those makes decisions on who do they bet on in investing their money to develop products, for us or other [companies] to sell. That's a decision that they all make in an open market. So their challenge is where do they put their money?" [Interviewee 10]

Table 27: Evidence in support of 'systems and processes' definition

Definition	Target phenomenon	Exemplary Quotations
1.3 Systems and processes: Codified frameworks and sequences that attract and review information and support decision-making.	...frameworks and sequences	"You can bring the very best people in but if you haven't got the framework and the processes for them to work, effectively work within, then they won't be able to do their job. So my responsibility as head of the team is to ensure that they have the correct frameworks in place to do this." [Interviewee 2] "…your HR process…", "…you have a CAPEX process." [Interviewee 11]
	…attracting and reviewing information	"…basically, we have quarterly meetings. And you know the next meeting's coming, so you collect ideas of things that you think should be done. Obviously, we also get input from other management functions and outside ideas, It can be all sorts of things. It can be new ways of monitoring competitor intellectual property." "And then we do reviews every year in every business unit." [Interviewee 1]
	…supporting decision-making	"…the procedures are not meant to be primarily obstacles. We also have what we call a technology footprint, i.e. what do we do where, which has something to do with proximity to markets, as well as with cost performance." "It's a structure and a process. I mean it's a structural decision whether to set up a lab in Beijing for instance, or Bangalore. And it's a process thing how we allocate work and subject areas to those." [Interviewee 1] "…if your HR process is up to scratch the fact that you can identify the people within your organisation who have got the skills and attributes." [Interviewee 11]

6.3.2 Technology Entry/Exit Points

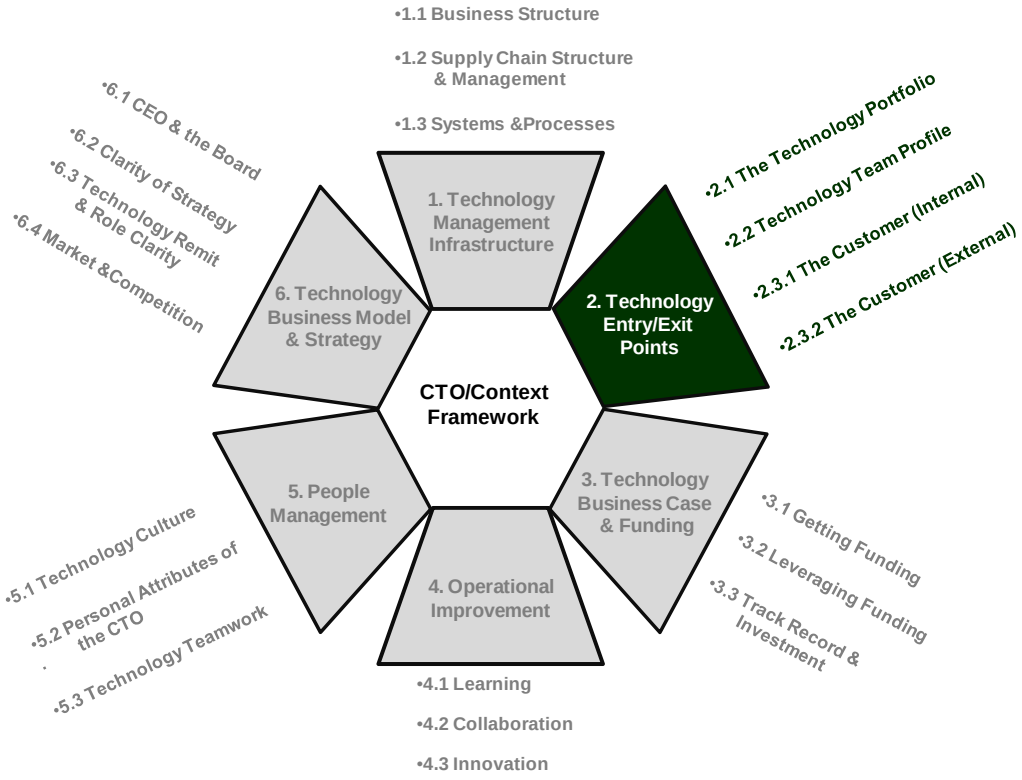


Figure 23: Technology entry/exit points

Definition for Technology Entry/Exit Points:

- CTO attending to technological shifts and changes in customer needs.
- To secure the alignment of technology capabilities with market opportunities.

The "Technology entry/exit points" element consists of three sub-elements. These are The Technology Portfolio, The Technology Team Profile, and the Internal and External Customer. The definitions and related exemplary statements are in Table 28, Table 29 and Table 30.

Table 28: Technology portfolio

Definition	Target phenomenon	Exemplary Quotations
2.1 Technology portfolio: The management act that efficiently allocates resources so as to maximize technology contribution, to align technology and business strategy, and to balance the need for short-term value with the need for a pipeline of technologies	…allocates resources	"…There are a number of forums where these heads of people get together and as a committee they discuss who is doing what and share information, but there is no coherent process for actually managing or prioritising." [Interviewee 5] "…And because we don't have the clear approach, we don't get the output from the resources that we could. So we've got opportunities in terms of improving the way we do what we do today, just to make it more effective. We've got opportunities to increase the economy of scope from the businesses that we have today." [Interviewee 9]
	…maximize technology contribution	"…to have a flexible mindset to competencies and staff skills required over the business life cycle." [Interviewee 3] "…And we also have a big opportunity and need to create, at either end of the product lifecycle, a way of generating richer ideas and a way of commercialising and managing the portfolio. So, that we actually end up pulling through the pipeline the products that are taking us into higher value add areas, or that are refreshing the product mix. So what we tend to end up with is a long tail of the client products. So there's a need to break that cycle and start to be more active in terms of managing the portfolio at the development end and managing the portfolio at the commercial end." [Interviewee 9]
	…align technology and business strategy	"…As we look longer term and as the vision emerges for the business, then you have to start to have the information to be able to select exactly what you're going to do. So you have to start to develop this kind of information. And once you've done that and you say, right, this is my portfolio, this is what I want my portfolio to look like, this is what it is now and this is what's in the pipeline, we need to adjust the portfolio. Then you get into the, right, now we're going to have to take risks, because the portfolio is built, currently, around what we understand. So what we're then saying is, if we want to focus on a particular way of doing things, we're going to have to move into things we don't understand and, clearly, there's a risk association there." [Interviewee 9]

Definition	Target phenomenon	Exemplary Quotations
	…balance short-term value with the need for a technology pipeline	"…one barrier is always the short-term versus long-term trade off. So, do I get this smaller thing here now, or do I get this bigger thing, potentially, in the future." "…Up here, short-term/long-term. One thing is, actually, educate them; educating models." [Interviewee 1] "…So I think perhaps what we've got here is there is this technology pipeline concept. I think there is this recognition that we need to start thinking about keeping a constant stream of new technologies and managing that much better." [Interviewee 5] "…to do with short-term-ism is that, as a result of this, most of the senior players are heavily incentivised on the performance of their business unit and on their performance during that year." [Interviewee 9]

Table 29: Technology team profile

Definition	Target phenomenon	Exemplary Quotations
2.2 Technology team profile: The capabilities embodied in the technology team.	capabilities	"…Because as my job as head of team I have to understand each of the SBUs, their structures and their cultures and the people that run those SBUs which then enables me to go out and find the right person that I think will be able to engage further trust and respect and deliver for those particular SBUs. And they are very different so you've got a mix of markets, a mix of cultures, a mix of [product name], a mix of acquiring, a mix of consumer commercial, yeah. And then within that I have to try and create the agility and flexibility within the team." [Interviewee 2]
		"It was a very incremental mindset. So how do you get an organisation that's very good at nailing costs and producing a commodity to one that can look to new markets, developing new product services within its existing business to create new revenue streams? Actually very difficult… …the core competencies of the organisation were not competencies that were going to facilitate innovation." [Interviewee 11]
	embodied in the technology team	"…But still is one of the better physicists we employ as a corporation. And absolutely, this guy understands the business. I mean, you could go to, wherever, China or somewhere with this guy and he'd be able to characterise the market needs, competitors, customers, where it's all going. And, at the same time, I think he could still engage with anyone in our organisation." [Interviewee 1]

Table 30: The customer

Definition	Target phenomenon	Exemplary Quotations
2.3 The customer: The market participants that value technologies and the outputs of technology management.	market participants that value technologies	"We've had a change, part of the change we talked about was we have moved away from waiting for the phone to ring and the customer saying I want one of these with that on it and here's a spec, which is where we were four or five years ago. Our Marketing Department which is four or five people strong is a totally new entity for us. So as an engineering group we've had to modify our approach and our processes to be able to design for a very fluffy marketing remit which is very much at odds with what we had before. And very much at odds with what most of the engineers are comfortable with." [Interviewee 4] "Well in our organisation we have as you may call it, sales forces. We call them Customer Relation Managers. And through this Customer Relation Manager organisation I have access to the road maps of our customers and that helps me to have a longer term view on the possible needs of our customers and therefore to adapt their competencies." [Interviewee 6] "…Yeah, people will suddenly realise actually there's a risk attached to not innovating. How do you increase your appetite for risk, well talk to the customers they'll tell you you need to come up with something different and if it's not you it will be somebody else." [Interviewee 11]
	market participants that value the outputs of technology management	"…you need to have the balanced view of not only good news and bad news but also as a team making sure the people who are really driving the technology are doing very well and are also seen by the Board for what their particular input is and they understand where the critical elements are of how people are doing different things." [Interviewee 3] "Yes, clearly there was a tendency for that, the [R&D at merger company 1] was more fundamental and certainly the [R&D at merger company 2] was much more applied. But the [R&D at merger company 1] one was fat and happy and not entirely industrially relevant because it did what it fancied doing, and the [R&D at merger company 2] was very lean in some respects. But also lacked some relevance because it was doing work for third parties and frankly a business our size, and what it is, it's never going to make a significant amount of money doing research for other people, it's not what it's about. And so neither were right and what we tried to do was join the two together and now a more central role of getting the thing much more industrially relevant and moving the [R&D at merger company 1] to a higher level of application, as it were, and the [R&D at merger company 2] one to being more focused internally on what we were doing." [Interviewee 7]

6.3.3 Technology business case and funding

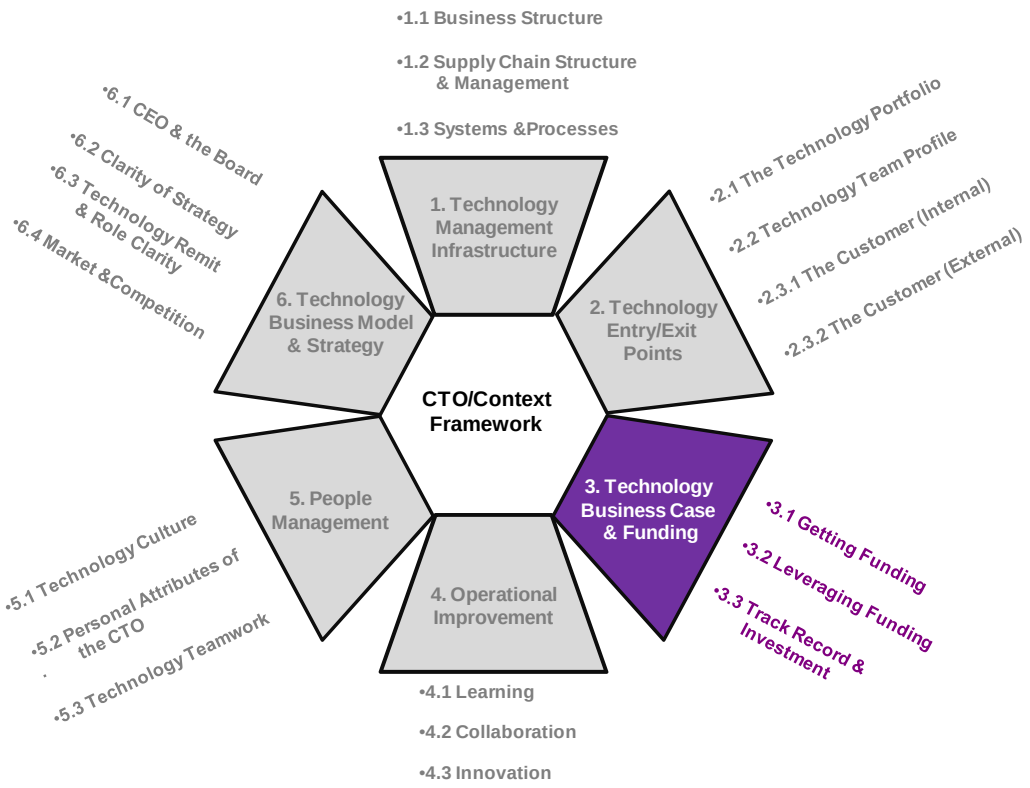


Figure 24: Technology business case & funding

Definition of Technology Business Case & Funding:

- CTO attending to changes in the technology business case.
- To balance the technology contribution to volume, profit, leverage and sustainability. In order to motivate external investors and secure internal budget.

This element consists of three sub-elements which are Getting Funding, Leveraging Funding and Track Record and Investment. The definitions and related exemplary statements are in Table 31, Table 32, and Table 33.

Table 31: Getting funding

Definition	Target phenomenon	Exemplary Quotations
3.1 Getting funding: Management approaches and arguments that facilitate availability, access and use of funding for technology initiatives.	…facilitate availability of funding for technology initiatives	"…So effectively we get an exploitation road map which shows this is the work that we'll do and that's how we're going to exploit it for you. Over that we're then going obviously to the next stage which is to enable us to actually put on where we expect to get the funding from, so it gives us an approach to actually focusing out there and targeting who we're going to attack for this money, how we're going to staff it and what else is there that's maybe worth noting?" [Interviewee 13]
	… facilitate access to funding for technology initiatives	"…you pick a couple of people off and perhaps even go and see a customer and gain an interest. And, actually, 'Well, the customer really wants to do this...,' and you leverage, if you like, things from outside influences that will affect the thinking of the people sitting around that room." [Interviewee 15]
	.. facilitate use of funding for technology initiatives	"Actually the way he sets his companies up as separate standalone entities means there's a very modular approach. So he'll take debt, buys an asset, he'll attribute the debt to the asset so that the net value of that asset on day one is zero and then that asset's job is to pay the debt." [Interviewee 14]

Table 32: Leveraging funding

Definition	Target phenomenon	Exemplary Quotations
3.2 Leveraging funding: Deliberate management interventions to ensure that technology resources return higher multiples of value than expected from the use of cash alone.	…Deliberate management interventions	"Their expectation well, what would make them nervous is they agree some multi-million dollar joint development project with us which we under-fund or lose interest in and they've put all their efforts in and basically this partnership of equals, each pushing hard to deliver the new technology,.." [Interviewee 14]
	…to ensure that technology resources return higher multiples of value	"…And we've recruited somebody, an M & A guy to bring those skills in to the business to look at … whether it be a portfolio fit or a skills or whatever." [Interviewee 4]
		"Because what I recognise for the business that we've got is that we've got a huge number of, it's called, innovations and ideas that people can't leverage because things are in silos or compartments." [Interviewee 9]
		"This is an enabler because it allows us to leverage our skills by accessing complimentary skills in partnership." [Interviewee 14]
	…than expected from the use of cash alone.	"There is very limited sharing across the businesses. So for example procurement is an area that we probably share just because of the weight of the task and the leverage that you can get."
		"The other thing I think we do is we leverage on our historical plants where appropriate." [Interviewee 14]

Table 33: Track record and investment

Definition	Target phenomenon	Exemplary Quotations
3.3 Track record and investment: The historical contribution of technology to value / growth and the recent performance of the organisation in influencing decision makers about investing in the technology pipeline.	…historical contribution of technology to value / growth	"…So, our capability as an R&D organisation to deliver, you can say, well, it's people, but it's more. It's people, processes, technology, reputation to attract those people, reputation to attract collaboration and network partners. And then it's proximity to the customers including all the processes that back that up. It's people and all the processes that back up the recruitment, development of people, transfer of people into the business, and so on, and then the collaboration and network." [Interviewee 1]
	…the recent performance of the organisation	"…Right now, we just published numbers yesterday. We're doing great. So there's certainly more openness to also look a little more left and right, but five years ago we were very close to disaster. Then, of course, you are very much focusing on course. This isn't a constant thing, but it moves around. So, what gives us leverage against short-term-ism?" [Interviewee 1] "…So that ties into one of the barriers, which is resource. Because at this time we are still very much haunted with the revenues and the margin, a short fall of last year. So we are holding our breath and walking slowly, so there is no major expense, no more major project that we can really introduce now. So that has been a barrier for the time being, and also for this." [Interviewee 8]
	…in influencing decision makers about investing in the technology pipeline.	"But if you hadn't kicked of the whole thing by having a track record and demonstrating that you're delivering value everywhere else, you're not allowed to take a judgement call on something that's unpopular. [Interviewee 10] "…one barrier is always the short-term versus long-term trade off. So, do I get this smaller thing here now, or do I get this bigger thing, potentially, in the future." [Interviewee 1] "…to do with short-term-ism is that, as a result of this, most of the senior players are heavily incentivised on the performance of their business unit and on their performance during that year." [Interviewee 9]

6.3.4 Operational improvement

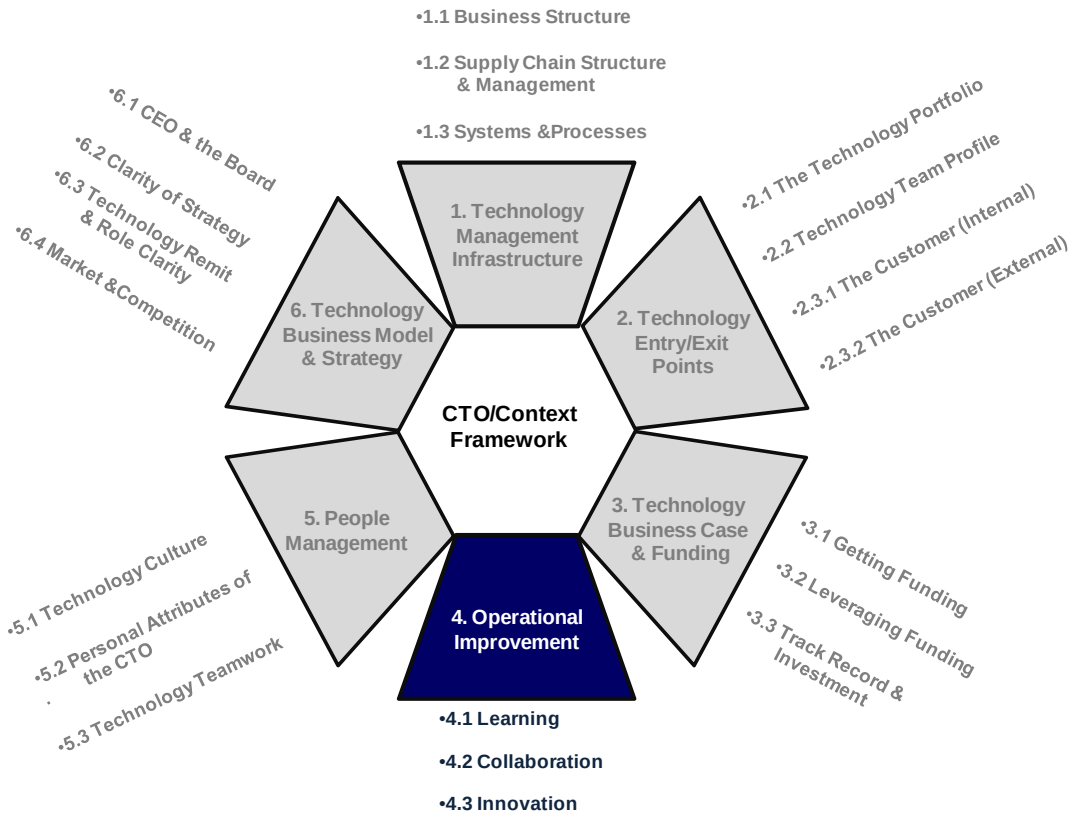


Figure 25: Operational improvement

Definition of Operational Improvement:

- CTO attending to the need to create and sustain learning, collaboration and change.
- To ensure appropriate technology scope and eliminate errors and efficiency gaps.

This element consists of three sub-elements which are Learning, Collaboration and Innovation. The definitions and related exemplary statements are in Table 34, Table 35, and Table 36.

Table 34: Learning

Definition	Target phenomenon	Exemplary Quotations
4.1 Learning: Sourcing and use of information (including feedback loops) that improve operations by reducing errors and eliminating efficiency gaps.	…Sourcing and use of information	"…There is a lot of rumour and hype that's done, not only by journalists but also by the other companies to put you off the scent of where is the next technology going. Or if you have a materials partner that you think you know quite well and you can see basically where their road map is going and they will rarely tell you about their goodies in the back of their pockets. Obviously they're looking at having multiple options for people to take their materials to make new products from so it's trying to work out what people are doing as opposed to what the spin is in the outside world." [Interviewee 3] "...We haven't really done external expertise. Yeah what I would you say is the reason that that is an enabler to that purpose? I think it just gets you over a short term skills gap actually." [Interviewee 11]
	…that improve operations by reducing errors and eliminating efficiency gaps.	"…you take technology from the lab and actually run it with customers, which is part of convincing them, which is part of gaining experience. So one is, say, field testing, which creates credibility and references. The other is, you could call it field learning. Which is actually the process of understanding this more. I mean, both feed into it. So I would call one 'field trialling' or 'field testing'. So, we've got learning and we've got reference points." [Interviewee 1] "Then you get into the, right, now we're going to have to take risks, because the portfolio is built, currently, around what we understand. So what we're then saying is, if we want to focus on a particular way of doing things, we're going to have to move into things we don't understand and, clearly, there's a risk association there." [Interviewee 9]

Table 35: Collaboration

Definition	Target phenomenon	Exemplary Quotations
4.2 Collaboration: Use of networks to harness the best contributions across technology and business domains, both internally and external to the organisation.	…Use of networks to harness the best contributions	"…So sometimes you just listen in the network and other times you actually sit down with somebody and say, "Hey, how can we take this further?" "Or can we take this technology that you've developed one step further to also solve our problem?" or the other way round. We want to make sure we don't overlook anything and the informal communication there. And, to some extent, this is business understanding because you also exchange thoughts on how is this thing you're in working, how are you contributing to value? " [Interviewee 1] "…you need to evangelise and market your IP position and your core competencies to everybody else out in the world and then that will stimulate ideas, will bring more people to the table and they'll be able to extract more value because you won't do all of it on your own." [Interviewee 3]
	…best contributions across technology and business domains	"…close network internally. And this is at all levels. This is the guys running our business divisions on the global level and it is sometimes, whatever, the local Sales Group Manager and it's important that you get the information. This core network internally, that feeds into what we also do on the level of actions, but it may deal with collaboration and network, it may have something to do with capability, business understanding, is actually we do external benchmarking also of various parameters." [Interviewee 1] "…And these are the most important inputs from me; that is the requirements from our customers and the technology trends in the world." [Interviewee 6]
	…both internally and external	"…I stick him [team member] in the partners, I physically locate them together. Okay, so we collocate. That also gives us the opportunity to get some cross fertilisation of skills and ideas so the [team members] feel that they're learning something from these outside partners that we go to 'cause we don't have the skills in house. So they, it helps to develop them as well." [Interviewee 4] "…I'm a member of the [country name] Science Council. And I have a number of functions, which are very much related to that which links me up to the scientific community and which allows me to have insight on the longer-term technology developments and in fact to an extent to steer those." [Interviewee 6] "…is obviously transferring personnel. And if you're on a project knowing that if you have a boffin across the sea that you could plug into your problem here, that it would be something that you could do, it's quite a nice possibility." [Interviewee 7]

Table 36: Innovation

Definition	Target phenomenon	Exemplary Quotations
4.3 Innovation: The social and organisational view of the review of existing technologies and/or introduction of alternative technologies and approaches.	…social and organisational view	"…My feeling is that is the sole problem I think. You know, you restructure any function and there are people who have things to lose by changing. [Interviewee 5] "…in a company where 50% is owned by management it is obviously a very, very entrepreneurial kind of set up and everyone wants to protect what they have." [Interviewee 8]
	…review of existing technologies	"…I'm speculating but it's like turkeys don't vote for Christmas do they? I think there are some people in play here who would be game for it. They're confident enough to know there's a role for them whatever. Others, I'm not so sure on. So I think I'd say some self-interest." "…I mean there are physical location issues but we're actually quite good at dealing with those. A lot of the functions right now are geographically distributed and they seem to work quite well but their divisional orientation remains. You know, to break that down I think would be quite tough. And it is so big it's like where is the single point of responsibility that actually could resolve that?" [Interviewee 5]
	…introduction of alternative technologies and approaches.	"…And then sometimes say, 'Well this has got to come to an end. Nobody wants that anymore. And then we identified that [segment name] became very important and we didn't have any [scientific field] people and [technology field] people in house so we start hiring [these] people and now we have [technology type] technology in house so we can do [various work types]. We didn't have that technology in house five years ago. We now have a [technology type] platform, which is appreciated by a lot of customers." [Interviewee 6] "…Well, as we're bringing new things into the business, often there's no stories around them, often they've not got any demonstrable benefit when you first introduce them. And often you need to explain them in a way that the explanation wouldn't fit all the people in the business. So you have a very targeted approach to the people who are the innovation community, who generally have an ability to understand the more sophisticated concept who you need to explain the context to them but you can't demonstrate the results. So you need people who are prepared to work on a bit of faith." [Interviewee 9]

6.3.5 People management

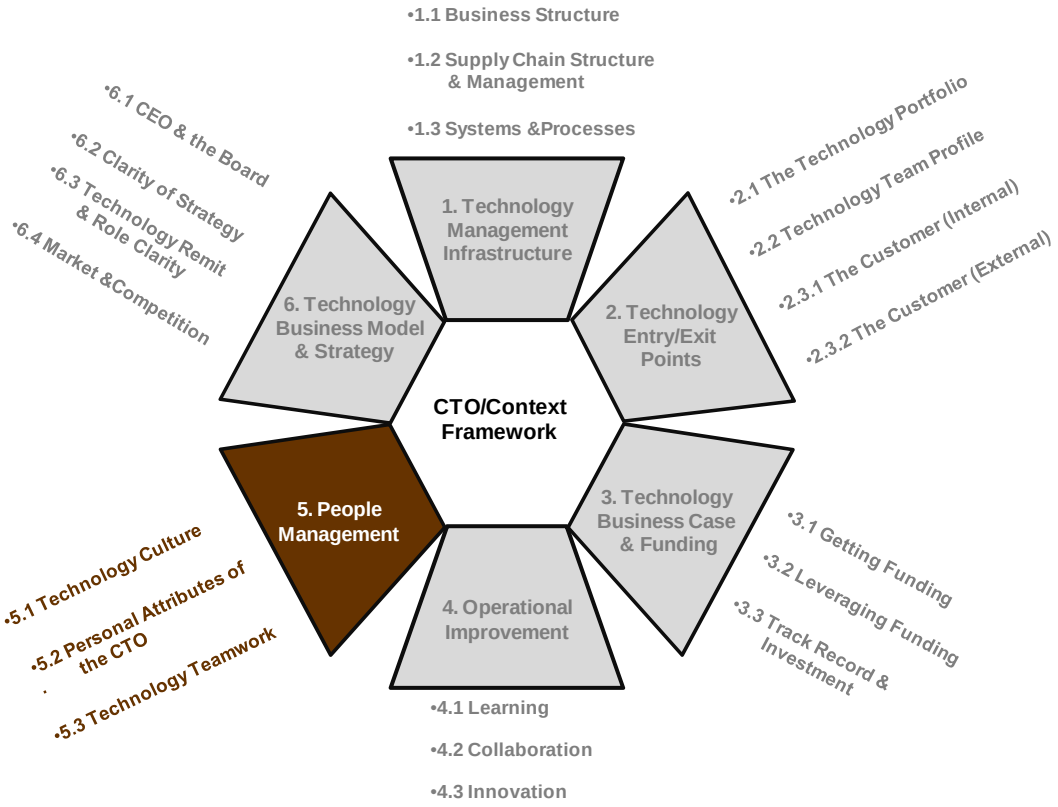


Figure 26: People Management

Definition of People Management:

- CTO attending to changes in the technological capabilities requirement.
- To refresh skills, attitudes and the working context.

This element consists of three sub-elements which are Technology Culture, Personal Attributes of the CTO and Technology Teamwork. The definitions and related exemplary statements are in Table 37, Table 38 and Table 39.

Table 37: Technology culture

Definition	Target phenomenon	Exemplary Quotations
5.1 Technology culture: The feel of the working environment within the technology domain and the attitude towards technology more broadly in the organisation.	feel of the working environment	"…They're maybe not going to be your best buddies in the world. I've certainly found that for example with the [Asian country name] the way they work, if you really want to get the operators on your side was to take them all out for a beer and some [food] or something because they really appreciated that because their bosses never did it because that's there sort of culture." [Interviewee 3]
		"…we have a culture which is driven around incremental improvement in profitability through efficiency gains, loosely speaking. And that's run its course. We can't achieve any more significant step changes in efficiencies. So that's the overall driver to innovation. We have a business that's – I don't want to say it's become commoditised – but it has a mentality of incremental innovation in a relatively unstructured way. Within divisions, we lack the rationale, the clear rationale behind innovation which tends to make the businesses very responsive rather than proactive." [Interviewee 9]
	within the technology domain	"…The plus side of that is it's brought my immediate management team much closer into the discussions about strategy and how the department runs and is funded. They've been, we've just put in the budget submission for [year] and they've all been really big part of that. So it's building that team ethic that was probably starting to, well we know was starting to splinter previously." [Interviewee 4]
		"…and I don't suppose we were really worried about names, but we were the sort of Corporate Technology team or something. I'm not sure we bothered about calling ourselves anything in particular! We didn't, frankly, worry much about titles or anything, in that we each had a sort of specific role, but it was very much seven of us, seven people working together and we each had a … [team member name] principally looked after the university partnerships. And [team member name], the ex-[company name] looked after the technology acquisition. We each had a principle role but there weren't hard boundaries around it." [Interviewee 7]
	attitude towards technology more broadly	"…Yes I think it really helps and it's having this diversity of background, and having the business units owning these people and therefore feeling some responsibility for it, I think really does bring an inclusiveness, as it were. Rather than the centre just trying to dictate." [Interviewee 7]

Table 38: Personal attributes of the CTO

Definition	Target phenomenon	Exemplary Quotations
5.2 Personal attributes of the CTO: Leadership, management and technology related attributes of the technology executive.	…Leadership of the technology executive	"…most important about any CTO is this global view, being a world expert, being well connected and having a head of a lot of experience before you take over the CTO role. Certainly for me I don't think you can be a CTO that takes a business to commercial revenues until you've physically done the bench work, you've worked in the factories, you've transferred the technology, you know about the importance of relationships throughout the world." [Interviewee 3]
	…management of the technology executive	"…Including both the ugly side, i.e. restructuring, as well as the nice side, i.e. innovations and customers and so on. To recruit top talent. And then one of the actions is, close links with universities. The top talent attraction is certainly capability." [Interviewee 1]
		"…sometimes those intangibles skills. It's not the hard skills, it's the softer skills. So the ability through my management style, my personality to walk into a room or a meeting with an MD and within ten minutes earn their trust and respect that if I ask their team to help us with this innovation it's going to pay dividends again. It's … So I guess what I'm saying there is that selling is very important as well, being able to sell yourself and the team…" [Interviewee 2]
	…related attributes of the technology executive	"…I have plenty of very good support. I think one enabler is understanding the business. So, who ultimately decides? Is it the person who's in charge of the technology and who thinks he or she has an image of how we could drive this forward? Or is it the person in charge of the market?" [Interviewee 1]
		"…At the time I was very aware that it was a change programme we were involved in. It wasn't a nice gentle evolution. We had an organisation that was built to do a job and we were actually changing that job. So I would say in that scenario and it's completely different to say the work I did at [previous employer] where the chief technical officer would be something completely different. That is an innovative organisation, it's all about project management and those things. No it's change management I would say." [Interviewee 11]

Table 39: Technology teamwork

Definition	Target phenomenon	Exemplary Quotations
5.3 Technology teamwork: The attitude of the technology team.	…attitude of the technology team	"…because you need people with a very broad set of skills, for example people that understand marketing, technology, operations, call centres, it's very, very important. But more importantly you need people with the right attitude." [Interviewee 2] "…There is a legacy mindset with a lot of engineers 'cause our average length of stay in this business is fourteen and a half years…" "…The idea of taking them out of their comfort zone and cutting them adrift is what they fear." "…Engineers, funny some of them are very anti that [involvement in decision process], but basically it's to enable them to spend as much time engineering and as little time filling out stuff and trying to get their expenses…" [Interviewee 4] "And there's this thing about the confidence. There's a lot of pressure in some organisations, particularly this one, you know, to have a sort of positive attitude and I absolutely endorse that because it's terrible to work with a negative attitude but that can therefore make people a little shy of occasionally turning around and saying, 'Actually, I'm not sure that I agree with that. That's not the right answer. Can we explore an alternative?'" [Interviewee 10] "…maybe comes back to the macho type attitude that I think can easily appear within industry which is, you're a good guy because you actually got on with it and solved the problem. Well yes you can do that and I could probably carry on providing an answer to the problems over the next twelve months and a suitable smokescreen to what goes on beyond that, and then move jobs so that some other poor bugger gets to pick up the problem." [Interviewee 13]

6.3.6 Technology business model and strategy

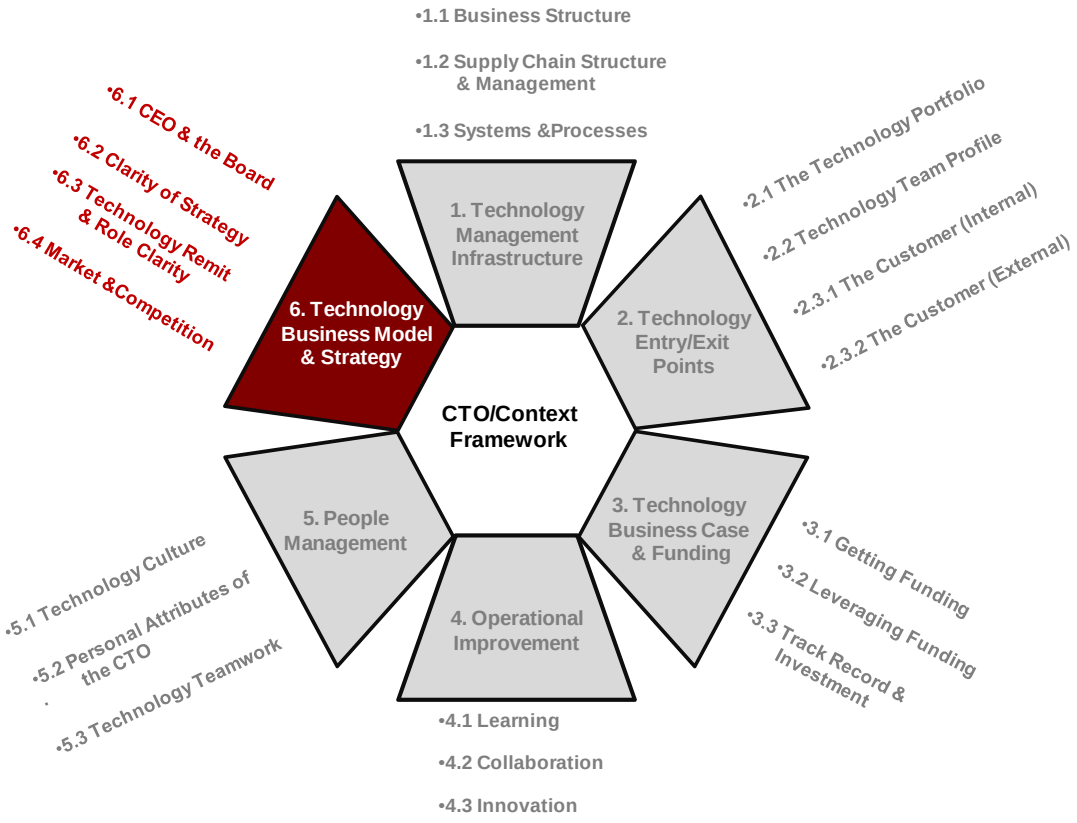


Figure 27: Technology business model & strategy

Definition of the Technology Business Model & Strategy:

- CTO attending to shifts in organisational strategic priorities.
- To provide clarity to the CEO, the board and organisation regarding technology value, focus, role and remit. To ensure engagement and support.

This element consists of three sub-elements which are the CEO & The Board, Clarity of Strategy, Technology Remit & Role Clarity, and Market & Competition. The definitions and related exemplary statements are in Table 40**,** Table 41, Table 42 and Table 43.

Table 40: CEO and the Board

Definition	Target phenomenon	Exemplary Quotations
6.1 CEO and the board: The attitude of owners and their agents to technology and the CTO and the related contributions and relationships.	…attitude of owners and their agents to technology	"…you've got very different people on the Board. If they're financial VC's they tend to know very little about technology so you have to tailor the message to them. We can come back to that but it's actually bringing them in as much as possible. When they are in town have dinner with them, bring them into the labs, show them what the teams have been doing. Introduce them to the technical team, so again they're getting the pull from the technology and can see how things have progressed over the last few months, otherwise it's just a case of a bland paper document of Board papers which most of them don't read before the Board meeting because they haven't got time." [Interviewee 3] "…You could argue that you [innovation team] shouldn't bother. You could argue that the organisation that produces that is so good at screwing out cost, don't mess it up with innovation. Let the shareholders decide to invest in innovative businesses… If you own the company that makes sense. If you're a shareholder well why not diversify your portfolio into, you say some companies are good at innovation, some are very good at throwing up enormous cash flows through actually not being innovative, not being sidetracked. I think that's quite a valid argument." [Interviewee 11]
	…attitude of owners and their agents to the CTO	"…And things like I do weekly one on ones with my Managing Director so yeah, that's a good position to be in. Otherwise, well again, it's the whole change isn't it? It's not supported from there you're on a hiding to nothing really." [Interviewee 4]
	…related contributions and relationships	"…I need to first begin with the people who are at the top. So a lot of the work, even before I actually start talking about innovation to the rest of the organisation, I'm doing that at the CEO of each business unit level. And in order to do that I have to sit here, at a group position, sit with the CEOs, sit with the people who are on the boards, sit with each business unit CEO. And if I were at any other level within the organisation I probably would not have that visibility." [Interviewee 8] "…one of the reasons that the CEO was an enabler, that buy-in was an enabler, was because you got budget." [Interviewee 11]

Table 41: Clarity of strategy

Definition	Target phenomenon	Exemplary Quotations
6.2 Clarity of strategy: The manner in which strategy provides heuristics across the organisation for the current deployment and future search for technologies.	…strategy provides heuristics	"…at this sort of Board level to know where the business strategy and how much of the technology you need to develop in house, as opposed to working outside with joint venturing partners and therefore are the individuals and the core competencies within your company, how much you need to do yourself and how much is effectively going to be outsourced via this strategy?" [Interviewee 3] "…We'll just keep churning it and doing it faster and cheaper and trying not to make so many mistakes. So there is like a strategic void." So there are implications here around integrating tech strategy. There is this thing around integrating technology strategy without the business really. [Interviewee 4] "…those have been the two growth engines, and the strategic view now is that we actually have to start driving organic growth, looking forward for the next business cycle." [Interviewee 9] "…So you're really got to agree the strategy. Is it better to evolve the organisation to acquire it or ... once you've made that decision and that kind of drops out of this in that sort of analysis doesn't it? How difficult were the risk and rewards of different strategies delivering innovation." [Interviewee 11]
	…for the current deployment of technologies	"…the question is, do you want to do that? And say, great, based on our core ability to innovate, we basically go and discover new markets. Or do you actually say, no, that's a waste of money because we don't have production for it, we don't have the sales force for it, we don't have the customer relation, and we're not willing to go there." [Interviewee 3]
	…future search for technologies	"What I'm highlighting here is you need to be aware that the skills you need will change over time and those skills are mostly dependent on what your business strategy is and how are you going to do the technology road map." [Interviewee 3] "…I mean the implication is almost you need to be more strategic about the source of ideas." "…The idea being that an [x type technology] is going to be seen as a threat to our core business but we need to back the right horse so we ought to do it anyway. We'll set it up as a separate business and if it wins it wins, if it doesn't it doesn't." [Interviewee 11]

Table 42: Technology remit and role

Definition	Target phenomenon	Exemplary Quotations
6.3 Technology remit and role clarity: Organisational mandate with delegated authority for the CTO to secure and deploy technology resources to enhance the business strategy.	…mandate with delegated authority	"…are you going to be a standalone company and manufacture yourself, or are you looking at having a joint venture or M&A? Are you looking at just process licensing, for example, so more like [Company name] who are actually licensing the materials they've developed to a whole series of partners. So they run in some aspects much more like a consultancy but they're having people actually coming in and using their materials, coming back and saying, 'Oh, we've got a problem here', and they'll help them through that. So there's normally some sort of retainer and they will also get royalties for anything that's actually produced. [Interviewee 3]
	…authority for the CTO to secure technology resources	"…it's [the IP portfolio] been owned by various bits, and only in literally the last few weeks it's gone back to being owned by the legal department. It was, for the last few years, owned by what's called the Shared Service organisation which is a sort of corporate, indirect procurement and stuff like that. And slightly bizarrely, the intellectual properly was bundled in with that lot. I know the people in IP are much happier now they've just come back under, the new legal director has come in and he's said, 'This is a legal function and we will take control of it.'" [Interviewee 7]
	…authority for the CTO to deploy technology resources	"…on the resource allocation side, of course, if you've got limited resource through that, it becomes a dilemma. But you can actually do both. You can innovate your [product name] making. You can innovate in totally different things by just running businesses because the opportunity on the market is so huge. Even so, you know nothing about it. You just think it's so much more attractive and then, at some point, that may turn out to be something where you actually want to break up the company for it." [Interviewee 3]
	…to enhance the business strategy	"…I think for me in a top level it's defining the technology road map in parallel with business strategy. And that's the main element of the CTO role that I've had." [Interviewee 3] "…as a CTO it's that strategic role to say, 'Yes, this is then impacting on the business strategy, we probably ought to go this way'. So again communicating that to your peers and also to the Board and saying, 'I think this might be happening'" [Interviewee 3] "…I specifically had a role trying to integrate and coordinate and set the strategy for technology for the company as a whole. " [Interviewee 7]

Table 43: Market and competition

Definition	Target phenomenon	Exemplary Quotations
6.4 Market and competition: The context (and related variables) within which the organisation and technology executives identify opportunities that are valued by customers and the mapping against existing and required technology capabilities.	…context	"…We're also market consolidators. Our strengths are not in understanding our consumers at the end of the value chain, and they're not in understanding where our markets will be going in three or four years time. Basically, that whole space of thinking doesn't exist. So the business develops what somebody's just asked it to do, which means that you have a zero risk profile in terms of I think we need [x type product] which is going to be the fastest growth market. We need to be developing products to do that and we will back out of developing products in known markets with low growth rates, even though we know that's going to cost us market share." [Interviewee 9]
	…organisation and technology executives identify opportunities	"…We're running out of ways to do it quicker and cheaper and compliant with our current platforms. So how would we capture that? The improvement potential is exhausted." [Interviewee 5]
		"…So my point at this time is to engage with each CEOs and say, 'This was your business model, what are the challenges that you see?' So in the case of [business unit], I talk about [x type asset] management being now downgraded to a playing level where you can't compete on [x type asset] management alone. So what are the challenges, how are the markets moving, what more can we do? Similarly I'll go to the CEOs of the other business units." [Interviewee 8]
	…valued by customers	"…If I put an ageing portfolio of products. And also in the [industry sector] market if you obsolete something, if you try and sell a customer a new part they are forced now to go to competitive tender which is a lot of work for them. So what they'll tend to do even though you've got one that's, it's thirty years old and it's made of [x dated material] they'll still have it, they still want it because otherwise it's going to take twelve months and they're going to have to put it out to competitive tender and they're going to have to get three quotes and lots of qualification. So it's not quite like the [alternative] market where you can just obsolete it and say right this is the latest one. There are some restrictions on how we can reduce this portfolio if that makes any sense." [Interviewee 4]
	…mapping against existing and required technology capabilities	"…So that whole industrial portfolio piece and the value chain and where the consumers are going at the end, we don't have a depth of thinking around that to enable us to move away from this one in and one out approach." [Interviewee 9]

6.4 Summary

In this chapter the derivation of the CTO/Context framework is set out (see also Chapter 5 for coding explanation and Table 24 for outputs). This is intended to demonstrate the relationship between the framework and the data from the original 'personal role maps'. That is, that the 6 primary elements and the 19 related sub-elements are grounded in the data from the original 'personal role maps'. That is, that the 6 primary elements and the 19 related sub-elements are grounded in the data from the cognitive mapping of the interviews. The resulting framework is graphically depicted and shown in Figure 28.

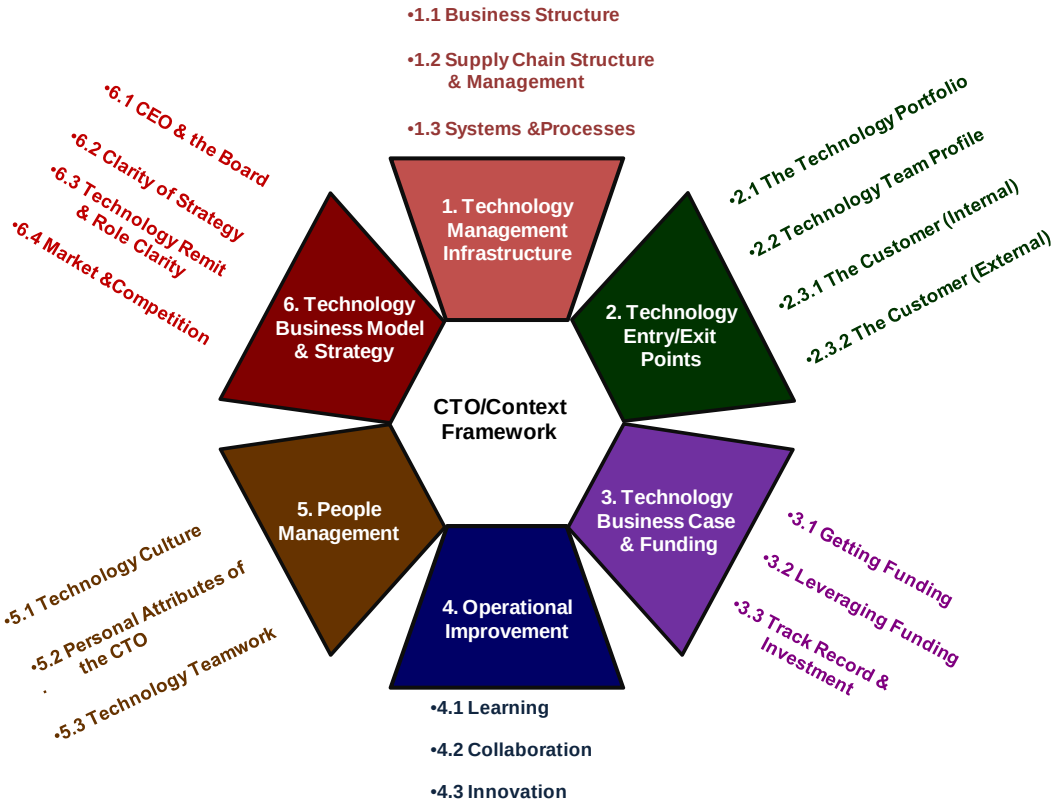


Figure 28: Summary graphic of CTO/Context Framework

Also, in Section 6.3 the definitions of the CTO/Context Framework elements are broken down into detailed 'target phenomena'. The target phenomena are then cross-referenced using 'exemplary quotations'. This cross-referencing uses data (narrative extracts) from the full transcripts of the interviews conducted. The 'exemplary quotations' are used to explain and illustrate the framework.

Furthermore, checking the efficacy of the framework in this way is useful for a number of reasons. Firstly, the phrases used by interviewees to describe barriers and enablers in their personal role maps are generally brief and cryptic. The concern may therefore be raised that the definitions that emerged using this data is taken out of context. Since the links between the nodes (phrases) on a personal role map relate the nodes to each other, using nodes in isolation to derive the element definitions would risk ignoring their context. However, the 'exemplary quotations' taken from the interview transcripts are referenced in such a way as to ensure the inclusion of their context. Generally, the 'exemplary quotations' include sufficient narrative text to make their context self-evident. This procedure has worked well because the cross-referencing process has not resulted in changes to the definitions.

Secondly, the 'exemplary' statements used demonstrate the perspectives of the CTOs interviewed. In particular, they demonstrate the variety of responses and approaches that they deploy.

Finally, while this framework helps to gain insights into the scope of activity (the remit) of the CTO, it is clear that there is a need for a dynamic model of the role. The framework will remain static if it is not developed further to take account of the ongoing change encountered in the role. What is highlighted is that the framework can be used by the CTO to plan or react to the change if the type of change is evident. The cross-referencing in this section demonstrates that the framework is sufficiently comprehensive to cover the eventualities raised in the interviews. Further data collection would refine the framework, and deductive research would improve confidence in the scope of activities.

7 Discussion

7.1 Introduction

In this chapter the focus is on two related concepts. These are drawn from the literature reviewed in this thesis and the interview data generated.

The first concept uses the derived CTO/Context framework and looks for the configuration of elements being emphasised by CTOs in their interviews. A number of sample configurations are generated and depicted graphically in an attempt to visualise alternative sets of priorities. The second concept considers the impact of random and planned change events on the technology context. In this research, these events are called 'technology transition points'.

These two concepts are related because the emphasis of the CTO's attention differs depending on the 'technology transition' being invoked (planned internally) or imposed (by random external phenomena). The visual depictions generated using the CTO/Context Framework allow comparisons between individual CTO priority configurations. The CTO's attention and goals (purpose) are continually adjusted in relation to technology transitions.

This is shown in Figure 29.

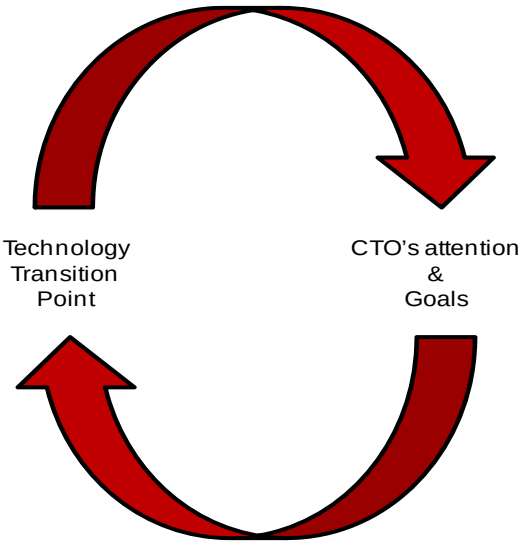


Figure 29: Relationship between Transition Points and CTO priorities

7.2 Sample CTO/Context configurations

In this section, graphical depictions of the CTO/Context are created by a process of text coding in NVivo™ that produces a measure of "coverage" (Bazeley, 2002). Coverage measures the text coded to a particular element, as a proportion of all text coded to all elements. For the purposes of this research, these proportions (converted to percentages) are plotted onto a spider diagram against each of the six elements for the derived CTO/Context framework.

The result allows a comparison between individual CTOs (in their context). The context and the related emphasis of the CTO is discussed and then compared in order to identify differences. Based on the transcripts of the interviews, possible reasons for these variations are explored. Also, the depiction of each configuration suggests a method to predict patterns of CTO/Context configurations.

7.2.1 Transition to an open innovation model

In Figure 30 the CTO/Context configuration shows that Interviewee No.1 is emphasising attention to Technology Management Infrastructure (i.e. the Organisational Structure, the Supplier Infrastructure and the Systems and Processes), as well as Operational Improvement (i.e. Learning, Collaboration and Innovation). There is relatively less emphasis on attention to People Management and Technology Entry/Exit Points.

In isolation, this configuration helps to raise the awareness of the CTO to his/her current focus, and provides the basis for staff incentives, development and recruitment. However, the configuration is also explained because the broader context of the business is taken into account. In this case, the business is a large, mature, industrial business with a limited product portfolio that is slow to change. The customer base is conservative and sales lead times are long. The business is functionally structured with relatively powerful business unit heads. There are significant barriers to entry for new competitors. All of these aspects have been detailed in the process of coding the interview against the elements and sub-elements of the CTO/Context Framework.

Because of the integrated nature of the framework, it is possible to speculate as to the appropriate technology management priorities. The CTO in this type of business is essentially prioritising activities that are typical of a relatively steady state technology context.

If a more strategic perspective is adopted, the CTO may question whether there is enough emphasis on People Management and Technology Entry/Exit Points. The lack of emphasis in these areas may signal a lack of flexibility and vulnerability to technology disruptions. The interview data suggests that this particular CTO is unlikely to be faced with alterations in the rate of change in the technology portfolio.

However, the CTO acknowledged the mounting challenge of a lack of growth in revenues and margins in the business more widely. The Technology Business Model and Strategy is a relatively high priority for this reason. In particular, the technology leadership is shifting towards a more open model for technology research, and higher levels of customer collaboration in development.

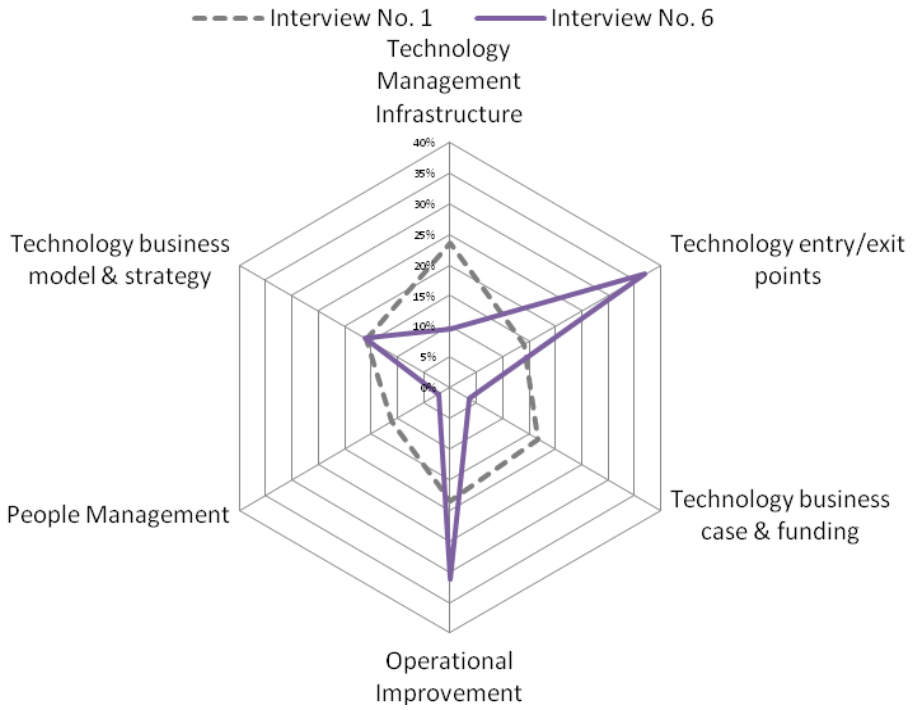


Figure 30: Interview No. 1 and No. 6

This emphasis does cause the CTO to reflect carefully on the right approach, as demonstrated by this comment on open innovation, " … you need to understand for what technology in the market areas which ones are the right tools. And I think some people today extend that, if all you've got is a hammer then anything looks like a nail. So open innovation has become that hammer on some occasions. I've really been part of some sessions where I would say they were ridiculous. At the same time, we've had some long-standing long before any trend

relations that, today, would absolutely summarise under open innovation and they've served us and our customers really well." [Interviewee 1]

The profile of Interviewee No.1 can be contrasted with Interviewee No. 6. This is also a large, mature, industrial business but operating in a very dynamic market with a highly changeable technology portfolio. This business already operates a highly open environment for research and is already highly collaborative with regard to co-development with customers.

What might interest Interviewee No.1 about the configuration of Interviewee No.6 is that in the open innovation model for technology, a higher emphasis is placed on Technology Entry/Exit Points and significantly less on People Management, Management Infrastructure, and the Technology Business Case and Funding.

To further demonstrate the potential utility of the framework, it may be useful to compare two businesses with similar technology portfolios (in terms of how hi-tech / low-tech and the rate of renewal) - particularly where one operated an open innovation model and the other did not. Nevertheless, this comparison does demonstrate how the technology leadership of a business can review a current configuration and speculate as to what it may need to look like, post a transition to an open innovation model.

7.2.2 Transition to innovation-led growth driven by the CEO

The following comparison is made between two businesses in the same industry. While they have similar technology portfolios to Interviewee No.1, these configurations show the perspectives of two Innovation Directors (i.e. not CTOs per se).

Except for the differences in emphasis on People Management the profiles appear to be very similar (See Figure 31). This is partly explained by the fact that under the instigation of the CEO, Interviewee No. 10 had launched a large campaign—with the help of a group of big five consultants—to ignite the innovation agenda in the business. This process had not had the desired effect, and the resulting confusion had drawn the Innovation Director into a much higher focus on people issues.

While there is no intention to claim any undue level of accuracy regarding the coverage percentages used, it may be worth noting that the percentages against each dimension in the framework add up to 100%.

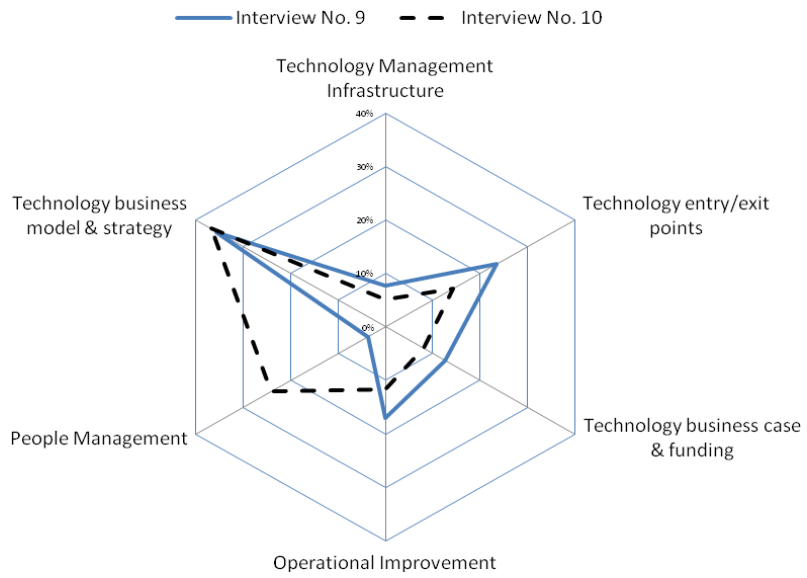


Figure 31: Interview 9 and 10

Therefore, in Figure 31, if the data for People Management is excluded or averaged, the profiles are likely to be even more similar.

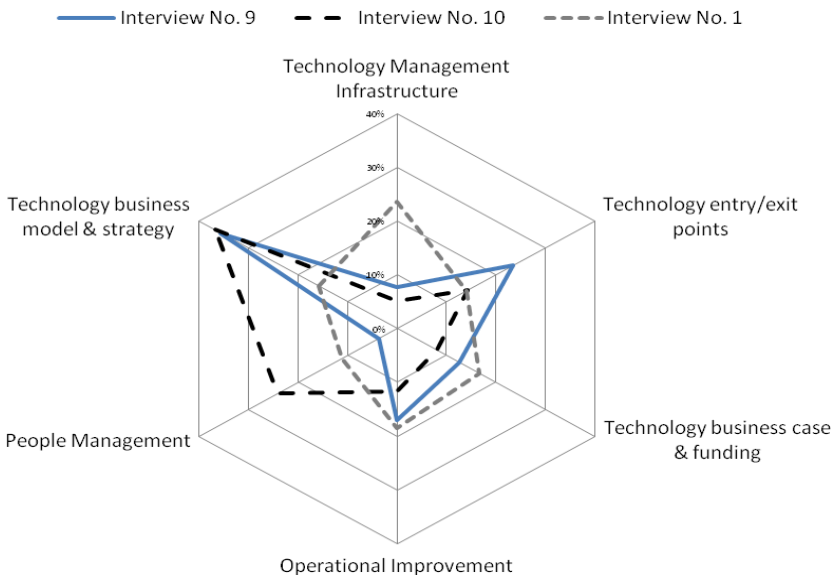


Figure 32: Interview 1, 9 and 10

When these configurations are contrasted with Interviewee No.1 (see Figure 32), that CTO would be able to visualise the differences in emphasis when the technology leader is focused on innovation. Also, the CTO may note the difference between an internal innovation model and an open innovation model.

7.2.3 Transition between service and product innovation

A variation on the Innovation Director view is provided by a comparison with a business that is more focused on service (in this case banking services). Interview No. 2 is compared with Interview No. 10 in Figure 33. Again, there is similarity in most dimensions, except that where The Technology Business Model & Strategy is emphasised in Interview No. 10, Technology Infrastructure is more of an emphasis in Interview No.2. The business context depicted by Interview No. 2 has many of the characteristics of the industrial businesses – large, mature, and slow to change.

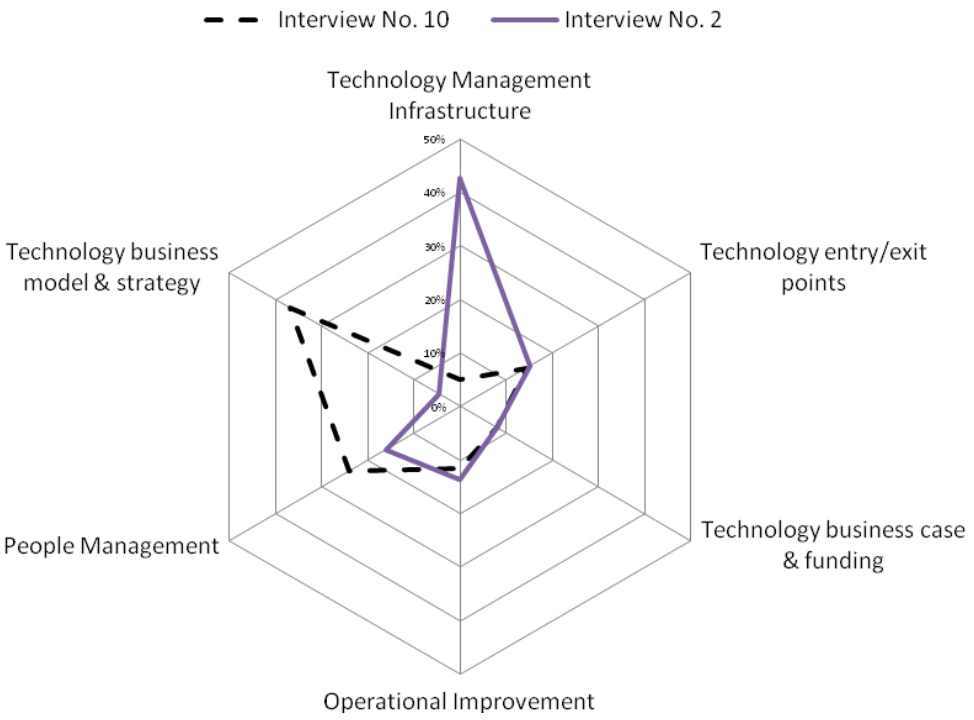


Figure 33: Interview 2 and 10

The contrast may be explained by the fact that the Innovation Director in Interview No. 10 had decided that because the business was incentivised to improve incrementally, a significant culture shift was required. His view was that the CEO and the Board needed to revise the strategic goals and related incentives to help the business break away from a "production efficiency culture". His contention was that new sources of growth were critical because production efficiencies across the industry had reached very high levels.

The emphasis on Technology Business Model & Strategy also reflected the fact that the industry had purchased more and more efficient production plant over time. The industry-wide race to minimum possible unit cost of production had run its course, and the industry now faced a surplus of capacity. As a result there was a need to transition from a focus on manufacturing innovation to product and service innovation.

However, product and service innovation is unfamiliar territory in the business and business units are not structured or incentivised to take risks in these alternative innovation dimensions. This was not an isolated concern, as demonstrated by a statement from Interviewee 11, " … The business was built to deliver a commodity product more efficiently. Be the lowest cost producer."

By contrast, in the services business, the strategy was clear and the focus was on implementation. The emphasis on Technology Management Infrastructure is unsurprising because implementation required a review of processes and systems to improve throughput for innovation. A lot of time was spent making sure that the members of the innovation team were capable of interfacing and influencing / supporting business unit members in the innovation process.

" … Because as my job as head of team I have to understand each of the SBUs, their structures and their cultures and the people that run those SBUs which then enables me to go out and find the right person that I think will be able to engage further trust and respect and deliver for those particular SBUs. And they are very different so you've got a mix of markets, a mix of cultures, a mix of [product name], a mix of acquiring, a mix of consumer commercial... And then within that I have to try and create the agility and flexibility within the team." [Interviewee 2]

The culture was still an issue, but much less so because innovation was clearly signposted in the strategy.

7.2.4 Transition of technology business model

In Figure 34, Interview No. 3 is in a hi-tech start up business that was included in the data set for comparison with the larger more mature businesses. This business had a limited technology portfolio (single product) and was still being run by the original inventors.

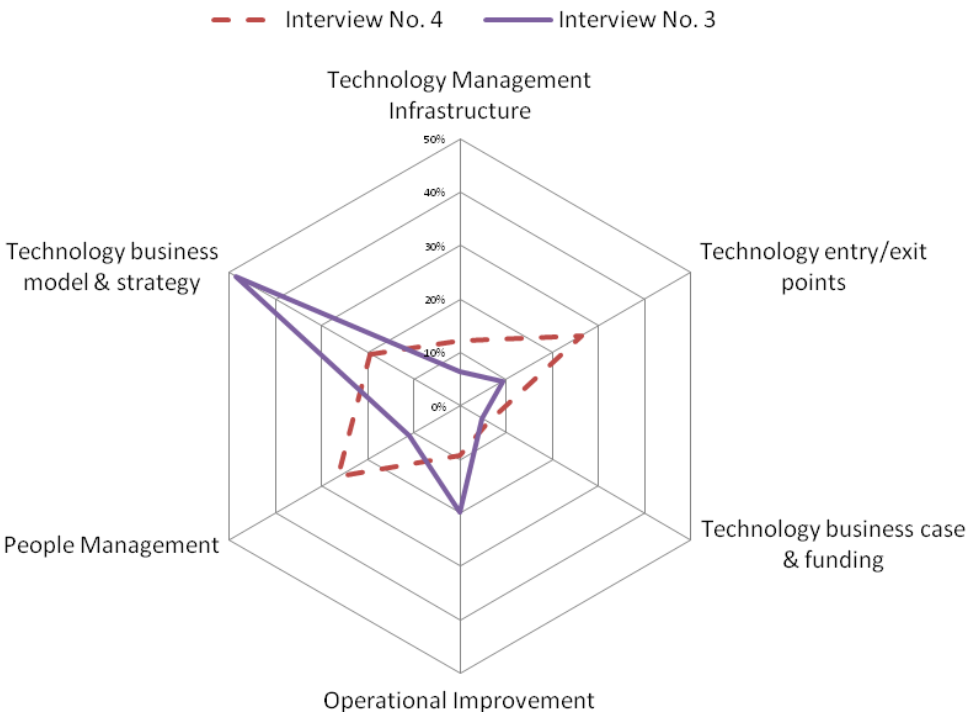


Figure 34: Interviews 3 and 4

The CTO had been brought in to help move the key product from a prototype to "scale production". This particular CTO had previously worked in a large consumer electronics business. The business was funded by venture capitalists and founder equity, and since the entire business revolved around the technology, the Technology Business Case was already obvious (hence low emphasis).

However, the Technology Business Model was very much on the minds of the Board and the CTO. This business was in the process of trying to decide whether to partner with a bigger player, or whether to attempt to access the market directly. Also, they were debating whether to scale up or licence the technology to a number of businesses with existing marketing and

production capabilities. At risk in this case was the possibility that competitors would work around the technology patent and then sideline the inventors. Smaller firms have the problem that they don't have the financial asset base or cash flow to contest patents in court. So, once again the emphasis on the Technology Business Model is understandable.

By contrast, Interview No. 4 is in a business that is the result of a debt financed management buyout (MBO) from a large industrial business in the defence industry. In this instance the new owners inherited watertight patents and had experience of the whole process from R&D to production. Also, the senior technology executive was the Engineering Director. His focus was on working out how to shift the capabilities of the business away from a legacy portfolio of technologies.

He talked about the portfolio as being "state of the ark" and suggested that this was due to two reasons. The first was that their customers had highly bureaucratic procurement procedures (military) and that it was easier for the procurement staff to order items that were preapproved for purchase. The second was that most of the technology staff in the business had been in the business for a long time (average tenure in excess of 12 years). His view was that this caused them to stick with what they knew and create "work-arounds" when customer issues / problems were raised, rather than explore new technology options. This would partly explain the emphasis on People and also Technology Entry/Exit Points.

7.2.5 Patterns of CTO/Context configurations

In Section 7.2 a total of 7 interviews are compared in different combinations. The visual depictions of each CTO/Context configuration are representative of the CTO's goal and priorities at a particular point in time (i.e. a static view). Comparing the configurations of different interviewees demonstrates a method by which further research (using the CTO/Context Framework) might find patterns of configurations. This is discussed further in Chapter 9.

The patterns of configurations would be of particular interest if they could be related to changes that occur over time (i.e. a dynamic view). In Section 7.3 a start is made on this perspective by looking at the typical types of change that are evident from this research.

7.3 Technology transition points

The literature in Chapter 2 and 3, and the interview data, provide typical examples of random and planned change events that can be categorised into a number of 'transition types'[18]. These are set out in Table 44 with examples that are associated with each type. The catalyst for these transitions could be internal or external.

Table 44: Typical transition points

	Transition Type	Transition Examples
1	Change in ownership	New shareholder, management buy-out, acquisition or merger.
2	Change in leadership	New CEO, switch from technology committee arrangement to CTO, new strategy.
3	Change in competitive context	Competitor entry / exit, regulator intervention, market entry/exit (and regional entry/exit).
4	Change in economic context	Boom / bust, credit crisis, trade tariffs.
5	Change in governance	Re-structure (centralise / de-centralise), JV or alliance, shift to open innovation format.
6	Change in customer / supplier context	Co-development, vertical integration, procurement rules, relative supply and demand, global/local sourcing, CROs.
7	Change in technology context	Disruptive attack or discovery, patent secured / lost, change in focus of innovation dimensions (product to production or vice versa), development speed v cost.
8	Change in management tools	Six sigma, open innovation format, CAD.

Internal transitions (planned change events) are those that are initiated or invoked deliberately by the organisation. These may be in response to the need to raise capital (e.g. a change in ownership), or in order to enter a new market. The key for internal transitions is that they are initiated by the organisation, and so the expectation is that the CTO can plan the change (or plan for the change). External transitions (random change events) would be those that are not controlled by the organisation. These include changes in regulation and market entry by a competitor. The difference for the CTO is the need to react to the transition that is imposed.

[18] The process used to gather and categorise this data is described in Chapter 5.

For example, priorities may shift over time because of cyclical behaviours in the organisation. In Figure 35 this type of transition may be represented by points 2 and 5 – where (hypothetically) a new CEO's priorities for a de-centralized technology function (say at point 2) are the extreme opposite to priorities for a completely centralised technology function (say at point 5).

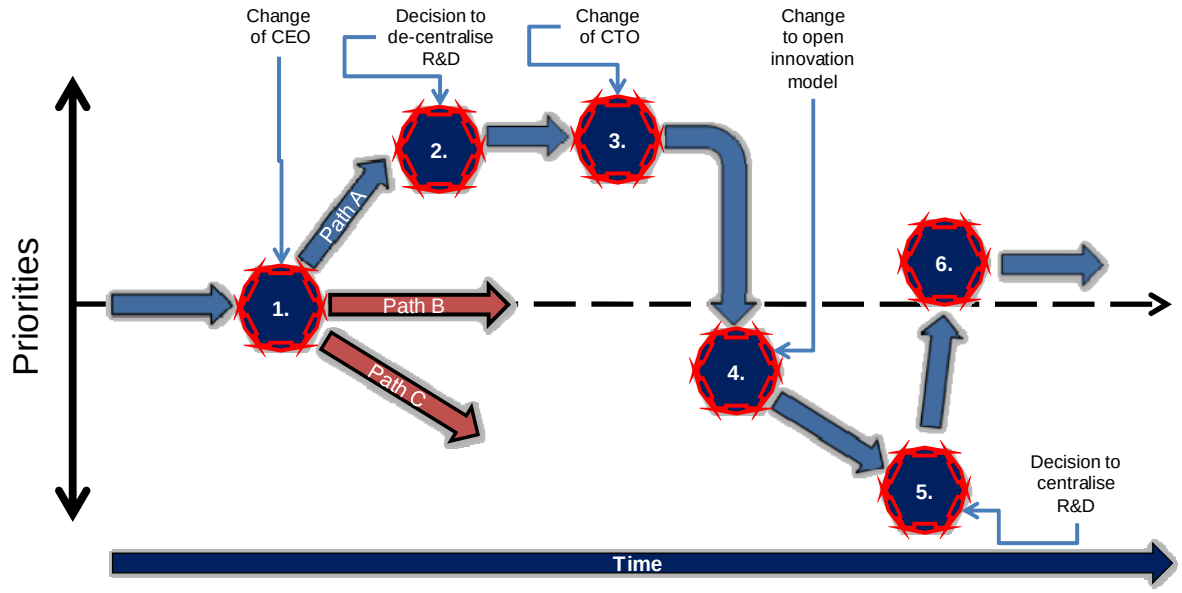


Figure 35: Hypothetical series of transition points and priority changes

As noted by Interviewee 7 the priorities may shift backwards and forwards between these two extremes. " … I've been with the company and its predecessor companies for thirty-five years or so and its model has moved backwards and forward from being centrally driven to autonomous units, to central."

There is no evidence to suggest that these transitions happen discretely. It seems more likely that when transitions occur a number of change types are invoked simultaneously. An example of this from the interview data is a business that was bought out (change type = change of ownership) and where the new shareholders wanted to shift to an open innovation model (change type = change in governance). These changes were precipitated by a credit crunch (change type = change in economic context). See point 3 in Figure 36.

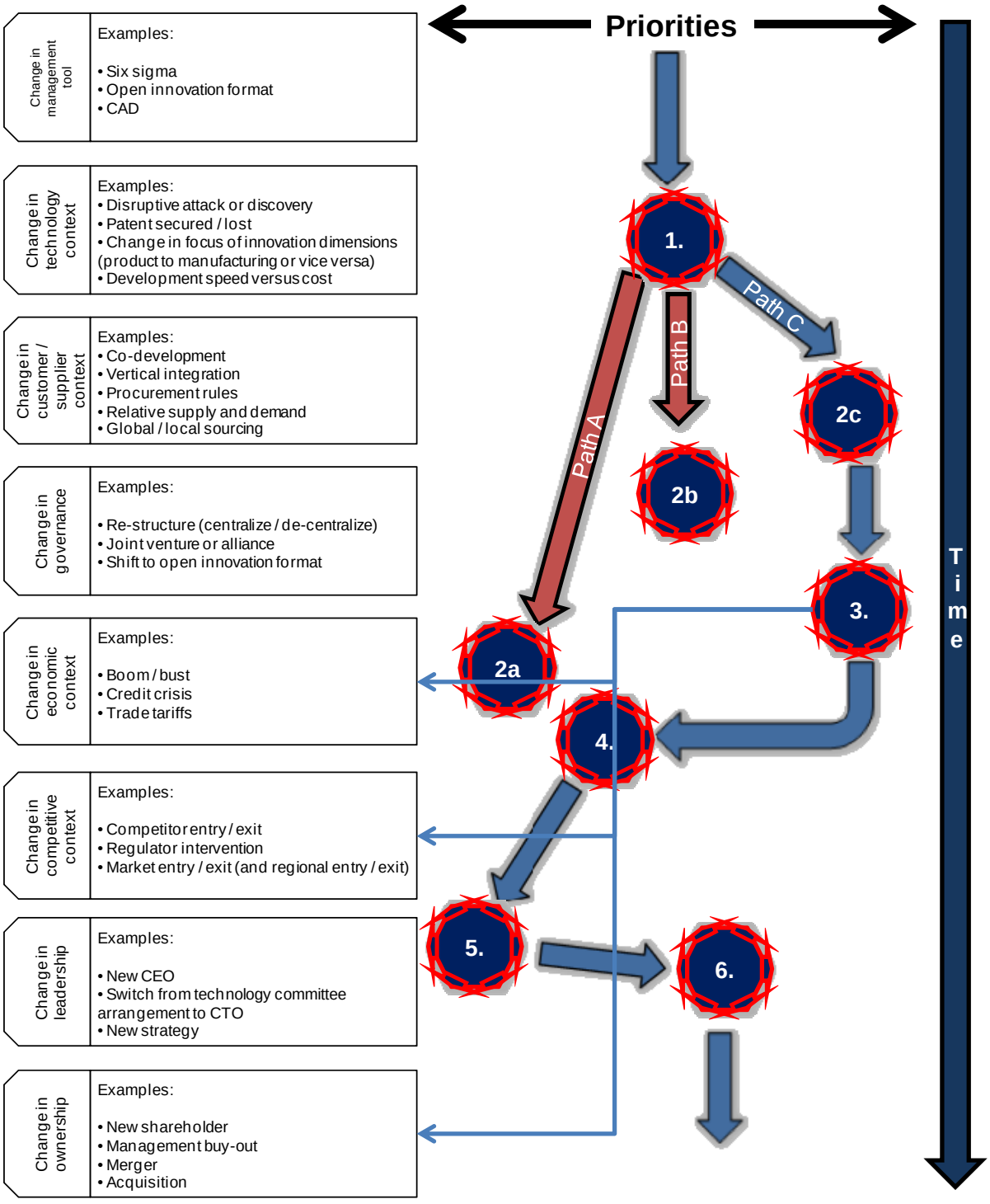


Figure 36: Example of multiple change types related to a transition point

Another example may occur at a transition that is precipitated by a change in customer needs. The CTO's response to this would be to reassign or remove technology assets that no longer match, or introduce assets that have become a requirement. One interviewee talks about

'shaping' the technology capabilities, " … And shaping means to make sure that in the longer term we do have a proper match between our competencies and the requirements of our customers." [Interviewee 6]

The comment from Interviewee 6 does not reveal whether the 'customer' in question is an internal customer (i.e. employed in the same organisation) or external. However, certain CTOs do very much recognise the distinction, " … And they often will have a portfolio of internal and external customers needing slightly different things …" [Interviewee 3] Where the CTO has to deal with internal customers, there are additional considerations of the relationship between the technology team and these internal customers.

An example of the way in which technology transitions points are introduced is reflected in the views of two particular interviewees. The first talks about the recruitment motives of the CTO if change is to be feasible. That is, the ability of the technology team to engage with functional staff (the internal customer). The second, relates to the 'absorptive capacity' (Phelps et al., 2007) of the functional staff. 'Absorptive capacity' is the ability and inclination of the internal customer to take on change.

In the example of the abilities of the technology team to engage with functional staff, the CTO talks about the required 'trust and respect' needed for the relationships with Strategic Business Units (SBUs) to work. The challenge (the focus of attention) is to recognise the variety of technology team member skills needed, and the attitude required of the team when they interact with a constantly changing context. Interviewee 2 puts this as follows: " … able to engage further trust and respect and deliver for those particular SBUs. And they are very different so you've got a mix of markets, a mix of cultures, a mix of [product name], a mix of acquiring, a mix of consumer commercial… And then within that I have to try and create the agility and flexibility within the team."

In some instances, the priorities may be a matter of choice (for example as part of a deliberate strategy). This is represented in Figure 36 by point 1 which has a number of possible paths (A, B or C) that the CTO would deliberately consider. However, as is noted by this quote, culture is a significant part of the priority selection process. " … If you're looking at something new, by definition it is riskier. And you can say that in big organisations people survive who don't make big mistakes. If you're an innovator you might make a big mistake. It's a high profile mistake and you perish why bother taking that risk? Do a little bit better than everybody else you get promoted. Drop a clanger - you don't. There has to be a

portfolio attitude, I would suggest, to innovation, because some will work, some won't." [Interviewee 11]

Interviewee 11 refers to the structural setup of the organisation, which is essentially functional. The technology team have great difficulty introducing transitions because the functional staff are incentivised and 'performance managed' in a way that focuses them on their existing operations. More importantly, the interviewee felt that this dis-incentivised staff from pursuing novel approaches. In other words they lack the 'absorptive capacity' – the ability and inclination to take on the transitions being driven by the CTO.

Planning to deal with a 'technology transition point' can be handled via a longer term strategy to build the internal infrastructure that helps functional staff to take on change. An example is a CTO talking to heads of business units as 'owners' of seconded business resources: " … I guess it was talking to the owners of the individuals [seconded to R&D] to make sure that they still remember they own them, and I was quite diligent, from the personal development reviews of the individual, in making sure that there was a significant input from me into their functional personal development reviews and objectives that they had." [Interviewee 7] In this instance, the CTO emphasises the autonomy of the business unit 'owner', but has a technology team member seconded from within the BU.

Finally, Section 7.2 demonstrated that the CTO/Context Framework can be used to depict certain steady state configurations in the CTO/Context. This section links these configurations to various types of change. The CTO/Context framework requires the CTO to 'attend' to 'technology transition points' in order to achieve specific 'goals'. This is a platform for the creation of a dynamic model for the role of the CTO.

7.4 A model for the role of the CTO

The combination model links the relationship between the 'technology transition points' and the CTO/Context Framework. So, for this purpose, the model is described as the 'technology management compass'. The compass metaphor is useful because it alludes to changes over time and the need to shift technology management priorities.

If the 'compass' metaphor is used, it is appropriate to speak about the 6 points on the compass (these are numbered 1 – 6 in Figure 37). The compass points are each defined in a way that sets out what the CTO is 'attending to' and the 'goal' of that attention. In

combination with an awareness of the 'technology transition points', this model for the CTO role becomes 'dynamic'.

1. Technology management infrastructure

✓ CTO attending to the need to review and replace systems, processes, policies, governance and organisational structures.

✓ To secure appropriate, accurate and timely information and decisions.

2. Technology entry/exit points

✓ CTO attending to technological shifts and changes in customer needs.

✓ To ensure the alignment of technology capabilities with market opportunities.

3. Technology business case and funding

✓ CTO attending to changes in the technology business case.

✓ To balance the technology contribution to volume, profit, leverage and sustainability. In order to motivate external investors and secure internal budget.

4. Operational improvement

✓ CTO attending to the need to create and sustain learning, collaboration and change.

✓ To ensure appropriate technology scope and eliminate errors and efficiency gaps.

5. People management

✓ CTO attending to changes in the technological capabilities requirement.

✓ To refresh skills, attitudes and the working context.

6. Technology business model & strategy

✓ CTO attending to shifts in organisational strategic priorities.

✓ To provide clarity to CEO, the board and organisation regarding technology value, focus, role and remit. To ensure engagement and support.

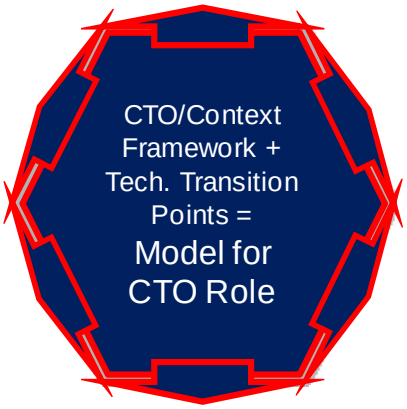


Figure 37: The Technology Management Compass

The 'Technology Management Compass' thus combines the idea of the CTO/Context Framework derived in Chapter 6 with the 'Technology transition Points' discussed in Section 7.3. Taken together these are proposed as a 'model' for the role of the CTO.

7.5 Summary

This chapter extends the idea of the 'static' CTO/Context Framework by taking account of the way in which CTOs would create or react to 'Technology Transition Points'. There are a number of types of change that frame the emphasis of the CTO – that is, the technology management priorities at these transition points. These priorities vary depending on the type of transition being encountered or initiated by the CTO.

Section 7.2 shows the outcome of a process to visualise the differences in emphasis between sample interviews that are coded against the elements of the CTO/Context Framework. The resulting measures of 'coverage' are mapped onto spider diagrams and the contrasts between CTOs are discussed. The types of transition visualised—to further demonstrate the approach—includes a shift to open innovation, a shift to innovation-led growth by the CEO, a shift from production to service innovation, and a change in technology business model.

This ability to visualise the emphasis of the CTO, raises the possibility of testing whether certain CTO/Context configurations are typical for a given technology transition point. While the technique used in this chapter relies on 'coverage' as a proxy for 'emphasis', it cannot reliably be used as a proxy for 'importance' (and thus to emphatically prescribe the technology management priorities). Nevertheless, it does provide a comprehensive platform for planning and further research. A suitable approach to testing is discussed in Chapter 9.

8 Implications for Practice

8.1 Introduction

In seventeen of the CTO interviews[19] it was possible to ask the interviewees to consider the 'implications for practice' (that is, implications revealed by their 'personal role map'). This approach was taken for two reasons. The first is that understanding implications for practice was a specific research objective. The second was that asking interviewees to interpret their own maps avoided over-reliance on third-party interpretations of the map in the first instance (thus reducing researcher bias).

However, this chapter also looks beyond the immediate interpretations of the interviewees. This is because the research data highlights a gap between the perceptions of interviewees regarding purpose, barriers and enablers (on the one hand), and their stated 'implications' (on the other hand). In Section 8.2 the different categories of implications that emerged are explained in order to enable a third party interpretation of the maps.

This explanation is followed in Section 8.3 by a discussion about the perception gaps made visible by anomalies between the declared 'implications for practice' from the interviewees, and the implied implications from the derived CTO/Context Framework.

Section 8.4 shows the results of coding the 'implications' to the 6 main elements of the CTO/Context Framework. The section explores both explicitly stated as well as unrevealed implications based on interviewee responses. The unrevealed implications are those that are either withheld or not contemplated by the interviewees. The chapter is summarised in Section 8.5.

Table 45 sets out the definitions of a number of terms used specifically for this part of the research.

[19] In other interviews time constraints meant that the interviewee did not reach this stage.

Table 45: Terminology used in this chapter

Term	Use
CTO remit:	The remit is the scope of work that is to be executed. This scope may be authorised via the governance arrangements in the business. The CTO remit is the scope of work that the CTO would expect to be measured against. This may be a formal brief within an employment or performance contract and/or job description, and may include a delegation of authority related to capital and operational expenditure and tenure and value of contracts. The remit describes the boundaries of the work being performed or may be the self-imposed limits of the scope of the CTO role.
Technology remit:	This is the scope of work that the technology team are measured against. This scope matches technology capabilities and market opportunities. The technology remit may exclude certain market opportunities on the basis that the leadership of the business has deliberately decided not to pursue certain prospects. Also, the scope may include certain opportunities for which the business currently does not have the capability, but for which there is a leadership ambition to pursue the prospects. This may be captured in technology roadmaps and the technology and business strategy. The degree to which the business moves between a top-down vision/business strategy/ technology strategy/CTO role context and a more random / opportunistic and emergent strategy, will affect the rate of change of the remit.
Technology team	This is the group of individuals who define and /or carry out the technology remit. This may include the CTO and technology staff reporting directly or indirectly to the CTO.
Technology entry points:	These occur where there is an opportunity (i.e. the market values what is offered), but the business does not currently have the capability to deliver on the opportunity. The mismatch is dealt with by actively seeking new technology capability in the form of people, patents, facilities, technologies and processes (e.g. via acquisition, open business models, recruitment and re-training).
Technology exit points:	These occur when either the market no longer values offerings that are based on current technology capabilities in the business, or the leadership elect not to pursue prospects that are valued. Either way, a component of the technology portfolio is made redundant. This means that people, patents, processes, facilities and technologies will exit the business (e.g. via asset sales, mothballing and/or job losses).
Technology capabilities:	These are people, patents, processes, technologies and facilities that underpin value creation for the customer. At any point in time this includes capabilities that were valuable historically, are currently valuable, or have the potential to be valuable in the future. These capabilities are the sources of technology value for the business.
Market opportunities:	These are prospects that customers value. They may result from accessing new geographical regions, novel combinations of existing technologies, emergence or convergence of technologies, changes in regulation / competition / customer need / and supplier or partner offerings.
Technology performance gap:	This gap occurs where there is a measurable difference between what is required from technology and what is achieved. This may take the form of a lack of functionality or reduced functionality, as benchmarked against customer need (i.e. what the customer is attempting to achieve). The performance gap may also occur when regulatory compliance is not achieved, when a patent lapses or is made redundant, or when an industry standard is superseded.

Term	Use
Technology strategy:	The means by which technology capabilities are identified, acquired, and configured to take advantage of market opportunities envisaged in the business strategy. This takes account of the customer, non-customer and blue-sky needs that technology addresses.
Technology portfolio:	A portfolio is a selected mix of technology initiatives directed by the technology strategy and deploying people, patents, processes, and technologies.
Current customers:	Current customers are organisations or individuals who represent opportunities for the business and engage with the business on an ongoing basis. These customers are served by current products or services, and may provide feedback for enhancements to these products and services.
Current non-customers:	These are customers who are not currently able to place a value on what the business has to offer. These customers would value the offerings of the business, either in the current form, or in a re-configured form, if they were identified and engaged by the business.
Future customers:	These are potential customers who may be served by products and services that do not currently exist. These customers may or may not be aware of available technology or their needs and could thus not help by providing feedback or co-developing a future offering.
Internal customers:	These are individuals or groups employed directly by the business, who value the management and/or products and services outputs generated by the technology team. They may be end-users of technology outputs, or representatives of external customers (e.g. sales and marketing departments).
External customers:	These are individuals or groups who value the products and services offered by the business. In any transaction they constitute a separate legal entity from a contractual point of view.

8.2 Implication categories

The interview process built up a view of the role of the interviewee. Interviewees first looked at their core purpose and then at barriers or enablers to that purpose. Once these barriers and enablers were identified, the reasons they occur (i.e. the causes of the barriers or enablers) were mapped out. The penultimate step was to map management actions against each cause of the barriers (i.e. actions to mitigate) and each reason an enabler occurs (e.g. actions to nurture these enablers).

Finally, interviewees were asked to reflect on their completed map and declare implications that emerged. The resulting data suggests a number of categories of 'implications for practice'. The implications are broadly located in four domains (refer also to Figure 38):

1. Implications that are current and revealed by the mapping process: These are current in that they require immediate attention, but also that they impact in the short-term. The fact that they are 'revealed' is recognition that the implications have been surfaced by the mapping

process. Implications in this category may be novel (i.e. the revealed implication had not previously been consciously envisaged). Alternatively, implications were previously envisaged, and interviewees were then prompted by the process to renew a commitment or to reemphasise an element of their remit and role.

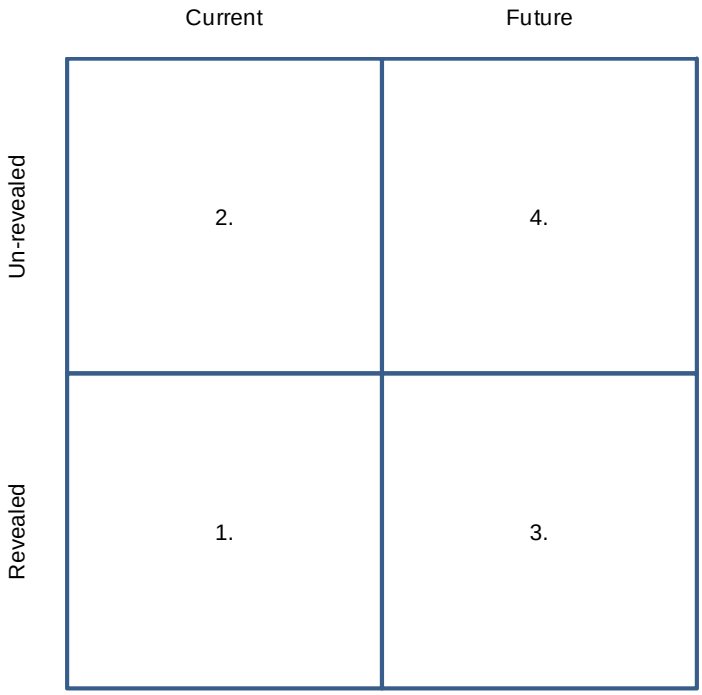


Figure 38: Implication categories matrix

2. Implications that are current and un-revealed: These are implications that require immediate attention, but did not come to light explicitly as part of the discussion regarding implications (hence, 'un-revealed'). Of course for reasons of confidentiality (or possibly not wanting to openly declare a personal oversight), implications may have been revealed to interviewees but withheld in the interview. However, whether or not related implications were withheld or not contemplated, implications may be implicit (and thus inadvertently revealed) in interviewees' revelations regarding purpose, barriers and enablers. This gap demonstrates the value of the cognitive mapping process and provides opportunities to suggest previously tacit implications.

3. Future implications that are revealed: These occur where the interviewee notes an aspect of their role as revealed by the interview process. These implications may require immediate attention, but have longer term impacts.

4. Future implications that are not revealed: These are implications that the interviewees did not reveal. This is either because they did not want to reveal them, or did not contemplate them. The impact of not contemplating these implications, and thus not attending to them, would become evident in the future.

8.3 Implications and the CTO/Context Framework

The CTO/Context Framework developed in this research is derived exclusively from declared barriers and enablers to the purpose stated by each interviewee. The derivation does not include the stated implications for practice taken from the interviewees. However, considering the relationship between the stated implications and stated barriers/enablers used to derive the framework does reveal gaps. In Figure 39 these gaps are referred to as perception gap 1 and perception gap 2.

Perception gap 1 - occurs when interviewees have declared certain barriers and enablers, and then either withhold or cannot conceive of related implications. As noted previously, withholding an implication may occur because the mapping has surfaced something that the interviewees would rather not reveal in the interview. An example would be where the implication is confidential to the business, or where the interviewees' revelations highlight previously flawed thinking (oversights or incorrect perceptions).

On the other hand, the inability to perceive related implications, highlights the value of the CTO/Context Framework. The scope of the framework is sufficiently broad to act as a proxy for wider benchmarks of technology management practice. In other words, users of the framework could work through the elements and sub-elements of the framework and in so doing catalyse implications that they might not otherwise contemplate. A complete failure of individual imagination or vision is still possible and prompts the notion that the framework would be most robust when used with peer inputs.

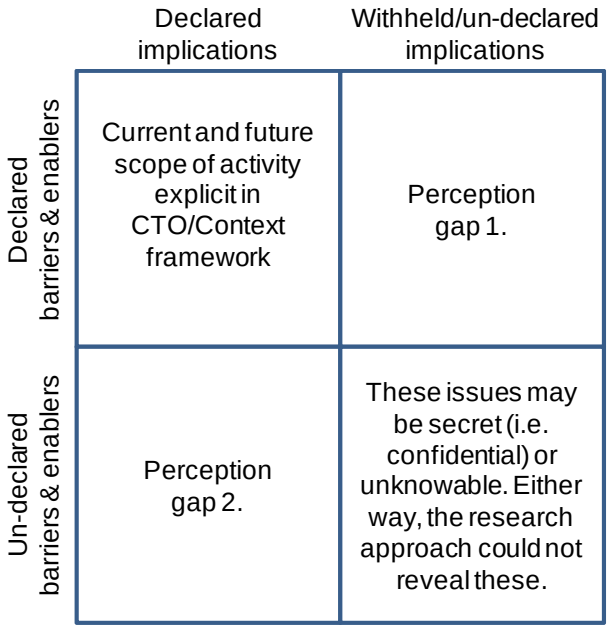


Figure 39: Perception gaps matrix

Perception gap 2 - occurs where for some reason the interviewees reflect on their role mapping and declare implications that do not appear to be related to barriers and enablers that they have noted. Since the CTO/Context Framework is derived from the barriers and enablers noted and captured during the interviews, this perception gap suggests a lack of direct cause and effect. This means that these implications appear to have nothing to do with the actual role map created.

However, there are two further considerations in this regard. The first is that the role maps include causes of barriers and enablers, and related management actions. When interviewees reflect on their maps, they may note that they are taking the wrong action; putting too little emphasis on certain actions; or that they are not taking action at all. Secondly, where conscious implications are surfaced that do not explicitly relate back to the role mapping, these can be used to test the CTO/Context Framework. The implications should be capable of being mapped back onto the framework. Where this is not possible, this would suggest that the framework needs further development.

In Figure 39 at the intersection of un-revealed implications and undeclared barriers/enablers, implications are either withheld by the interviewee or unknown to them for some reason. In the interim, the anecdotal literature and intuitive speculation by researchers and

commentators may supplement the data. However, these speculations fall outside of any attempts at grounded formulations.

Future research techniques may reduce the scope of what is currently considered to be 'unknown', and alternative research strategies may reduce the elements of interviewee self-censorship. In the following section, the intersection between the declared barriers/enablers (as formulated in the CTO/Context Framework) and the revealed implications, is explored.

8.4 Implications mapped to the CTO/Context Framework

When revealed implications are mapped against the elements and sub-elements of the CTO/Context Framework, the absence of one or more implications within a sub-element raises a question about meaning. For example – in all the interviews where implications were raised, only one interviewee had an 'implication' related to the "market and competition". This is so, even though the sub-element ("market and competition") was derived from the interviewees' noted barriers and enablers that were coded to the sub-element.

In this research there is no way of knowing whether this is because the interviewees felt they already managed market and competitive matters sufficiently well, or whether there is some other reason that this sub-element does not feature in their implications.

In the interviews where 'implications for practice' were explicitly explored, the bulk of the responses related to – 1st: Technology business model & strategy (33%), and then 2nd: People management (25%). The overall 'spread' of implications is represented as a proportion across the CTO/Context Framework elements in Figure 40.

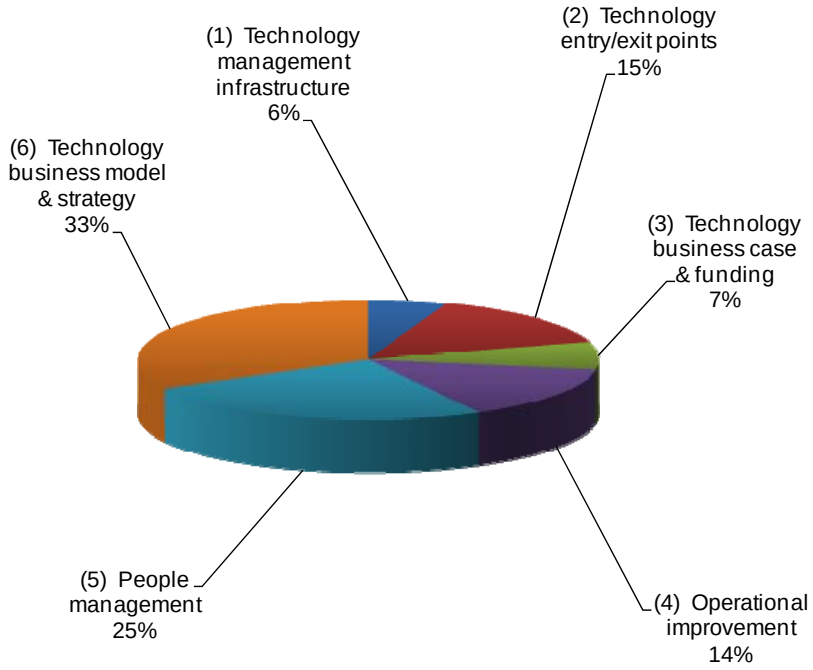


Figure 40: Spread of implications across elements (based on word count)

Given the crudeness of word count as a measure of emphasis, it is necessary to look at the actual responses in more detail. What follows is a consideration of the exemplary quotations[20] (Plowman et al., 2007) that emerged from the interviews. These are considered in relation to each of the six elements on the CTO/Context Framework:

Technology management infrastructure	(1)
Technology entry/exit points	(2)
Technology business case & funding	(3)
Operational improvement	(4)
People management	(5)
Technology business model & strategy	(6)

[20] Note: Unless the revealed 'implications' repeat or do not reveal new ideas, they are generally included in the tables that follow. In some cases, implications that repeat are included to demonstrate the degree to which these were emphasised by different CTOs.

Technology management infrastructure (1) is defined as, "The CTO attention to the need to review and replace systems, processes, policies, governance and organisational structures – in order to secure appropriate and timely information and decisions." The specific implications are set out in relation to the sub-elements of the CTO/Context Framework in Table 46.

Table 46: Exemplary statements for 'technology management infrastructure'

Sub-element 1	Implications stated by interviewees
Business structure	" … We need to reduce the number of sites."
	" … Set up infrastructure to capture ideas across the business – then find people to support that infrastructure."
	" … Big four consultants helped set this up for us and it failed because it became too expensive."
Supply chain structure & management	" … We have to change our supply base to achieve our goals."
	" … our suppliers 'sell us a pup' – we buy new machines but not necessarily better performance over time – actually only increase market capacity so market price drops."
Systems & processes	" … We need to get everyone to buy-in to the process."
	" … We need to build cases to show how to do this well – based on our practices."
	" … we have a very rigid project management process because we want to deliver for our customers, but we need to be agile by avoiding too much formal process and reporting."

In all, eight specific implications are noted by the interviewees regarding 'technology management infrastructure'. Relatively fewer implications were surfaced in respect of 'technology management infrastructure' than were noted for other elements of the CTO/Context Framework (see Figure 40).

However, the importance of some of these implications to the interviewees is clear from their statements. For example, only two implications are surfaced regarding 'supply chain structure and management'. In the first, the interviewee notes the need to use changes in the supplier base, " … to achieve our goals." [Interviewee 10] The interviewee's thought process can be

traced back to the cognitive mapping references that built up to this implication. The following clusters of thought contributed to surfacing the implication:

- "Capability of supply base to deliver what I need."
- "Feedback trends to supply base to support them (we can capture customer reaction)."
- " … Utilise management information and data to help supply base intervene ahead of the curve."
- "Historical model of primary supply base was a big enabler to develop innovation."
- " … gives our supply base confidence to invest in our ideas."
- "Must be delivering "flexibly" from a relatively static supply base."
- "We are questioning the role of our supply base."

These revealed constructs start with statements about barriers / enablers (e.g. "Capability of supply base ..." - noted as a 'barrier'). They then go on to mitigation / enabling actions (e.g. "Feedback trends to supply base …" - noted as a mitigating action). Finally, the various nodes on the map emerge in the form of the implication, " … We have to change our supply base to achieve our goals."

The second supply chain implication notes, " … our suppliers 'sell us a pup' – we buy new machines but not necessarily better performance over time – actually only increase market capacity so market price drops." [Interviewee 11] In this case the interviewee noted that one of the barriers to achieving his purpose was, "Comfort zones". The interviewee made the connection between this barrier and the stated implication by noting that this is a " … Business built to be lowest cost producer." The interviewee has recognized the need to encourage a shift away from innovating the manufacturing dimension. The implication is based on the realisation that the future benefits of pursuing lower cost of manufacturing are marginal.

Technology entry/exit points (2) are defined as "The CTO's attention to technological shifts and changes in customer needs; to ensure the alignment of technology capabilities and market opportunities." The stated implications are set out in relation to the sub-elements of the CTO/Context Framework in Table 47 and Table 48.

Table 47: Exemplary statements for 'technology entry/exit points'

Sub-element 2	Implications stated by interviewees
Technology portfolio	" … Use the IP portfolio for competitive positioning ... Need to patent the "applications" - NB to create barriers for competitors."
	" … CTO Life cycle - single product - then more industrialists brought in - then full factory setup."
	" … Proof of concept to product pilot to full ramp up."
	" … The sheer volume of work causes some intended actions to be compromised."
	" … Need to prioritise based on the BU shortfall."
	" … We have a lot of metrics that ensure we do the projects right and not any that really ensure that we do the right projects."
	" … We have no mechanism to reject commercial opportunities that do not fit with our current strategy."
	" … Establish portfolio approach - hopper management - mix strategy - 3 year production planning."
	" … 'Seed funding'. Unassigned funding. Spend on Innovation 'mandated'. Marketing and portfolio management."

The implications noted in Table 47 are self-explanatory. However, it is possible to summarise how the portfolio implications cover various aspects related to the technology entry/exit points. In essence, they relate to the use of metrics (e.g. to encourage project selection accuracy), to the use of process mechanisms (e.g. to incorporate project exit protocols), and policies (e.g. making 'unassigned' funding available for unforeseen prospects). The portfolio is also seen as a way to get buy-in from internal stakeholders (e.g. prioritising projects that BUs need), and a mechanism to deal with competitors (e.g. patenting 'applications' as well as designs).

Figure 41[21] shows the relationship between the technology team and the customer (see also Table 48). More broadly, the diagram shows the challenge the CTO faces when defining a technology strategy (and remit). The remit for the technology team should be the alignment of technology capabilities with outcomes that are valuable to the market. As the market changes, internal and externally accessed capabilities need to change.

[21] Reminder: Terminology used in Figures 41 to 47 is defined in Table 45.

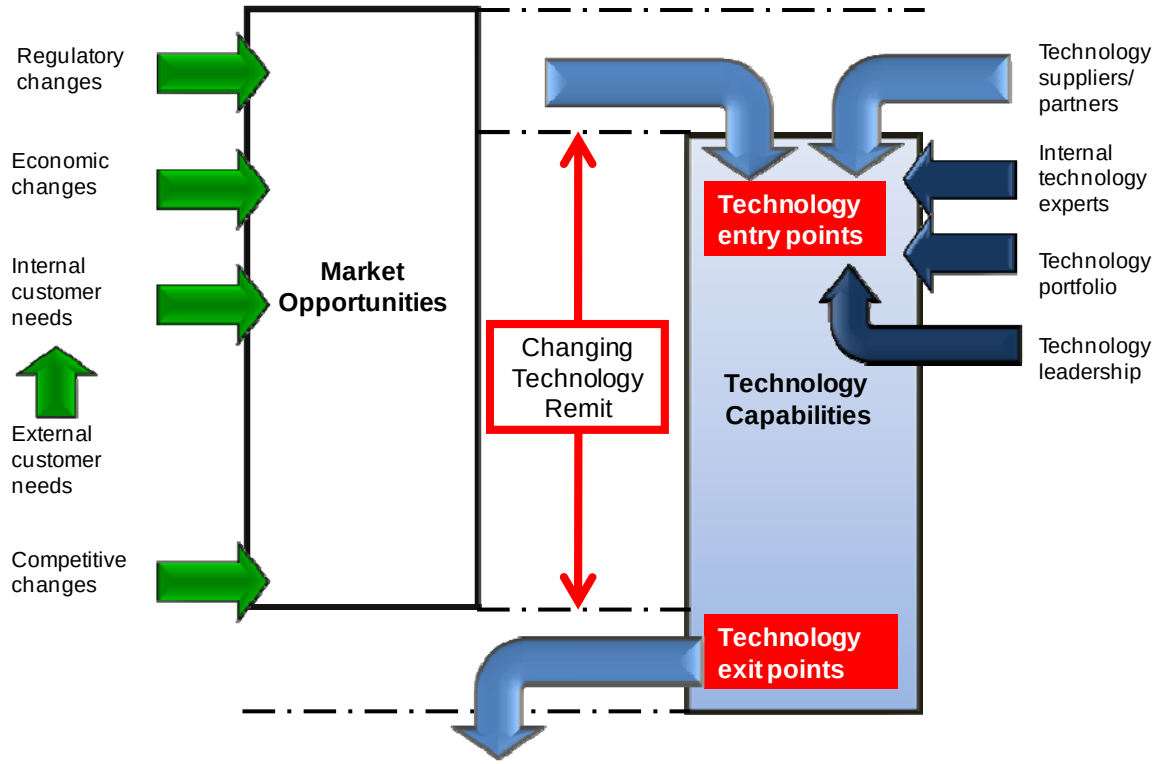


Figure 41: Technology entry/exit points

Market opportunities may change because of regulatory shifts, economic shifts, competitor moves and variations in the requirements of customers. The over-arching implication is that there are technology entry points - i.e. market driven ideas; supplier and partner driven ideas, and internal ideas that can be translated into value for the business. There are also technology capabilities that are redundant i.e. technology exit points.

These entry/exit points are particularly difficult to manage where product portfolios are fast changing. This is the case for example in consumer electronics, where a CTO has to change capabilities constantly. The following are examples of narratives from Interviewee [6]:

- "Our ability to respond to changing customer requirements is limited (Barrier)
- I do not determine the customer portfolio (Barrier causes)
- Uncertainty about whether I will get the skills I need (Barrier causes)
- Uncertainty about how long it will take to get the skills I need (Barrier causes)
- We need to be able to change skills and make certain unneeded skills redundant (Barrier causes)
- Internal tendency to find work to support existing skills (Barrier causes)"

The first bullet is a barrier, and the following bullets are the CTOs view of why this barrier occurs. In essence, these allude to the need to rapidly re-align the portfolio (and related capabilities). In the process of aligning the technology strategy and the business strategy, the CTO will need to make judgments about which technologies to pursue (technology entry/exit points). Additionally, changes to the remit may need to be rapid for a number of reasons:

- The costs of retaining redundant expertise may be high and where redeployment or retraining is not possible, these costs may accumulate and draw funds away from other initiatives.
- Where redundant staff remain in place, there is a potential morale and thus productivity impact on technology staff whose skills need to be retained.
- The prospect of gaining rapid market share and charging premium prices may hinge on entering a market ahead of a competitor.

Table 48: Exemplary statements for 'technology entry/exit points' (cont.)

Sub-element 2	Implications stated by interviewees
Technology team profile	" … I am working towards being able to act more strategically as a result of my team changes."
	" … CTO must be comfortable with moving people to "sit" within the context that is appropriate to the lifecycle of the product and the company."
	" … Nevertheless, getting the right people is still a BIG problem for us."
	" … This is important because if I am not good at engaging trust and respect from the MDs in the business, then the team and the processes ensure this."
	" … Team's soft skills more important in a matrix structure."
	" … Because I am based in the Technology Group I can mediate between product and design."
	" … Sourcing philosophy linked to perception of our capability."
The customer	" … Our brand is very strong and valued by the market."
	" … Our business is reactive in as much as we respond to a single customer demand."
	" … The CTO role is also about being a 'technology consultant' to the customer."
	" … I can present a picture of the customers business that demonstrates that we understand their issues and can suggest solutions."
	" … We are setting up "Application domain Leaders" to ensure a broader customer interface and reduce reliance on the CTO profile."
	" … Customer philosophy relating to whether to develop own differentiated technologies or to source differs."

However, changes to the technology remit may be difficult to achieve:

- Where existing arrangements bind the business legally to pursue projects, see out partnerships, fulfil purchase agreements, comply with employment contracts, await the sale of patents and continue to serve existing customers who are reliant on the existing technology portfolio;
- In industries or regions that are unionized;
- Where physical infrastructure such as laboratories need to be reconfigured;
- If the creation of new alliances (a shift to open business models) is novel and the business lacks either the expertise or the risk appetite;
- Where operational business units have budgets and incentives that encourage the status quo;
- If the CEO and the board do not have faith in the track record of technology leadership.

A further challenge for the CTO is that in some circumstances the remit is partially defined by an internal customer. For example, an internal marketing department defining their needs based on a received perception of the external customer requirements. Additionally, the CTO needs to balance the opportunities provided by the 'technology push' element of the technology portfolio and the 'market pull' element. This research revealed situations where the sales force in a business felt threatened by the introduction of new products. Also, where take-up of technology-push prospects was slow to take hold, as demonstrated by the following quote:

"It was only when we started to get [increased technological performance] from [a particular new product generation] that suddenly the [older generation product] business started to wake up to the value of [the improved performance], now that our customers are actually seeing it demonstrated in the working context." [Interviewee 12]

The tendency to stay with what is familiar is pervasive in the commentary related to the need to shift capabilities periodically. The CTO is not immune to the risk of inertia, as is highlighted by the reflection of another interviewee:

" … But looking back – and I've never done this quite before until this moment – I realise that actually there weren't very many people other than me – who felt this way. It's a real example of how your normal competitive thrust becomes embedded in the company. And you just go on and on doing the same thing if you're not careful." [Interviewee 21]

Technology business case & funding (3) is defined as, "The CTO's attention to changes in the technology business case - to balance the technology contribution to volume, profit, leverage and sustainability. In order to motivate external investors and secure internal budget." The stated implications are set out in relation to the sub-elements of the CTO/Context Framework in Table 49.

A particular challenge for CTOs is the need to balance the demand to support either profit or market share (or volume) strategies in the business. Interviewees note a tension between short-term goals (volume and profit) and longer-term sustainability goals (capability building and a technology pipeline). The relationship between these elements is depicted in Figure 42.

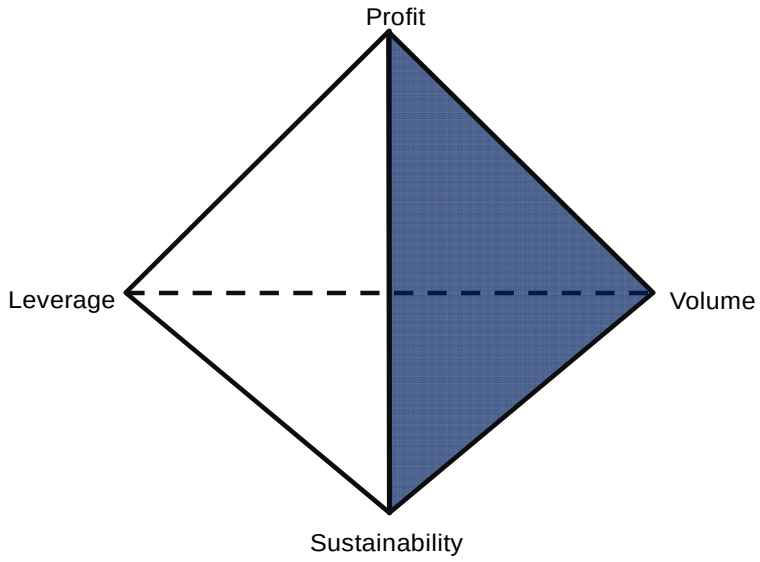


Figure 42: Technology business case trade-offs

The elements in Figure 42 are considered to be traded-offs because typically, in a competitive market, high margins are gained at the expense of market share (volume). Also, resourcing volume or profit initiatives can divert investment in capability building and the technology (and thus product) pipeline.

Table 49: Exemplary statements for 'business case and funding'

Sub-element 3	Implications stated by interviewees
Getting funding	" … By the time all the other priorities are dealt with, we are lucky if we have 10% of the change resource available for innovation."
	" … Nodes 50, 51 & 52 are all about EBITDA."
	" … I have to prioritise the time line - Innovation pipeline needs to be short because tolerance for long-term pipeline is low."
	" … 3 year time horizon in P+Ls. Ring-fenced long-term funding. Cost of innovation "priced" into the budget annually."
	" … BUT, it is not easy to divert energy in a culture where people are actively encouraged to focus on what their BU is dealing with immediate term."
	" … Could - articulate business cases for expenditure and make releases supportive to business direction."
Leveraging funding	" … Could get rapid growth if you could find a business that could be leveraged through existing businesses infrastructure."
Track record & investment	" … Must be focused on next and next generation "longer term business play" - need to play between short and long term."
	" … If there is more money around then more is spent on R&D and vice versa."
	" … Keep the business focused on generating cash rather than trying to innovate."

A further consideration that emerged from the interviews is the need to optimise budgets for R&D. When compiling the technology business case for a particular initiative, the CTO takes account of the possibility of using technologies that require relatively less investment. At an organisational level, the total capital available for investment is spread between technology needs and the needs of the rest of the business. Given the untested (risky) nature of new and emerging technologies, making the case for funding is another challenge for the CTO. This is why creating 'leverage' (stretching the value of R&D investment beyond the monetary value committed), is a useful motivator. Leverage for R&D investment may be created using an open innovation model, by acquisition, or by collaboration with university researchers who are co-sponsored by government research grants. This perspective is noted in the following quote:

"And the real problem is we were getting no external funding into this. Now [similar industry example] who have university technology centres and have been doing this for years, always boasted that for every [currency] 1 they put in they got about [currency] 4 of external money

supporting this, mainly from the research councils and things like that. And they always bragged about the gearing they got with the university relationships. And our gearing was absolutely zero, we were getting absolutely nothing at all out of this." [Interviewee 7]

Operational improvement (4) is defined as, "The CTO's attention to the need to create and sustain learning, collaboration and change - to ensure appropriate technology scope and eliminate errors and efficiency gaps." The specific implications are set out in relation to the sub-elements of the 'CTO/Context Framework' in Table 50.

Table 50: Exemplary statements for 'operational improvement'

Sub-element 4	Implications stated by interviewees
Learning	" … Actions 59-62 are about generic communications and tailoring the message to the audience on a need to know basis to buffer information flow."
	" … What about skills and knowledge transfer?"
	" … The addition of the feedback loops and the mixture of good AND bad news is a major change in the way we now run these."
	" … We tend to over-communicate - everyone is interested regardless of the relevance to them."
	" … Better intranet site for sharing skills and problems."
	" … Communications definitely crucial at so many different levels."
	" … They are now more eager to learn."
	" … Operational meetings are not structured / timetabled to efficiently use the CTOs time (I can get bored)."
	" … I don't attend the operations meetings even though the skills and equipment needs are discussed."
	" … Celebrate successes and share failure stories - learning organisations."
	" … An option to have a more "viral" approach to peer-to-peer communications (such as Face-Book) - to allow growth (community of practice)."
Collaboration	" … It is very important to partner with the right people to create symbiotic relationships."
	" … In a JV / alliance the communications become more complex (hierarchical, culture, law, etc)."
	" … We also see the benefits of speed from partnerships."
	" … Selected internal conferences for problem solving and new idea development."
	" … Need to create a platform for cross-group collaboration."

Sub-element 4	Implications stated by interviewees
Innovation	" … We need to deliver. We could do more - specifically around packaging . Need to understand that not everybody is comfortable with change. I am very comfortable with change." " … Necessary to fundamentally change the way we deliver these services." " … 'Top-down buy-in' but bottom-up resistance - therefore need to find a way to resolve this!." " … We were too technology focused - Net result is that we now do not have many entrepreneurial people who are prepared to take risks." " … I have an Innovation Success Scoring process - but we do not score the impact of innovations we did not pursue." " … To manage the innovation culture we created a separate team who solely look after forward thinking projects - no "day-to-day". " … Implicit within their remit is the promotion of the innovation strategy and creation of the need to have one / deliver a pipeline."

A persistent theme in the interviews is the challenge related to short-term vs. long-term behaviours. Figure 43 shows how these needs arise due to a perceived technology performance gap (e.g. due to errors or efficiency gaps). The CTO response is broadly serving different sets of stakeholders.

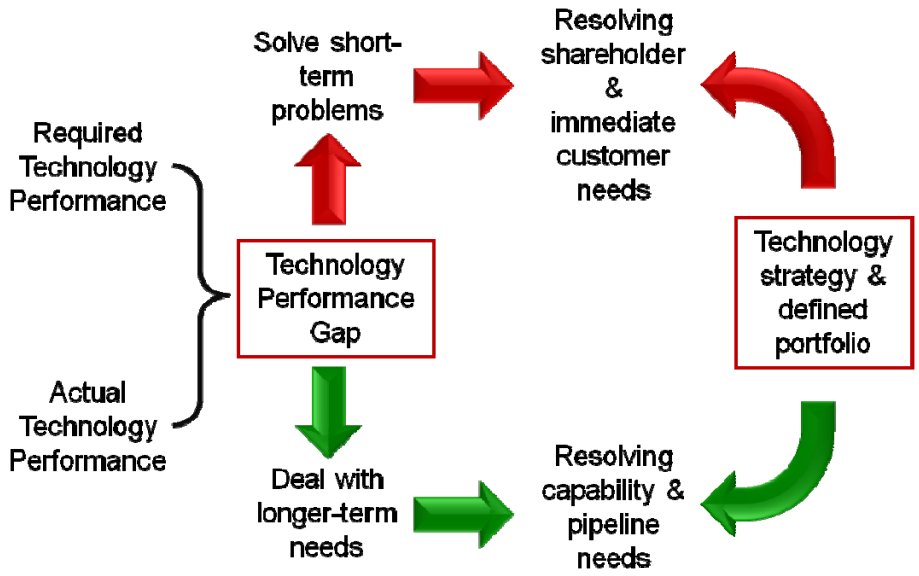


Figure 43: The technology performance gap

On the one hand, the CEO and the board act as agents of the shareholder and the customer. In this instance, the focus is on making sure that the immediate needs of customers are met and that short-term EBITDA[22] targets are maximised. Where these fall short, market analysts tend to undermine the share price with negative reports on the performance of the business.

The following quote provides an example of this:

"So I think you've got, driving the short-termism, is of course stock markets, activists, shareholders. And I realise that, in theory, stock markets should be objective, so markets shouldn't drive short-termism. They should drive sustainable performance. The truth is somehow not always." "…It also has something to do with, you could say, limited insight of elders. I mean we are not the sort of people who attract armies of analysts. But there are people who spend most of their time covering us and a couple of competitors. But these people, typically, don't have a detailed insight of what it actually means we're doing. So it's qualification of, say, market participants. I've discussed with some of those analysts and many of them are early-thirties, proud MBA, but … … don't have any experience in anything real. So they're very good at doing spreadsheet valuation models, which we, as a hobby, also maintain. But beyond that, sometimes it's amazingly thin." [Interviewee 1]

On the other hand, the CEO and board also act as agents of the future needs of customers and shareholders. This involves redirecting resources to projects that change/ or build new capability and serve the need to create a pipeline of viable products. The implication for practice is that the technology strategy and the defined portfolio need to reflect the agreed balance between these conflicting needs. Furthermore, shareholders need to be aware of the negative impact analysts can have on the longer term growth of the business.

People management (5) is defined as, "The CTO's attention to changes in the technological capabilities requirement - to refresh skills, attitudes and the working context." The stated implications are set out in relation to the sub-elements of 'people management' in the CTO/Context Framework in Table 51. Where technology culture is concerned, two aspects are particularly notable from the implications. Firstly, in large industrial organisations with mature portfolios the incentives and performance arrangements tend to support incremental behaviours. Risk-taking is not rewarded, and so innovation is problematic.

[22] EBITDA = Earnings Before Interest, Tax, Depreciation and Amortisation. Often used as a valuation alternative to Price/Earnings Ratio (P/E Ratio).

The second implication is the problem of succession planning for technology staff. The dilemma is that being a better technologist (e.g. becoming more highly specialised) militates against prospects of promotion to higher office in more general management roles. Also, specialist technical skills are in demand within a business while a particular technology capability profile is pursued. However, if customer needs change, or business strategy dictates, these skills may quickly become redundant. Re-training or re-deployment to alternative roles is more difficult for highly specialised staff (see Figure 44).

Table 51: Exemplary statements for 'people management'

Sub-element 5	Implications stated by interviewees
Technology culture	" … Need trust, confidence and transparency."
	" … How do you create a succession model in this environment?"
	" … We need proactive succession planning for customer facing technical staff."
	" … If you only focus internally you'll promote people that do well at current operations - that is not necessarily innovative behaviours."
	" … Innovators are not necessarily successful in existing organisation - latent skills because different from BAU skills needs."
	" … You have got to take on board the context / environment."
	" … In future need to get on board with new big projects."
	" … Sometimes do things to a better or higher standard than we need to - we need to recognise this and accept the problem."
	" … We are very self-critical - we need to keep a perspective on how well the business actually does – 98.7% well vs. 1.3% bad!"
	" … We need to stop and think before we "do"."
	" … Some things can be done better and we could get better people - this is ongoing."
	"…In my formal role, I do not have any way to demonstrate / assess whether or not I have 'shaped' the programme in the correct way - It is easy for operations to demonstrate success because their metrics are simple and obvious."
	" … I try not to embed a particular project or approach by avoiding too much formal reporting - this is more sympathetic to our culture which tries to empower. I try to ensure that the focus is on results rather than control."
	" … Developing "newsletter" approach and include "stories"."…Developing innovation communication."
	" … Gather and share stories."
	" … Change programme in disguise?" "…CEO in role for 1 year - and you don't change the culture of a large PLC in a year."

Also, the CTO may be recruiting new staff (with valued skills) while simultaneously making existing staff redundant. Hence comments related to the 'Personal Attributes of the CTO' in Table 52 such as, "…Maturity and resilience is very important."

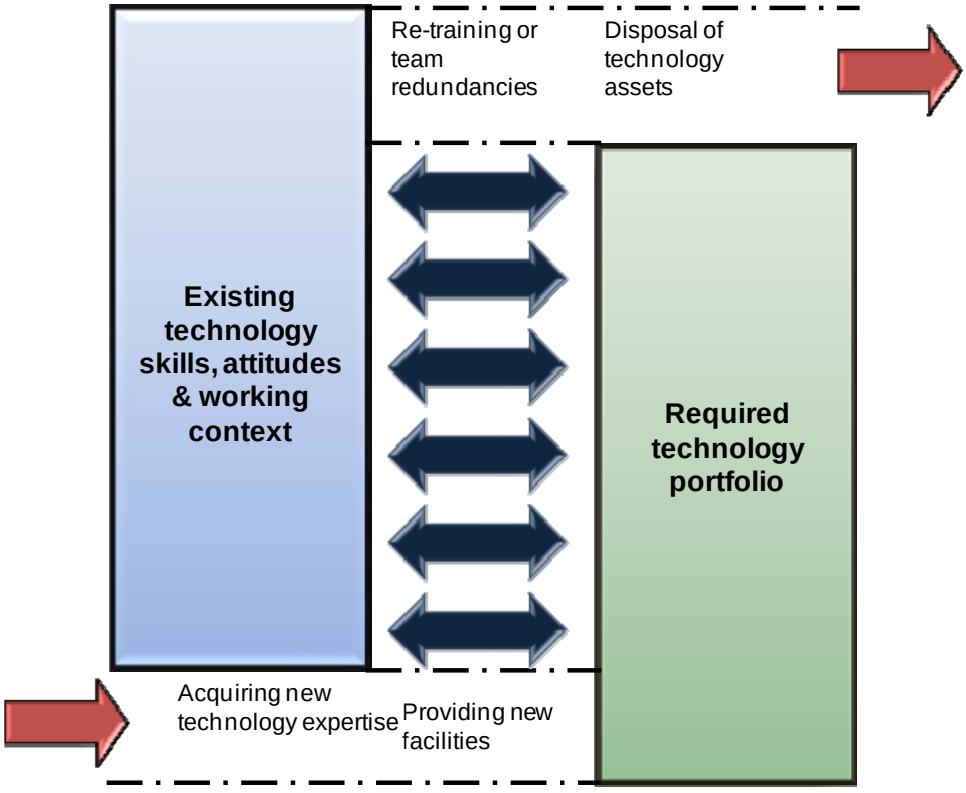


Figure 44: Matching people and the technology portfolio

In businesses with a high rate of change in the technology remit, people will be changed regularly (assuming the skills are embodied in the people). The CTO needs various related personal attributes to be able to cope. For example, " … The CTO really needs to be very positive and optimistic because there is a lot of risk, the outcome is often unknown and you fail often." And, " … I am quite easily frustrated - so really worth investing time in the soft and woolly elements."

Table 52: Exemplary statements for 'people management' (cont.)

Sub-element 5	Implications stated by interviewees
Personal attributes of the CTO	" … Core skills for me are around influencing."
	" … Being aware that the role changes depending on the life cycle stage of the business."
	" … Absolutely need to be experienced, well connected and must have done the "bench-work" and have the relationships."
	" … CTO may be transferable across industries provided you have been involved with taking 'lab scale through to production revenues' - techie mindset helpful."
	" … Some general management aspects -example- team elements but also factory manager/techie aspects to be able to transfer ideas between - be interface & feedback mechanism."
	" … reputation - good people will talk to you if you are a world leader."
	" … What are the implications of tenure in the Technical Director role?" "…Maturity and resilience is very important."
	" … No way that one individual could understand all the detailed knowledge."
	" … Personal motivation, clarity of objectives and purpose etc, and commitment."
	" … The CTO needs to be able to trade in knowledge and ideas."
	" … The CTO needs to be able to take "deep dives" into the technology with senior scientists within the business."
	" … I need to identify people's skills and enable them to talk to each other."
	" … Could do more - strategic level - reprioritise activities - maintain - ask for help / question and 'say no!'."
Technology teamwork	" … My map is very much around behavioural aspects."
	" … This helps to develop cross-fertilisation of skills."
	" … It's all about recruitment."
	" … It is hard to provide evidence required to justify recognition and reward."
	" … It helps us that our senior team all have a similar attitude towards the appropriate levels of control."
	" … The CTO needs to be able to translate technical aspects and technology into business needs in simple language."
	" … Recognition for innovation."
	" … Gather and share measurement and metrics."
	" … Incentivisation changes."
	" … Competency development & leadership training."

The ‘Technology Teamwork’ part of Table 52 centres around getting and keeping the right technologists. One of the most experienced CTOs interviewed made this comment, “ … Like all relationships, having created them, they’re very valuable. I suppose in my experience, it was one of those very rare things, albeit it was a relatively small team of seven or eight of us, we just all got on extremely well together and so there were no clashes of personality within the team.” [Interviewee 7]. This was in relation to a cross-functional technology team that was recruited from across the organisation and externally, to set technology strategy and implement a big integration following a merger.

Technology business model and strategy (6) is defined as, “The CTO’s attention to shifts in organisational strategic priorities; to provide clarity to the CEO, the board and organisation regarding technology value, focus, role and remit; to ensure engagement and support.”

The specific implications are set out in relation to the sub-elements of the ‘CTO/Context Framework’ starting with the ‘CEO & the Board’ in Table 53.

Table 53: Exemplary statements for ‘business model and strategy’

Sub-element 6	Implications stated by interviewees
CEO & the board	“ … Board needs to buy-in to actions that are taken to try to grow.”
	“ … Purpose changes over time.”
	“ … The role of the CTO is impacted by the "basis of discussion" between the COO, CFO, CEO and CTO - hierarchy is important.”
	“ … Commercial team need to be able to trust technical team.”
	“ … Being accountable for [customer related value] means clashes / disagreements with key people - for example the CEO.”
	“ … Much greater awareness to the management board.”
	“ … VCs - technology hostile; asset investors - technology friendly; IPO - technology neutral.”
	“ … Workers strongly represented and gained increased shareholding through evolution from government owned to today (0% - 15% - 29% - 20% - 35%).”
	“ … We must learn to make good use of "board member presence" in negotiations.”
	“ … Also needed to be realistic and focused on what you can implement - definitely need quick wins to be sure of ongoing buy-in.”
	“ … Our board does not have engineers on it - it is dominated by marketing and accounting.”
	“ … The propensity to look at process innovation is higher in the short -term because of

shareholder pressures."

" … Could get buy-in from commercial and broader disciplines."

The over-arching implication regarding the 'CEO and the board' of the company, is that these individuals act as agents for various parties at various times. This means that they are required to deliver on short-term targets while simultaneously ensuring long-term value. Members of the board may also be responsible for business units and be measured on the performance of these units. They are expected to advocate vigorously for as much resource as possible for their business unit – for example in annual budget allocations. The implication is that in order to advocate for technology resource, the CTO must be party to these allocation meetings, or have a knowledgeable and robust proxy.

Whereas the statements that fit with the 'CEO & the Board' are dominated by references to the main stakeholders, the 'clarity of strategy' sub-element is dominated by communication and alignment references. Table 54 includes statements that demonstrate a degree of frustration with having to 'sell' technology and technology benefits to the board. Through different levels the need is for staff to be aligned behind a clear view of what needs to be done. The time horizon, the regularity of strategy reviews, and the need to be proactive are also mentioned.

Table 54: Exemplary statements for 'business model and strategy' (cont.)

Sub-element 6	Implications stated by interviewees
Clarity of strategy	" … Need to align energy to ensure we compete externally so good communications - therefore no internal misunderstandings."
	" … If you are not demonstrating that you are adding value you constantly reacting / responding rather than dealing with medium / long-term value creation."
	" … There is higher visibility of performance whether it is good or bad." " … We have permanent and timed objectives- We'll make this more visible by mapping to show the links and making the "stretch" more obvious."
	" … The ambiguity of the strategy means that much more effort needs to be put into managing the politics ... There is a constant trade-off between targets BU vs. group."
	" … Node 53 is about forward looking indicators - Nodes 54 and 55 are about reacting - Overall - we are too reactive and we are mostly being driven by aspects that are not part of a strategy." " … We needed to be more strategic about sources of innovation."
	" … This encourages more of a 'group' outlook (perspective) - Cross-selling is now a key Kpi - Now a mix of own and group products incentivised - Now more keen on adopting new measures."
	" … We need greater clarity of what is going on - Everything falls into place once the clarity is there - We need to have a consistency of communication of the BU strategy - We need to keep seeking clarity - We need to avoid passing on inconsistencies and potentially making things worse."
	" … The infrequency of review of the strategy results in a delay / lag in implementation."
	"…The skills and capital equipment needs are not sufficiently tightly defined at the strategy stage and this may result in an imperfect match of my requirements."
	" … Question raised about 'how much innovation is enough?' We are awash with ideas - are there implications regarding open innovation?"
	" … 3 year time horizon in P+Ls - Increase richness of strategy - "drive" strategy - not "in" strategy - Refer to throughout the year as "guiding principal" for decisions - Risk money - changes to spending "rules"."

Changes in strategy are not specifically mentioned by interviewees. However, many of the frustrations raised imply that key stakeholders are not aligned to strategy. If the strategy has changed, the technology remit will change. The extent of change in the technology remit (see Table 55) can have been mandated by the CEO and the Board via the organisational strategy.

For example, Figure 45 depicts a changed technology remit brought on by an acquisition. In this hypothetical case, the acquisition provides a mixture of technology driven opportunities that are balanced between 'technology push' (i.e. potentially viable prospects that customers don't expect) and new 'market pull' opportunities (i.e. customer demands not considered

viable with a previous technology portfolio). In order to re-deploy the technology team and related capabilities, the CTO may need to deal with the 'technology exit points'.

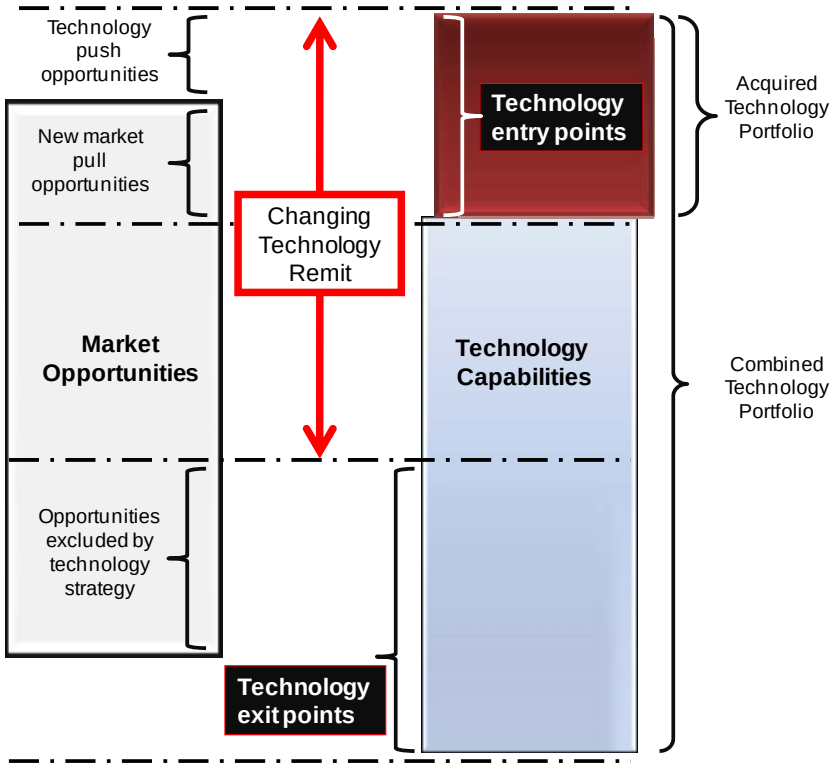


Figure 45: Remit changed as the result of an acquisition

Also, as Figure 46 shows, a changed strategy may require the removal of staff and facilities that are completely redundant (i.e. not valued by the market).

However, a more difficult challenge is potentially to remove capability for which there is obviously still a market, but which is deliberately excluded by a new strategy (for example because margins or market share are declining or disruptive technologies are looming or in the market). The CTO needs to be very clear about the role and remit of technology and proactive in communicating impending changes as early as possible.

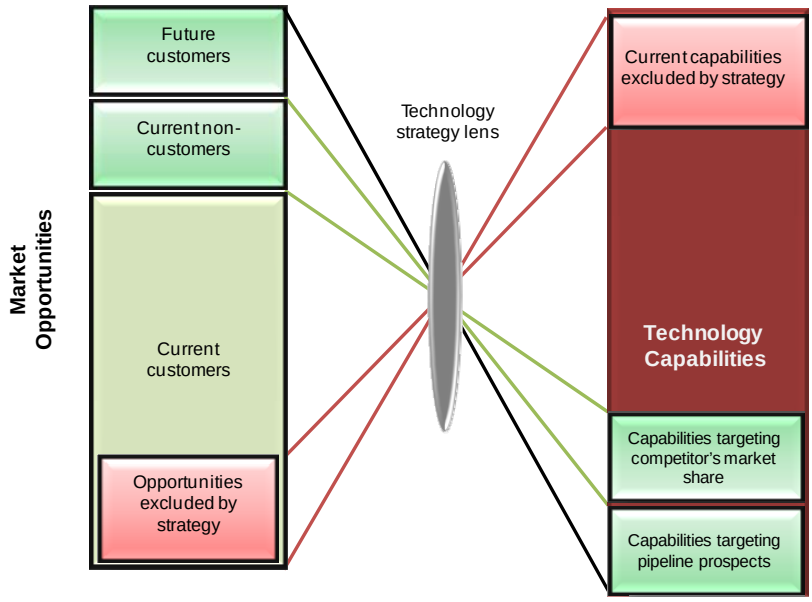


Figure 46: Technology strategy lens

The 'technology remit and role clarity' is covered in Table 55. The supporting statements in this table include references to the 'purpose' of the CTO. More particularly the statements demonstrate the value of the CTO/Context Framework idea because of the references to goals and priorities and how these change (and/or are changed by the CTO).

The statements about product specification are also raised in the interviews in a slightly different way. For example, " … and they often will have a portfolio of internal and external customers needing slightly different things…" [Interviewee 3]. The link back to 'strategy and remit' may seem obscure, but revisiting Figure 46 in conjunction with Figure 47 will demonstrate the implication better.

Table 55: Exemplary statements for 'business model and strategy' (cont.)

Sub-element 6	Implications stated by interviewees
Technology remit & role clarity	" … CTO Life cycle - single product - then more industrialists brought in - then full factory setup."
	" … All the time you are being challenged about your role - there are times when you can say and do controversial things."
	" … We are absolutely a service to the main business."
	" … Our core model is around 3 key structural roles – technologist, product developer and buyer."
	" … One of the first businesses to use "specification buying" therefore needed a technologist to specify the products."
	" … I do not want to change to a more administrative role - which is what would happen if I had formal authority."
	" … We do not have a CTO at a supra-functional level to escalate issues to - when I escalate an issue upwards, I encounter a very operationally focused environment."
	" … I have difficulty discussing technical content of my work at the senior level (above me) because they are focused on budgets and control - Historically there was a lot of power for "techie people" and many technologies did not get commercialised and the backlash was to hire operationally excellent people."
	" … I am perceived as an independent thinker and senior management consider this to be an important aspect of the profile of the individual CTO."
	" … CTO Purpose: Jointly with the BUs to deliver higher value added - new products and manufacturing technologies in line with the business budget."
	" … Changed purpose - the business is focusing more on innovation in products and manufacturing technologies - remit previously included consumer focused innovation."
	" … Get support for priorities - "delegate" (assumes expertise /capacity available)."
	" … Could seek input from Commercial Heads."

The interpretation of the capabilities required (or available) can be made more difficult where for example a 'marketing department' (the 'internal customer') translates market opportunities (from the 'external customer') on behalf of the CTO. On the other hand, when marketing and particularly sales people are explaining the technology capability for the 'external customer', interpretation may cause mismatches in understanding and loss of opportunities.

As shown in Figure 47, the CEO and the Board (also internal customers) will have a view of the organisational strategy based on their understanding of the technology capabilities and the market opportunities. Where the strategy (and thus a technology and CTO remit) targets

competitive prospects then typically certain opportunities will be excluded. This creates another strand of interpretation ending in the need for the CTO to exit certain technologies and capabilities.

This interpretation can flow in either direction depending on the nature of the relationship of the CTO and the board. In other words, in certain circumstances the CTO can drive the organisation strategy by making the case that the technology portfolio and remit take account of the external opportunities (current and future). So, the technology strategy will drive the organisation strategy. Alternatively, the CTO may set the technology strategy to follow the organisation strategy. The priorities related to the CTO/Context Framework will differ depending on the direction of influence.

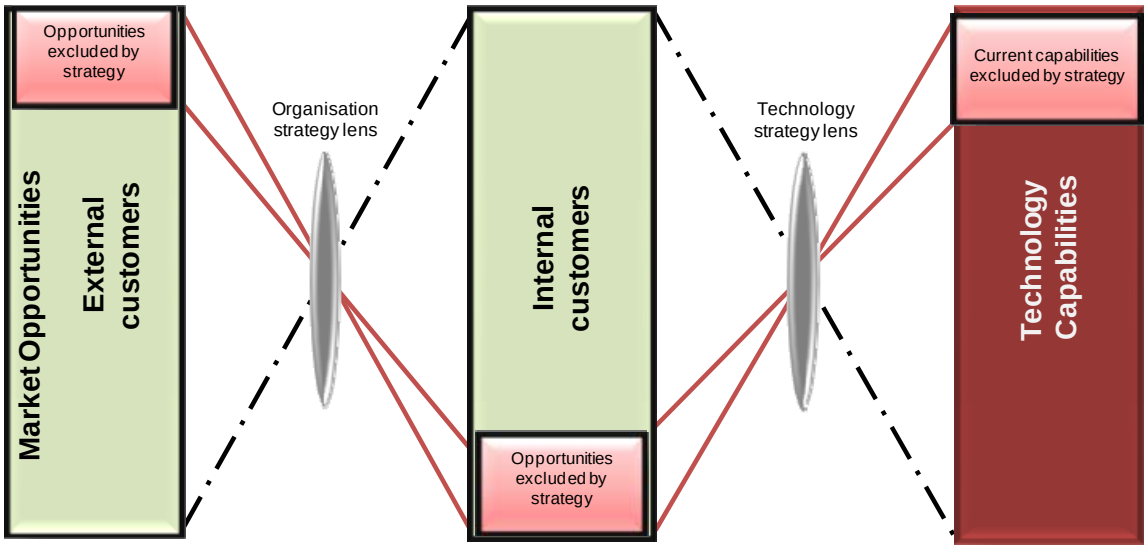


Figure 47: Interpreting strategy

The final aspect related to Business Model & Strategy is to clarify two apparent anomalies related to the 'Technology Business Model'. The first is that there is no specific reference to a 'Technology Business Model' – this did not explicitly emerge in the analysis for this research. In their definition of 'Market entry', Phelps et al. (2007) talk about how there is a requirement to be able to adapt the 'business model' in order to access markets. They think of

the business model in the context of 'market entry'. In the CTO/Context Framework, the 'Business model' (with 'strategy') is a standalone element.

This is partly because it is unclear what a 'technology business model' is – as opposed to a standard commercial business model. A commercial business model takes many forms, but generally includes the constituents depicted in Figure 48.

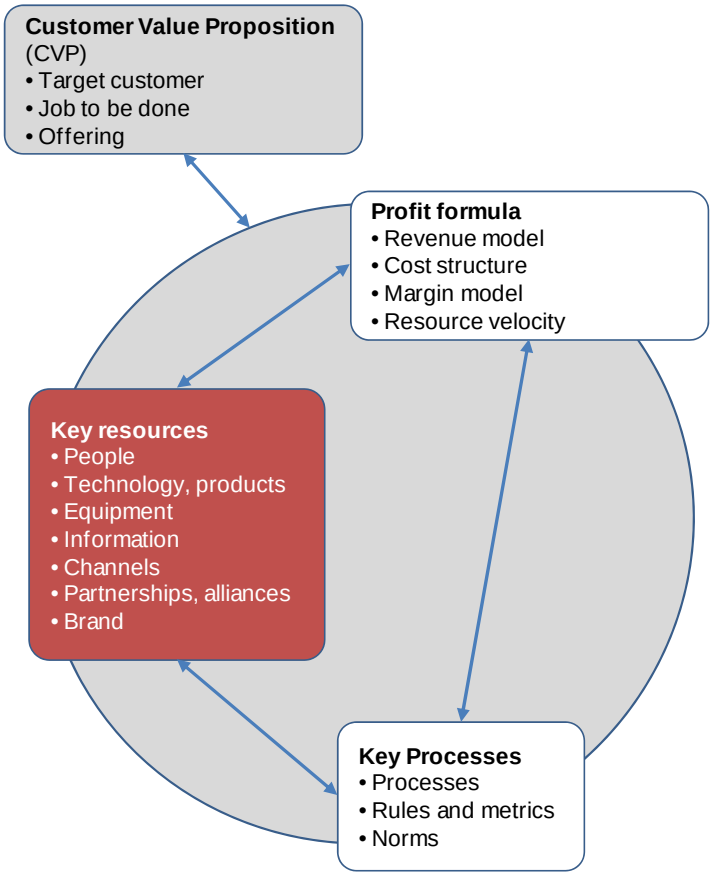


Figure 48: Commercial business model (Johnson et al., 2008)

This form of business model clearly links the strategy to the rest of the capabilities. The strategy sets the direction and defines where the organisation will compete (defining markets and 'customer value propositions'), and the business model sets out the combination of resources, processes and related profit formulae (the mechanism to make money). Or, as

Teece (2010, p.188) puts it, " … a business model articulates the underlying business or 'industrial logic' of a firm's go-to-market strategy."

Even though this research does not directly address a Technology Business Model, the first review and last summary when using the CTO/Context Framework should take account of a business model such as in Figure 48.

Introducing a new business model or changing a business model is not straightforward. The following statement explains the problem and the opportunity that business models present, " … once a business model is successfully established, changing technology and enhanced competition will require more than defenses against imitation. It is also likely that even successful business models will at some point need to be revamped, and possibly even abandoned." (Teece 2010, p.189.) While the business model will help to configure the CTO's response at technology transition points, they are also a source of inertia.

The combination of the technology or business strategy, and the business model makes sense. As Teece (2010, p.184) explains, "In short, getting the business model and the technology strategy right is necessary to achieve commercial viability if sustainable competitive advantage is to be built and innovators are to profit from their innovations." At the strategic level the role of the CTO is very much about 'sustainable competitive advantage'. At the technology level, the role of the CTO is about demonstrating the contribution of the technology investment. Put another way, "The economic value of a technology remains latent until it is commercialised in some way via a business model. The same technology commercialized in two different ways will yield two different returns." (Chesbrough, 2010, p.354)

8.5 Summary

In this chapter the implications for practice are discussed. The first part sets out the idea that whereas certain implications were directly stated by the interviewees, there were others that were either implied or overlooked. The categorisation of the implications into short-term and longer term, and between declared and undeclared is thus a necessary background to the rest of the chapter.

The declared 'implications' (i.e. those stated by the interviewees) are set out in tables. Statements are used verbatim to give direct impact to the interpretation intended by the interviewee. Also, as wide a variety of statements as possible, are included (i.e. duplications

are removed). The declared implications are summarised, and the undeclared implications are discussed and represented graphically where possible.

As is demonstrated by the final discussion on the Technology Business Model, there is also discussion about the implications that the interviewees appear to have withheld or overlooked.

9 Conclusions

9.1 Introduction

This research set out to investigate the 'role and contribution of the CTO'. The literature on the CTO and the analysis of the data collected for this dissertation, highlight vastly differing perspectives on the role of the CTO. However, there is broad commonality in the way that researchers tend to report on the CTO role. The literature is generally divided into three ways of thinking about the CTO role. These include the technology management context (the context), the technology management priorities (the work), and considerations about the attributes of the CTO (the worker). The conclusions from the literature are discussed in Section 9.2.

Because the literature tends to stream the ways of thinking about the CTO role, a decision was taken to design a research approach that simultaneously incorporated the perspective on the work, the worker and the context. The approach selected was thus to investigate the role from the perspective of the CTO. More specifically, it was decided to ask CTOs about their 'core purpose', the related barriers and enablers, and what they do about these i.e. their management actions. CTOs were asked to create a 'personal role map' using a variation of a cognitive mapping technique. Once they had completed the mapping, they were asked to report their views on 'implications for practice'.

The analysis, discussion and implications for practice resulted in a number of conclusions. Broadly, the main conclusion is that except for a specific context at a specific point in time, there is little value in providing a single 'core purpose' with related barriers and enablers, and linked technology management actions. The conclusions from the interviews analysed are discussed in Section 9.3.

However, taking the literature and the analysis together, it is possible to show a way to deal with the changes in technology management priorities ('core purpose') for a number of specific situations. It is possible to demonstrate that there are particular types of change and that as the business moves from one context to another, there is a need to re-configure the technology management priorities (i.e. the core purpose). This approach holds for both anticipated and unanticipated changes. The contribution to knowledge is summarised in Section 9.4. This chapter closes with a section on future research.

9.2 Conclusions from the literature

The literature establishes that the role of the CTO is relatively understudied (Herstatt et al., 2007; Medcof, 2007; Smith, 2007). It is also noted that the role has changed as the context has changed (Adler and Ferdows, 1990; MacMillan and McGrath, 2004; Smith, 2007). There is support for the importance of the role as implied in the desire to have the CTO on the top team (Heininger, 1988; Uttal et al., 1992; Larson, 1996). However, there is a reminder that this desire should be based on a contingency perspective (Medcof, 2007) i.e. it depends on contextual variables.

The context itself is changing over time as it moves from one 'R&D generation' to another (Roussel et al., 1991; Erickson 1993; Rothwell, 1994; Nobelius, 2004). Also, various authors note that certain technology management priorities can be associated with certain 'generations' (Erickson, 1993; Nobelius, 2004; Smith, 2007). However, the diversity of contexts is acknowledged, as is the limited usefulness of prescribing specific priorities to specific 'generations'. There is a view that it is more likely that CTOs would have to draw on mixed configurations of management priorities drawn from different generations depending on their unique context (Chester, 1994).

The literature on the generations of R&D provides a way of scoping the technology context. Also, the various descriptions of context raise the awareness of technology leaders regarding organisational structure requirements and recruitment needs. However, the evolutionary perspective of R&D (i.e. a sequential set of changes in the character of R&D management over specific decades), does not imply that today's organisations will encounter these as they proceed through time. So, while technology leaders are aware of the generations, they could not necessarily use this awareness to anticipate organisational structure and resource needs (i.e. management priorities) in the future. In other words the descriptions in the literature may no longer offer the most useful prescriptions for prioritisation of technology management responses.

In the literature the actual technology management priorities have also been viewed in relative isolation from their context. However, this may be of limited use without taking into account the numerous contextual features (Scott, 2007). The CTO may also make dubious assumptions about the management priorities based on a view that there is a pre-determined set of priorities associated with predictable stages in the growth 'life-cycle' of a firm (Phelps et al., 2007). It is more likely that the organisation will encounter random changes

(transitions) that require a rearrangement of technology management priorities. These transitions may be both unpredictable and rapid (Gladwell, 2000).

In general, there is a case made that the CTO needs to prioritise technology management actions. These priorities will vary depending on the context. The context will differ depending on unpredictable variables (at transition points), such as the macroeconomic situation, the organisation strategy, the industry sector and type of organisation. Furthermore, the leadership style, experience and key relationships of the CTO also influence these priorities (Uttal et al., 1992; Papadakis and Bourantas, 1998).

The conclusion from the literature is thus that the organisational context and the incumbent in the CTO role are integral to considerations about the technology management priorities. The configuration of variables around the CTO and context must also be integrated in order to prioritise action at key transition points that the organisation encounters. This supports the need for a model that predicts or explains the CTO activities in context. A model would be useful if it supports the prioritisation of technology management actions at technology transition points.

9.3 Conclusions based on this research

In investigating the core purpose of the CTO role and the related barriers and enablers, a framework has been derived in Chapter 6 that captures the scope of activity across a number of contexts. Although there are similarities between the configurations from the data collected, the CTO roles appear to be idiosyncratic. This suggests that an awareness of the stages of evolution of R&D/Innovation and the life-cycle growth concept may be of limited value.

There is support (both in the literature and in the analysis) for the conclusion that the management priorities of the CTO require an integrated view of both the CTO and the context. Furthermore, as discussed in Chapter 7 it is possible to depict different configurations of management priorities using the CTO/Context Framework. The framework depicts a steady state configuration by helping to understand how the CTO is responding in a given circumstance (a type of change in a particular context). It is also useful as a way to compare different steady states and to highlight the transition that might be required. When the CTO/Context Framework is used in conjunction with Technology Transition Points, a model is created that helps the CTO to explain or predict technology management priorities.

It is thus possible to rapidly redefine the CTO's 'core purpose' and predict or explain the barriers, enablers, management actions and implications. In this research, this model has been called the Technology Management Compass. As shown in Chapter 8 relevance and utility can be tested by mapping the implications for practice back to the context elements and sub-elements of the model.

9.4 Contribution to knowledge

As regards the process for this research, the technique used to collect the interviewee inputs—called Personal Role Mapping in this dissertation—has proven to be very effective in eliciting so-called 'rich data'. As discussed in Chapter 5 it is based on the cognitive mapping approach and is designed specifically to investigate the perception of CTOs regarding their role and contribution. As this work progressed, the role mapping technique was used in unrelated workshop situations as part of various learning interventions[23]. The conclusion emerged that there is no obvious limitation regarding the type of role being investigated.

Additionally, as shown in Chapter 5 the process of analysis is set out in such a way as to render it replicable. Both the approach to derive the model (Technology Management Compass) and the manner in which the (CTO's) management emphasis is depicted graphically, can be replicated by other researchers (conceivably for most roles).

As regards the subject of this research, the role and contribution of the CTO - a generic model called the Technology Management Compass is derived. The model consists of two elements, a framework called the CTO/Context Framework, and a set of change types called Technology Transition Points. The combination of these elements can be used as a way for the CTO to plan the likely technology management priorities at anticipated transition points. Alternatively, the CTO can use the model to retrospectively review technology management priorities when transition points were unanticipated.

The role mapping technique and the model of the CTO role are offered as unique contributions to knowledge arising from this dissertation.

[23] The author has applied this technique with approximately 200 managers from numerous roles in multiple workshops.

9.5 Limitations and future research

The research conducted to date has been inductive i.e., no *a priori* theoretical perspectives or frameworks have been assumed. This is in order to minimise the impact of existing assumptions about the role of the CTO and the influence of context. The interview technique has elicited a rich data set on the role (in context) using a generic set of research questions and ultimately resulting in the derivation of a model for the CTO role.

In this section a view is taken on the explanatory and predictive validity of the model of the CTO role. Weaknesses in the approach are also discussed, as is a suggested approach for further research.

9.5.1 Limitations

Investigating any executive role (such as the CTO role), is potentially hampered by a number of challenges. Some examples include:

- the fact that the investigation should simultaneously take account of the work, the worker and the context (Sandberg, 2000; Partington, 2005);
- that the variables of personality combine with those of the environment to determine behaviour (Lewin, 1936). So, to create a framework to model the behaviour in the role implies an ability to identify and control for these personality and environmental variables;
- that at best the mental models that represent the perceptions of the executive about that role, are a "snapshot in a stream of consciousness" (Weick, 1995). These models incorporate elements of tacit knowledge that by their nature are extremely difficult to identify and operationalise (Ambrosini and Bowman, 2002);
- that to model good practice for the executive in the role would imply an ability to show cause and effect between the practice of the role player and the performance of the business;
- that qualitative research methods that use abstraction to generate knowledge and structure, sometimes move too far from practice (Boyd, 2008).

The way the CTO thinks about the role can to some extent be considered to bridge between the organisation (and the broader context) and the individual (personal context) in one

dimension and between the past and the future in another. On one hand this makes the mapping process used for this research topical at the time the mapping interview is conducted, but on the other it raises the need for a longitudinal perspective to research trends.

Also, Hodgkinson (2005) raises a number of challenges pertinent to this work. For example, he suggests the need to compare maps across industries. This entails generating further maps in each industry and looking at variations within and between industries. He confirms the contention in this research that the mapping approach captures the intersection between the individual and the context. He recommends that the research be designed to capture the view of successors in the same business, and to map the perceptions of stakeholders around an individual [CTO] as a cross–reference. He also endorses the need to capture the evolution of the individual's perception of the role (a longitudinal view).

In Chapter 7 a technique using 'coding coverage' from NVivo8™ (Bazeley, 2002) has been used to show each interviewee's management emphasis graphically. The depictions raise the possibility of patterns of management configurations at technology transition points. There is therefore a possibility to prove the existence of transition point patterns, using follow up research that is deductive (Christensen, 2007).

However, the 'coding coverage' used poses a number of problems. In the first instance, while 'coverage' can be used to note what the CTO talks about in the interview (i.e. the emphasis), 'coverage' is not a proxy for 'importance'. In other words, the cross-referencing approach used in Chapter 7 may not always accurately represent the technology management priorities of the CTO.

The problem is one of quality versus quantity – since 'coding coverage' is a measure of quantity, the importance of the content is unclear. Griffin and Hauser (1993) allude to a similar concern in their analysis of the 'voice of the customer'. They point out that 'regrettably' frequency of mention is not a good surrogate for importance. There is also the concern that the interviewer might have steered the interviewee and thus skewed the coverage in a particular way.

However, since the coverage approach is only used to demonstrate an application of the Technology Management Compass in this thesis, it is felt that this problem does not hinder the outcome. Furthermore, as shown in Chapter 5, while the interviews are structured in terms of process, the interviewees controlled the content and thus the coverage. This means that while a degree of interviewer bias is inevitable, it is deemed to be insignificant.

9.5.2 Validity

In this section there are four broad areas of clarification regarding validity. The first to be discussed is the validity attributed to the self analysis / interpretation done by a number of interviewees as part of the cognitive mapping process. The second is a report back from an interview conducted with a technology executive. The third is to consider cross-references with the literature. Finally, there is an explanation of how this type of research fits within the broader theory building perspective and what is required for higher validity.

Validity attributed to the self analysis / interpretation:

Chapter 8 covers implications for practice, partly by using the direct interpretations of the interviewees. The process involved stopping the explorative aspect of the cognitive mapping part of each interview approximately twenty minutes from the end. In these final twenty minutes the interviewee was asked to review and reflect on the personal role map that they had created during the interview to that point.

Specifically, they were asked, "What are the implications for practice / for you in this role?" The answers are discussed extensively in this dissertation, and thus do not require further comment or summary. However, the reason for this approach is that researcher bias in the initial interpretation of the map is significantly reduced. This is an important contributor to the validity of the implications for practice, and the interpretations that rely on these initial interviewee perspectives.

Report back from a validation interview:

After the Technology Management Compass model was derived, an interview was conducted with the technology director of an organisation not included in the original interview list. This was in order to explore the validity of the model. Overall the framework was found to be, "unsurprising" and, "…interesting, because of the possibility that it can be used to show changes in priorities based on dynamic and often short-term remits." The following specific comments related to the model were noted.

Table 56: Comment on the Technology Management Compass

Reference No.	Related to…	Interviewee comment
1.1	Business structure	" … need to be sure that you understand that you are not just looking at your own shop – you need the broader business structure to work too."
3.3	Track record and investment	" … industry regulators may require you to develop infrastructure that is not financially viable. When this happens, trade-offs are possible and opportunities for a quid pro quo need to be capitalised."
4.3	Innovation	" … we are recruiting graduates who expect the level of openness that they experience in their private lives when they use Facebook and Twitter. The full Web 2.0. In a business there are security and productivity issues with this, so the challenge is to allow openness while ensuring the job gets done and while protecting your proprietary knowledge."
6.4	Market and competition	" … we have access to customer usage statistics, so we know before our marketing people what the technology usage trends are…"

The comments support the validity of the model by adding richness via further examples. When asked, the interviewee reported that they would not want to change the model in any way. It is recognised that this is single interpretation and thus of limited value.

Cross-references with the literature:

A further validation procedure is to check the scope of activities discussed in the technology context literature to ensure there are no obvious exclusions. More specifically, the approach is to consider whether activity highlighted in the literature can be accommodated within the derived model. This has been done on an ongoing basis throughout the research. However, over time, definitions may be modified where clashes or omissions are surfaced. Cross-referencing with the literature is helpful because the explanatory validity will improve if the scope of the sub-elements of the model improves.

If there are potential weaknesses in the approach these will be surfaced in future research. For example, the predictive validity (Tauber, 1975) is less obvious and untested pending further research. In order to understand this, it is necessary to put this study in the context of a broader view of theory building.

Requirements for higher validity:

The outcome of the research conducted for this dissertation complies with a three step process suggested by Christensen (2006). According to Christensen, 'descriptive theory' is built in three steps, 1- observation, 2- categorization and 3- association as shown in Figure 49. Christensen (2006, p.39) proposes, " … a model of the process by which theory is built and improved." (See also Carlile and Christensen, 2009) He says the process involves two stages, a descriptive stage and a normative stage. Descriptive theory is put forward as a necessary precursor to the development of normative theory.

The process of moving from steps 1 to 3 follows an 'inductive' flow in the development of a descriptive theory. This flow is from the bottom to the top of the pyramid in Figure 49. In the broader scheme of theory building, it is necessary to follow-up this inductive process with a deductive process that tests the derived models with new data, with a view to predicting associated outcomes.

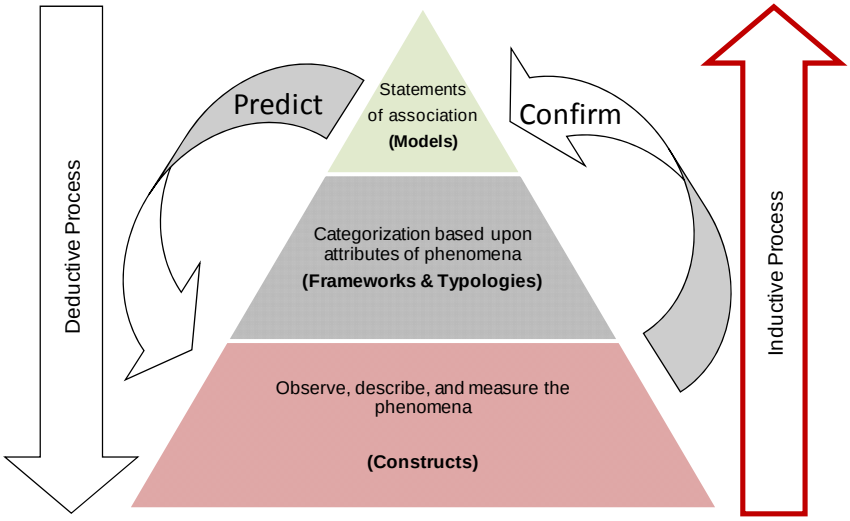


Figure 49: The Process of Theory Building (Christensen 2006, p.42)

Christensen also distinguishes between descriptive theory (where models are based on correlations) and normative theory (where models are defined as statements of causality). The transition from descriptive to normative is pertinent because, "Their understanding of causality enables researchers to assert what actions managers ought to take to get the results

they need." Christensen (2006, p.42), further states that normative theory has " … greater predictive power than descriptive theory does."

It is for this reason that the research conducted so far can be said to have explanatory validity, but would need to be followed up by a deductive study in order to ensure predictive validity.

9.6 Proposal for follow up research

So far, this research has been carried out 'inductively'. The model made up of the CTO/Context Framework and the Technology Transition Points is grounded in the data from the interviews. However, while an attempt has been made to depict the configurations graphically (see Chapter 7), there is still a need for a broader based test. The proposal for future research is thus to apply the CTO/Context Framework 'deductively' (Christensen, 2006) in a survey that seeks to identify patterns at (and for) particular types of technology transition points.

9.6.1 Suggested approach:

A rigorous test using the CTO/Context Framework is required. To simplify the approach, two separate surveys are suggested. The first would be to ask CTOs to consider Technology Transition Points that they do / would plan to introduce (i.e. anticipated change). The second would be to ask CTOs to reflect on Technology Transition Points that they have already encountered (i.e. unanticipated change). In each case, a research process is needed that will gather data on:

- demographics and the type of transition the CTO is reflecting on; then,
- the CTO's view on (see Figure 50):
  - 'amount of effort' - how much of their time is taken by each sub-element (out of 10).
  - 'importance' - how important each dimension and sub-element is (out of 10).

After a pilot survey the relationships between the types of transition and the configuration of technology management priorities on the compass need to be tested. Also, an analysis of the relationship between what CTO's say is important, vs. how they feel they are using their time (or, technology management priorities vs. technology management actions) will be possible.

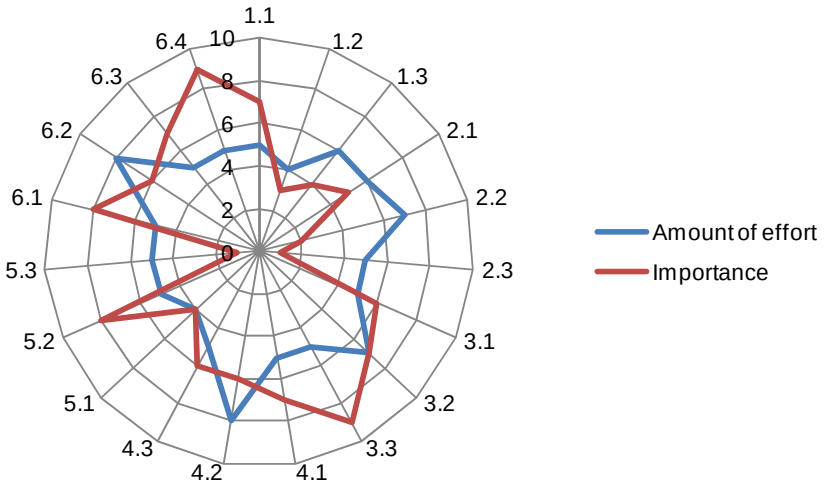


Figure 50: Sample survey output

The demographic data is required in order to allow an analysis that can isolate outcomes that can be generalised. In further research, the last requirement can be technologically framed to identify whether the technology portfolio is complex or simple, static or rapidly changing, peripheral or central to the product portfolio and the business strategy etc. The nature of ownership and governance in the business is also of interest.

Assuming the pilot survey works, the assumption is that this type of research would lend itself to internet based data gathering in collaboration with multiple researchers or institutions. The research planning should envisage a longitudinal study so that trends can be surfaced. The research should aim to provide practical inputs for practitioners and support for regional policy-makers.

Finally, the demographic profile should also allow for the isolation of data from executives with varying titles such as Chief Scientist, Head of Engineering, Head of R&D and Innovation Director.

9.7 Summary

This final chapter covers the conclusions drawn from the literature and the conclusions that emerged from this research. Also, there is a brief overview of the contribution to knowledge. The final section considers the limitations of the study and makes suggestions about future research.

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Appendix 1. Chronological listing of empirical studies

This table includes a chronological listing with date, author(s), title, article length and a description of the source of knowledge. Where references were listed in an article the number of references is noted.

Date	Author(s)	Title	Length (pages)	Source of knowledge
1981	Roberts and Fusfeld	"Staffing the innovative technology-based organization"	16	Empirical and expert witness: The authors compiled "several thousand" staff profiles for this research, and also drew on their work at MIT and consulting for US firms. Number of references: 16
1990	Adler and Ferdows	"The Chief Technology Officer"	7	Empirical: Based on 26 CTO responses to survey and 22 follow-up interviews. Number of references: 8
1992	Uttal, Kantrow, Linden and Stock	"Building R&D leadership and credibility"	10	Empirical: Authors associated with McKinsey & Co. conducted interviews with key stakeholders to CEO-CTO relationship in 24 US firms. Number of references: 4
1995	Roberts	"Benchmarking the strategic management of technology - I"	13	Empirical: surveyed 244 companies representing 80% of R&D spend in US, Europe and Japan. Number of references: 14
1995	Roberts	"Benchmarking the strategic management of technology - II"	8	Empirical: surveyed 244 companies representing 80% of R&D spend in US, Europe and Japan. Number of references: 6
1996	Jonash	"Strategic technology leveraging: Making outsourcing work for you"	7	Empirical: Based on the work done for a joint survey with the Economist Intelligence Unit includes "over 50" interviews with CEOs and CTOs worldwide. The author worked at Arthur D. Little at the time of writing. Number of references: 0
1996	Thurlings and Debackere	"Trends in managing industrial innovation – First insights from a field survey"	2	Empirical: Interviews with 25 CTOs at a multi-national and 22 academic "experts" in the management of technology. Thurlings worked at Philips Research Laboratories, and Debackere at the University of Gent. Number of references: 0

Date	Author(s)	Title	Length (pages)	Source of knowledge
1997	Lefebvre, Mason and Lefebvre	"The Influence Prism in SMEs: The power of CEO's perceptions on technology policy and its organizational impacts"	23	Empirical: 82 CEOs of firms with fewer than 200 staff located within the same sector (metal) and the same region (Quebec, Canada). Semi-structured interviews used by 4 researchers using the same protocol over 4 months of data collection. The paper is quantitative. Number of references: 80
1998	Papadakis and Bourantas	"The Chief Executive Officer as corporate champion of technological innovation: An empirical investigation"	21	Empirical: 97 Greek owned companies in 5 industry sectors – average size 255 employees. Data collections using a combination of structured interviews and questionnaires. Number of references: 87
2001	Scott	"Strategic planning for high-tech product development"	22	Empirical: A 3 questionnaire DELPHI study was used. Three rounds of questions were used and finally, 13 respondents from UK, 24 from the rest of Europe and 22 from the USA were analysed. Most respondents were attendees at the International Association of Managers of Technology (IAMOT) conferences. Number of references: 33
2001	Roberts	"Benchmarking the global strategic management of technology"	12	Empirical: 400 firms surveyed – 209 responses from USA, Japan and Europe. Number of references: 2
2001	Roberts and Liu	"Ally or acquire? How technology leaders decide"	9	Case study: The authors use a Technology Life-cycle perspective (after Utterback, 1994) to review how Microsoft Corporation managed their external activities from 1975 through to 1999. Number of references: 18
2004	MacMillan and McGrath	"Nine new roles for technology managers"	11	Empirical: The research is based on a 37 venture study in a major financial institution, followed by a 35 venture study of the process through which new ventures lead to new competencies in 5 established companies. Number of references: 18
2004	Roberts	"Linkage, leverage and leadership drive successful technological innovation"	3	Empirical: The author bases this review on two large benchmarking studies that he carried out in 1992 and 1999. Number of references: 4

Date	Author(s)	Title	Length (pages)	Source of knowledge
2007	Herstatt, Tietze, Nagahira, and Probert	"The chief technology officer (CTO) in literature and practice – a review and results from field research in Japan"	28	Empirical: This article surveys 10 CTOs in the electrical engineering industry in Japan. Each company has in excess of 50 000 staff and all but one has revenues in excess of 10 Bn Euros. They all spend between 10 – 15% of revenues on developing new products and services, are globally active with manufacturing facilities outside of Japan, and are divisionally organised. Number of references: 28
2007	Scinta	"Industrial Research Institute's R&D trends forecast for 2007"	4	Empirical: The author is the chair of the Industrial Research Institute's Research-on-Research Committee. The surveys were completed by 99 of the 200 members of the IRI in the US that carry out R&D. The author is also the manager of the Heavy Oil Division, R&D and Shared Services at ConocoPhillips Company. Number of references: 1
2007	Smith	"What CTOs do"	5	Empirical and expert witness: Roger Smith studied the web sites of 200 CTOs found using a Google search. At the time of writing ,he was also the CTO of the US Army Simulation, Training, and Instrumentation. He had previously been Group CTO for Titan Corporation and also VP Technology at BTG Inc. Number of references: 11

Appendix 2. Chronological listing of articles by experts

Date	Author(s)	Title	Length (pages)	Source of knowledge
1988	Heininger	"R&D and competitiveness – What leaders must do"	2	Expert: Allen Heininger was VP Resource Planning at Monsanto in the US and had been President of the Industrial Research Institute. The article was adapted from a conference paper. Number of references: 0
1990	Lewis and Linden	"A new mission for corporate technology"	11	Expert: Authors worked for McKinsey & Co. at time of writing. Also, used a "..recent McKinsey study…" – no detail provided. They acknowledge the inputs of 3 senior technology leaders. Number of references: 0
1990	Erickson, Magee, Roussel and Saad	"Managing technology as a business strategy"	6	Expert: Tamara Erickson, John Magee, Philip Roussel and Kamal Saad were all with Arthur D. Little. They were based in the US except for Mr Saad who was based in Brussels at the time. Number of references: 1
1990	Wolff	"How to talk to your CEO"	3	Expert: based on interview with William H. Matthews of IMD. Number of references: 0
1991	Wolff	"Are you credible with your CEO?"	3	Expert: Author summarises interim results of research that is reported by Uttal et al. in 1992. Adds related quotes from 6 senior technology leaders. Number of references: 0
1992	O'Neill	"Credibility between CEO and CTO – A CEO's perspective"	2	Expert: Paul O'Neill was Chairman and CEO of Alcoa in the US from 1987 to the time of writing this article. Number of references: 0
1992	Bridenbaugh	"Credibility between CEO and CTO – A CTO's perspective"	7	Expert: Peter Bridenbaugh was Executive VP – science, technology, engineering, environment, safety and health for Alcoa in the US from 1991, having worked in Alcoa since 1967. Number of references: 0
1993	Erickson	"R&D Managing the link to corporate strategy"	8	Expert: Tamara Erickson was a Senior VP of Arthur D. Little at the time of writing the article. The article includes direct substantial quotes from 15 prominent technology leaders and 3 senior academics. Number of references: 0

Date	Author(s)	Title	Length (pages)	Source of knowledge
1994	Chester	"Aligning technology with business strategy"	8	Expert: Arthur Chester was Senior VP for research and technology at GM Hughes Electronics and Hughes Aircraft Company in the US – having served with the company since 1969. This article is also empirical in that it draws on 16 examples of major US companies that worked together in the benchmarking process. Number of references: 9
1994	Robb	"Selling technology to your CEO"	3	Expert: Walter Robb was Senior VP for Corporate R&D at GEC and on the GEC Corporate Executive Council until 1993. Number of references: 0
1996	Gwynne	"The CTO as line manager"	5	Expert: Peter Gwynne is a freelance science and technology writer based in the US. He has covered stories in the US, Europe and Asia for Newsweek, The New York Times, The New York Herald Tribune, IEEE Spectrum, New Scientist, Technology Review and several for Research Technology Management. Number of references: 0
1996	Larson	"Critical success factors for R&D leaders"	3	Expert: Charles Larson was Executive Director of the Industrial Research Institute, Inc. at the time of writing this article. Number of references: 3
1999	Smith, Lederman and Jonash	"Alcoa's technology change process"	7	Expert: At the time of writing, Frank Lederman had been the Alcoa CTO, Greg Smith had previously been the Director of Technology Strategy and Planning at Alcoa and Ron Jonash was a Senior VP at Arthur D. Little Inc. in the US. The article is a case study of change at Alcoa. Number of references: 4
2000	Fisher	"Changing of the guard: CIOs, CTOs in flux" (See also: "Keys to delivering quality executives" (2000) which includes a CTO checklist.)	2	Expert: Susan Fisher was Senior Editor at InfoWorld at the time of writing this article. She interviewed a cross section of technology executives to demonstrate the various reporting configurations and to help illustrate the shift she is suggesting. Number of references: 0

Date	Author(s)	Title	Length (pages)	Source of knowledge
2003	Smith	"The Chief Technology Officer: Strategic responsibilities and relationships"	9	Expert: Roger Smith was Group CTO for Titan Corporation at the time of writing this article. Number of references: 25
2003	Delmar	"The rise of the CSO"	3	Expert: Dan Delmar has been VP Strategy Planning at Carrier Corporation, a $4Bn company in the air conditioning industry. He had also been with Bain & Co and Accenture Strategic Services. Number of references: 0
2004	Giordan and Kossovsky	"It's time to think differently about R&D assets and the CTO's role"	4	Expert: Judith Giordan was a director of I/C/M/B Ocean Tomo (an IP Merchant bank) at the time of writing. She has been VP Global R&D at PepsiCola, VP R&D at Henkel Corporation and a board member of the Industrial Research Institute in the US. Nir Kossovsky was the CEO of I/C/M/B Ocean Tomo at the time of writing, having previously been CEO of what became Plx Systems, Inc, and a tenured Professor at UCLA. Number of references: 0
2005	Cannon	"What it means to be a CTO"	3	Expert: Peter Cannon served as VP-Research and Chief Scientist for Rockwell International and various posts in GE. He also co-founded two NASDAQ listed companies. He is an Honorary Fellow of the Industrial Research Institute and a Fellow of the Royal Society of Chemistry. Number of references: 0
2007	Medcof	"CTO power"	9	Expert: Professor Medcof is based at the De Groot School of Business at McMaster University. This article is conceptually based on a thorough review of the related literature and his previous research into 'upper echelon' leadership. Number of references: 19
2008	Medcof	"The organizational influence of the Chief Technology Officer"	15	Expert: Professor Medcof is based at the De Groot School of Business at McMaster University. This article is conceptually based on a thorough review of the related literature and his previous research into 'upper echelon' leadership. Number of references: 31

Appendix 3. Annotated bibliography: tech leader articles

Date	Author(s)	Title	Focus
1981	Roberts and Fusfeld	"Staffing the innovative technology-based organization"	Identify 5 "critical job roles" in innovation teams. These are: idea generating, entrepreneuring or championing, project leading, gate keeping, sponsoring or coaching. Some individuals are capable of multiple roles. The patterns of capability in these roles change over time.
1988	Heininger	"R&D and competitiveness – What leaders must do"	Appeals to professional research managers to broaden their scope and interact with stakeholders better – particularly the CEO.
1990	Lewis and Linden	"A new mission for corporate technology"	Hails the introduction of the CTO role (typically incumbent seen as most senior R&D manager) to coordinate across business units. Distinguishes this as a leadership role – spokesperson, strategist and director of corporate R&D.
1990	Adler and Ferdows	"The Chief Technology Officer"	Suggest that the organisational response to increased importance of technology to competitiveness, and the increasing interdependence of technologies, is to create the role of the CTO. They define the role as having responsibility for at least two of the three major technology areas of – product, process and information technologies. Concludes that CTOs create synergy and economies of scale across business units, and supervise new technology development. Authors suggest a trend towards CTO positions being more common.
1990	Erickson, Magee, Roussel and Saad	"Managing technology as a business strategy"	Consider the issue of short-termism in technology investment. They describe the implications of various types of technology (termed base, key and pacing); the various types of R&D programme (…incremental, radical and fundamental). They suggest that the role of "strategic technology management" is to support the business by supporting sustainable cash flows that will grow. In doing so they will be part of the drive to ensure investor support. They point out that the level of investment is a reflection of technological strength. This can be characterised as – 1. Dominant; 2. Strong; 3. Favourable; 4. Tenable; 5. Weak. The authors suggest that in order to keep technology relevant, there are a number of principles to be applied: 1. Keep R&D personnel in touch with potential customers and markets; 2. Foster open communications between R&D, manufacturing and marketing; 3. Hold to time commitments and schedules; 4. Avoid fads; 5. Understand the reason for outside linkages.
1990	Wolff	"How to talk to your CEO"	Suggests that the onus is on the R&D manager to work with functional managers to present an integrated view of the value of technology in supporting the corporate strategy i.e. to the CEO. Uses the example of how lightweight materials for hand drill construction combined with a good insight into how single women use these at home provided a new opportunity. The central point being that the R&D manager needs to understand or create the "strategic context" within which to pursue the R&D work.

Date	Author(s)	Title	Focus
1991	Wolff	“Are you credible with your CEO?”	Reports interim findings from Uttal et al. study conducted for Industrial Research Institute in the US. The report concluded that R&D leaders with a business focus have highest credibility, and that credibility is less to do with personality and more to do with results.
1992	Uttal, Kantrow, Linden and Stock	“Building R&D leadership and credibility”	Confirmed that CTOs operate at various levels – functional to supra-functional. Where leadership gaps exist, this is generally an issue of credibility with the CEO. Findings included the need for CTOs to act as “technical businessmen” in order to close the credibility gap between themselves and the CEO.
1992	O’Neill	“”Credibility between CEO and CTO – A CEO’s perspective”	The author suggests that the historical notion of the CEO at the apex of a triangle with CTO and customersis “getting in the way” and is dated. He suggests that the triangle should be inverted, and that the CEO should be facilitating circumstances in which the CTO can serve the customer.
1992	Bridenbaugh	“”Credibility between CEO and CTO – A CTO’s perspective”	The author says that the ability to form productive partnerships, have a global perspective and to demonstrate “commercial savvy”, are key aspects of CTO credibility. Primarily the CTO needs to develop and lead the technical organisation in order to satisfy customer needs by applying scientific and engineering knowledge.
1993	Erickson	“R&D Managing the link to corporate strategy”	The author describes 1st, 2nd and 3rd generation R&D management styles. She suggests that 1st generation R&D involved setting scientists up in attractive premises and locations and leaving them to intuitively deliver the technology requirements. 2nd generation occurred because of pressure from shareholders to abandon the “wait and see” approach of the 1st generation. This generation was adversarial and decisions were based on a very quantitative approach. The risk in this mode is the erosion of the technology base in pursuit of short-term gains. The 3rd generation is then described under six headings: 1. Increase communications; 2. Encourage frequent employee interaction; 3. Minimize the fear of failure; 4. Create a flexible organisation capable of making tough choices; 5. Maintain a sense of urgency; 6. Put all your cards on the table. In summary the 3rd generation approach means that technologists can explain why, where, when and how technology is important to the business.
1994	Chester	“Aligning technology with business strategy”	Discusses benchmarking practices and outcomes. The article includes a meeting agenda which gives an insight into the topical issues for technology leadership (integrating strategy, getting technology staff closer to the customer, external relationships, researcher incentives, motivating staff transfers between research and product divisions, etc). The author also notes the uniqueness of each company context, but that certain processes are generic or need only minor adaptations.
1994	Robb	“Selling technology to your CEO”	CTO role is to defend technology when competing for funds against other functions. This is required to ensure long-term profitable growth. Highly credible CTOs demonstrate excellent teamwork and performance with an ability to take risks.

Date	Author(s)	Title	Focus
1995	Roberts	"Benchmarking the strategic management of technology - I"	CTOs of Japanese companies participate more at board level and have greater influence on company strategy than their US or European counterparts. Also, there is a trend toward acquiring technology from outside of the firm requiring more alliances and joint ventures.
1995	Roberts	"Benchmarking the strategic management of technology - II"	Identified that European firms are less involved with their customers than US or Japanese firms. There is also a positive correlation between R&D managerial capability and company sales growth. The article discusses key stakeholders, market linkages, R&D performance measures, project performance, and strategic indicators of performance.
1996	Jonash	"Strategic technology leveraging: Making outsourcing work for you"	Hails a "significant expansion" in the role of the CTO because few R&D managers are prepared to take on the burden of new relationships, processes and results that are difficult to control. This article sets up the CTO as the interface across the boundaries of the firm and into the market for outsourced technologies e.g. JVs, alliances, consortia, acquisitions, licensing, and a range of active and passive suppliers.
1996	Gwynne	"The CTO as line manager"	The author suggests that there is a trend away from the leadership role of the CTO in companies in the US. His solution, based on six examples, is for CTOs to assume a dual role – that of both technology leader and line manager. Gwynne argues that the P&L responsibility helps with the credibility of the CTO with peers in other line functions. He claims that over 5 years the trend toward outsourcing has caused a significant reduction in the size and function of R&D laboratories.
1996	Thurlings and Debackere	"Trends in managing industrial innovation – First insights from a field survey"	The authors set out their findings about trends going forward one decade. They set out these views in terms of scope, organisation, control, strategy and people. For example, the creation of a true "learning organization", a "value chain focus" to the innovation process, technical experts with a wide appreciation for different knowledge areas etc. Four important issues are raised as being on the research agenda: technology role in corporate strategy, intra-company innovation processes, management of complex projects, and basic research.
1996	Larson	"Critical success factors for R&D leaders"	The R&D leader role has evolved. The author suggests that the R&D leader role has been changing over 40 years. In the 50s and 60s (for the Research Director) the focus was on getting good people, building "beautiful" laboratories away from HQ, and producing information that may or may not be useful. In the 70s and 80s the VP of R&D attempted to link R&D to the corporate strategy, but was not part of the board. In the 80s and 90s the CTO appeared and was part of the strategic planning team with leadership of the innovation process.

Date	Author(s)	Title	Focus
1997	Lefebvre, Mason and Lefebvre	"The Influence Prism in SMEs: The power of CEO's perceptions on technology policy and its organizational impacts"	The authors use a prism metaphor to explain the multiple ways that CEOs of SMEs interpret the (same) external environment. They suggest the need to understand the "cognitive schema" of CEOs and their effects on strategy and technology policy formulation. They then test a model that links the interpretation to company performance via the strategy and technology policy that the CEO advocates. This research also mentions the link between the concentration of technology knowledge ("technocratization") and innovativeness and on technology policy. Firms with a more "aggressive" technology policy are more likely to be innovative.
1998	Papadakis and Bourantas	"The Chief Executive Officer as corporate champion of technological innovation: An empirical investigation"	Points out that research on innovation has focused largely on organisational and environmental factors, and that to that point in time, very little research had been done on "strategic leadership". The authors test a model of the relationship between the characteristics of the CEO and the context on the one hand, and technological innovation on the other. They conclude that while CEO characteristics do in fact influence technological innovation, the influence of the structural and environmental context is higher.
1999	Smith, Lederman and Jonash	"Alcoa's technology change process"	References new CTO responsibilities resulting from introduction at Alcoa of Technology Management Review Boards (TMRB). These boards are set up via the Alcoa Technology Board. The Technology Review Board included the CEO, CTO and business unit presidents, while the TMRBs included marketing, manufacturing, business leaders, etc. and were set up around common technologies. The objective was to get technology closer to the business units. They were successful, but inwardly focused. The remit was changed to encourage global networking and targets to close specific innovation gaps. The article describes the overall shift as being from traditional central laboratory, to a global 'virtual' technology organisation. Whereas the CTO was the department head of the central laboratory, the new role is as global facilitator ensuring technology capabilities – across geographies and technologies, and across business unit and functional domains.
2000	Fisher	"Changing of the guard: CIOs, CTOs in flux" (See also: "Keys to delivering quality executives" (2000) which includes a CTO checklist.)	This article is focused on the IT and internet industry. It suggests the CIO (traditionally the technology leader) may be several layers away from the CEO, have a set salary, be focused on tactics and run a department which is seen as a cost centre. By contrast it hails the introduction of the CTO, who is a strategy oriented IT professional who sits on the executive team, has compensation tied to performance, considers long-term possibilities and considers their department to be a profit centre.

Date	Author(s)	Title	Focus
2001	Scott	"Strategic planning for high-tech product development"	The author considers 24 technology management problems in advanced-technology firms, and finds that in a ranking, the most dominant problem is strategic planning for technology products. Furthermore, several of the 24 problems are related to the strategic planning problem. The author defines the technology management role as including technology acquisition, product development and market launch. However, the point is made that the technology activity is sometimes separated into "functional smokestacks", such as R&D, engineering design, process design, manufacturing, ramp-up management, product introduction and technology "product family" activities. The author states that strategic planning was a major element of coordinating in the 50s, 60s and 70s, and that from the mid 60s this had started to decline. In the 80s the quality and cost focus caused a shift to manufacturing and operating efficiency. The tools used included JIT, Kan Ban, Quality Circles, TQM, down-sizing and re-engineering, etc. Parts of the strategic planning capacity were seen as unnecessary overhead and cut back. At the same time, R&D and product development was de-centralised to line functions to increase the focus directly on customer needs and to reduce costs. This forced greater emphasis on short-term goals with immediate benefit to the business unit at the expense of longer-term research and development and more radical products. Additionally, while the proliferation of technologies and products in the market demanded more coordination within the firm, the de-centralised configuration tended to be less coordinated.
2001	Roberts	"Benchmarking the global strategic management of technology"	This is an update of the 1992 survey (Roberts, 1995) and includes a review of changes between the two studies. Discusses the idea of "critical linkages roles" including CEO and CTO as central figures in strategic level technology management and lesser roles for marketing and finance. Statistically, 90% of Japanese companies had the CTO on the main board. In Europe (35%) and USA (8%) the number of CTOs has declined over the period between the studies. The author notes a negative (but not significant) correlation to integration. There is no evidence of a correlation between board CTO membership and the size of the firm. No evidence was found to support the (previously held) idea that US firms have suffered because of a lack of technically trained CEOs. Also, there is no significant correlation between CEO technical background and firm performance. More technical CEOs tend to be more involved in technology strategy, but do not show any bias in terms of the decision to appoint the CTO to either the board or the senior management committee. The study does show a strong correlation between a high R&D spend as a percentage of revenue, and sales growth, new product sales (as a proportion of overall sales) and profitability.
2001	Roberts and Liu	"Ally or acquire? How technology leaders decide"	The authors suggest the need for technology executives to understand where their products are in the technology life-cycle, in order to make informed decisions about whether to use alliances or acquisitions. The objective of these "external partnerships" is faster development. The change in emphasis from product to process innovation in the mature phase of the technology life-cycle is cited as one reason to collaborate given the relatively higher cost of process innovations. The authors point out that acquisitions may be better where exclusive rights to technologies and the development of core competencies are required. They cite various examples, including Cisco Systems' purchases of 50 companies for "roughly $9 billion" between 1993 and 2000.

Date	Author(s)	Title	Focus
2001	Kwak	"Technical skills / people skills, it's not either /or"	The research looks at the technology background of Chief Information Officers (CIO) showing the impact on successful tactics.
2002	Boer	"Financial management of R&D 2002"	The author suggests that technology executives traditionally used an annual budget as their main financial metric. The budget was determined using industry benchmarks. As a result technology executives focused "largely" on cost accounting and cost control.
2003	Smith	"The Chief Technology Officer: Strategic responsibilities and relationships"	Smith emphasises the need for a CTO with key relationships in order to ensure that technology-based activity is integrated with the corporate strategy. The author tables a comparison between the roles of the CTO, the Chief Scientist and the Chief Information officer.
2003	Delmar	"The rise of the CSO"	The author states that the CTO and the CIO only joined the CxO ranks in the 80s and 90s. Prior to that the only executives labelled "Chief" were the CEO, COO and CFO. The CSO is the "Chief Strategy Officer", and the author goes on to describe this role, and notes examples of the companies that have a CSO. These "C-level" executives are distinguished by the fact that they have a dedicated focus on specific activity domains within the business. In the case of the CTO, the role involves " … responsibility for development and exploitation of technologies." The CSO is a senior executive put in place to compensate for the lack of dedicated attention provided by line managers to strategy. There has been a cycle of centralisation and de-centralisation. In the 70s and 80s strategy was centralised and given to a specific executive to lead. Then in the 90s, having become too bureaucratic and formulaic, strategy was moved back into the line functions. However, the author points out that experience has shown that line managers typically focus on short-term financial / day-to-day responsibilities, and thus do not have the time to dedicate to strategy. Long-term and innovative thinking is thus sacrificed.
2004	Giordan and Kossovsky	"It's time to think differently about R&D assets and the CTO's role"	CTO role may evolve to be Chief Asset Officer with P&L responsibility and accountability for valuable R&D outputs. Intangible assets need to managed in a portfolio as a particular asset class and accounted for in a way that recognises the market value. The authors argue that depreciating the value of R&D to zero ignores the future value, but also causes anomalies in management behaviour.

Date	Author(s)	Title	Focus
2004	MacMillan and McGrath	"Nine new roles for technology managers"	The authors identify nine processes – three at each level (venture, champion and "heatshield"), related to "opportunity pipeline", "market entry" and "takeoff". They suggest that the technology manager needs to carry out these processes in order to achieve success in technology development. They claim that this " … new type of technology development management" seeks speed to profitable commercialisation. The focus is " … on the challenges facing the technology program manager who is responsible for the innovation program as a whole." The authors also state the need to consider competitors reactions and the entire supply chain i.e. to take account of resources within and outside of the boundaries of the firm. They conclude that to succeed, firms need technology programs focused on business-building rather than R&D. They suggest that this role should be called the "Technology Development Manager".
2004	Roberts	"Linkage, leverage and leadership drive successful technological innovation"	The author reviews the studies he conducted in 1992 and 1999 and finds that there are three primary management areas for successful technology management. He refers to these as "linkage", "leverage" and technological leadership". Linkage is the label used for the link between the corporate and the technology strategy. The author says that there are two people related weaknesses in this regard – i.e. that neither the CFO nor the senior marketing executive are sufficiently involved in the strategy endeavours. The other "linkage" weakness is the decline in "research" resource allocation. Between 1991 and 1997 the shrinkage was from 41% to 32% of corporate level R&D expenditure dedicated to research. The focus (i.e. nearly two thirds) has been on "nearer-term product, process and technical support…" The author suggests that it follows that companies with near-term R&D allocations will only produce incremental results. With regard to the second element, "leverage" the author is referring to access to resources that are outside of usual R&D. Two access points are discussed, access to global technology skills and capabilities, and amplifying the technology knowhow using acquisitions and other external sources. One third of US and European R&D expenditure is used on continents other than the home base (only 10% of Japanese companies have technology operations outside of Japan). The final element is "technology leadership" by which the author means leadership in competitive technologies (rather than people leadership). Companies that set out to lead performed better on various metrics – growth rate in new products, percentage of sales from new products and services, and overall profitability.
2005	Cannon	"What it means to be a CTO"	The author argues that CTOs should be stronger custodians of the value of R&D work. In particular to monitor the impacts of outsourcing. These include the potential loss of IP in countries with slack IP laws, and the loss of R&D skills (off-shore) in exchange for lower cost short-term gains. The author recommends that the CTO should be seeking reciprocal relationships rather than having the procurement department seek the lowest cost option. He suggests 10 questions to test whether the CTO is, "…giving away the store."

Date	Author(s)	Title	Focus
2007	Herstatt et al.	"The chief technology officer (CTO) in literature and practice – a review and results from field research in Japan"	The authors review CTO specific literature and divide the papers into empirical and conceptual articles. They consider the tasks, responsibilities, authority and relationships across corporate functions. They suggest that the CTO has received very little attention from management researchers. They point out that very little is written, and that there is a need for more research in this area. They also present the results of CTO interviews conducted in 10 large Japanese firms in the electrical engineering industry. Only 5 out of the 10 interviewed used the title CTO, 2 were on the board of directors, 2 were on the executive management committee, 4 were on both. The interviewees had between zero and 150 direct reports. The authors discovered that in Japanese culture it is possible to be influential without having direct reports. All interviewees had budgets and authority for corporate R&D, with 3 having additional control over divisional R&D and senior technology appointments. In 4 cases the interviewees shared in the divisional decisions on budget and appointments and in one case the interviewee had a veto if the R&D activity had high novelty. In one case the CTO is also explicitly looking after the intellectual property area, and in another worked closely with their corporate M&A department. The interviewees were all autonomous regarding allocation of internal resources and the selection and prioritisation of R&D and technology development projects (to the limit of the corporate R&D budget which is agreed with the CEO). However, CEOs decide on technology strategy development and the selection of outside investments.
2007	Scinta	"Industrial Research Institute's R&D trends forecast for 2007"	The author reports the results of a survey conducted with Industrial Research Institute members in the US with a view to indentifying trends in R&D. The analysis shows that member companies expected to see an increase in R&D spend, but that funding for directed basic research continues to decline. The report also highlights a "continuation" in the growth of open innovation.
2007	Medcof	"CTO power"	The author reviews the CTO literature and based on an "upper echelons" perspective, suggests how CTOs can move beyond the functional activities and embrace higher-level role elements. He points out that the "traditional cornerstones" of CTO power are technical expertise and position in the organisation. Whereas these cornerstones remain useful role elements, CTOs would benefit from 'business savvy', strong personal relationships and ownership (in some instances). The CEO's leadership style is also considered to be important to the role of the CTO.

Date	Author(s)	Title	Focus
2007	Smith	"What CTOs do"	The author suggests that little research has been done on the responsibilities of the CTO, on methods of evaluating CTO performance, and on the skills that the CTO should bring to the role. Having conducted a literature search using, "Chief Technology Officer" and "CTO", he discovered "fewer than 20 published articles" in the 10 years prior to the search. It appears that, " … CTOs are not publishing their activities and few academics are researching the position." (2007, p.18) He states that this is in part because the CTO title and role is relatively new and emerged in the 1980s from the role of the R&D laboratory director. He finds that there are four drivers for the creation of the CTO role, i.e. that it is driven by unique business needs, by a process of evolution in the company, to mimic other companies, or as the result of a misunderstanding about the reasons for the role. The core purpose of having the CTO role is to leverage technology in products and service delivery. The author states that the position of the CTO fits into five possible patterns: genius (examples are Steve Wosniak of Apple and Sergey Brin of Google – the genius CTO is important to emerging companies), administrator (understand technical and commercial aspects of key relationships), director (focus on "leveraging" research and laboratory outputs into profitable products), executive (Large companies like GE Medical, Alcoa, IBM, Corning and ChevronTexaco – all noted for using CTO to guide strategic decisions and the innovation process), and advocate (often in retail and service businesses, this CTO works to understand / advocate for the customer). He discusses the need to match the pattern of CTO role with the needs of different types of companies. Roger Smith also hints at the need for a "Chief Innovation Officer" with a remit that extends beyond the technology field.
2008	Medcof	"The organizational influence of the Chief Technology Officer"	The author hypothesises a correlation between CTO influence on organisational strategy and the degree to which the organisation relies on technology. Also, where technology is more important, influence is more likely to be gained through technical expertise. However, technical expertise and position in the business is not enough in contexts of high ambiguity and uncertainty. Therefore it is suggested that the CTO needs to build relationships with key stakeholders such at the CEO, a strong network inside and outside of the firm, have expertise in non-technology areas of the business, and develop an ownership position in the business. The author states that the literature limits the role of the CTO to managing the technology function, advocating for technology in the company and that technical expertise and organisational position are the most important bases of CTO influence.

Appendix 4. Hart on research design (2001, p.86, Table 4.2)

What is reality?	*Ontological issues* concerned with what we believe to exist and able to be investigated. For example, what is the subject-matter for psychology? Is reality singular and objective, existing apart from me and my perceptions and cultural biases? Or is reality shaped by my prior understanding and assumptions?
What procedures can be used to establish what can be accepted as real?	*Epistemological issues* concerned with how we can know anything. For example, is my knowledge wholly gained through senses and is therefore objectively real or is my knowledge a matter of how I perceive the world? Can I include intuition, personal experience or only the data to make claims?
What is the process of research that can ensure valid knowledge?	*Methodological issues* concerned with how we can validate what we claim to be knowledge. For example, how can we have a logic of inquiry that gives us assurance in our knowledge? Should we use a deductive or inductive process; aim for generalization and explanation or context-based description aimed at an emerging design, categories and theories? Are we interested in prediction, explanation or understanding?
What is the role of values and ethics?	*Axiological issues* concerned with the personal values, morality and ethics of the researcher. For example, whose side should a researcher be on, if any, the underdog or elite? Should I aim to ignore the moral issues of the subject-matter and my own feeling or use these as part of my research?
What are reliable techniques for collecting data about claims?	*Data-collection issues* concerned with which techniques are the most reliable and which kinds of data the more accurate. For example, is the survey questionnaire better than the observational case study? Shall I use quantitative data rather than qualitative because people regard it as more objective? Or is qualitative evidence better because it will show that all data is dependent on interpretation for its meaning?
What is the language of research?	*Rhetorical issues* concerned with how to talk about and write up research. For example, is writing in the third person more objective than the first person? Should I be formal, precise with definitions and aim to quantify or use informal language that is easier to understand and show how understanding evolved?

Appendix 5. Interview protocol (Version 3)

Biographical Information

Name & Organisation? _____

Official title? _____

How long have you been employed in this position? _____

How long have you worked for this company? _____

How long were you in a management position? _____

How much of your career was spent "abroad" (years)? _____

What post school qualifications do you hold? _____

What post-graduate qualifications do you hold? _____

Main interview questions

"What is the purpose of the CTO role?" → *use interview map!*

"What are the barriers (Q2a) **and enablers** (Q2b) **to the fulfilment of the purpose you have described?"** → *use interview map!*

Note for the interviewer: It is important to be specific about the wording of this question, because the barriers and enablers need to be discussed in the context of the declared purpose. This purpose may vary between respondents, and this is an important aspect of the analysis.

"Please rank the barriers (Q3a) **and enablers** (Q3b)**."** → *use interview map!*

Note: This question will allow the interviewee to provide a relative perspective of the importance of the barriers and enablers without thinking about why. Our intention is to provide the basis on which to elicit the impacts of the barriers and enablers and to test whether these are discussed from a personal or an organisational, or indeed a team, point of view.

"Please describe the basis on which you ranked the barriers and enablers."

Note: This is a basis on which to understand the relative impact and importance of the various barriers and enablers. Map this on the A3 template "Barriers and enablers prioritised by…"

"Can you relate stories of specific examples of the barriers (Q5a) and enablers (Q5b) you have identified?"

→ *use interview map!*

Note: This is very important as a way to validate the responses and to provide link the interviewee with the reality of the circumstances being mapped. It is also likely to cause further detail to emerge, up to a point, and then detail will decline.

"What are the *causes* of the barriers (Q6a) and enablers (Q6b)?" → *use interview map!*

"What are counter (Q7a) and supporting (Q7b) measures to these causes of the barriers and enablers?" → *use interview map!*

"Having mapped the role of the CTO, what do you think are the implications?"

Note: Reponses to this question should be captured. The implications are a crucial part of the analysis. Like the Self Q technique, this allows the respondent to complete the personal construct without the bias of the interviewer. Use an A3 size mapping template "Implications…?".

"Do you know of anyone else in the CTO role who would allow us to interview them?"

Note: Ask this question to gain additional contacts, and to avoid having to cold-call interviewees.

"Thank you for your time." → Ask for CV and job description!

Appendix 6. Interview protocol (Version 6)

Biographical Information

Name & Organisation? _____

Official title? _____

Main interview questions

"What is the core purpose of your role?" → use interview map!

"What are the *barriers* (Q2a) and *enablers* (Q2b) to the fulfilment of the purpose you have described?" → *use interview map!*

Note **for the interviewer**: It is important to be specific about the wording of this question, because the barriers and enablers need to be discussed in the context of the declared purpose. This purpose will vary between respondents, and this may be an important aspect of the analysis.

"What are the *reasons* that XXXX is a barrier (Q6a) or enabler (Q6b)?" → *use interview map!*

"Can you give specific *examples* of the barriers (Q5a) and enablers (Q5b) identified?"
→ *use interview map!*

Note: Only use this question if the interviewee is having difficulty describing the *reasons* for a particular barrier or enabler.

"What *actions* do you currently take to counter (Q7a) or support (Q7b) the *reasons* for the barriers and enablers?" → *use interview map!*

"Having mapped your role, what do you think the *implications* are / will be?"

Note: Reponses to this question must be mapped. The implications allow the respondent to complete the personal construct without the bias of the interviewer.

"Do you know of anyone else in this role who would allow us to interview them?"
Note: Ask this question to gain additional contacts, and to avoid having to cold-call interviewees.

"Thank you for your time." → Request a telephonic follow-up to verify electronic version once captured.

Appendix 7. Project briefing note (sent to interviewees)

The role of the Chief Technology Officer (CTO or equivalent):

Current obstacles and enablers, and future implications for practice

Background:

In early 2006 at an EITIM forum, a group of industrialists held discussions about the role of the senior technology executive. Initial perspectives on ***the purpose, barriers and enablers*** were gathered. Whilst there was consensus that the role is important, views were sufficiently divergent to justify further work on this relatively under-researched aspect of technology leadership.

Objective and focus of the research:

The Chief Technology Officer (CTO) seems to be a largely US phenomenon. European organisations use the CTO designation, but also various alternative "labels" for the most senior technology executive (for example Technical or Technology Director, Chief Scientist, Director of Innovation, Chief Engineer and Vice President R&D to name a few). The objective of this research is to shed some light on the purpose of the role, the enablers and barriers that executives encounter and the implications for practice.

Research methodology:

Initially, a small group of executives will be interviewed in depth. Once this phase is concluded, a pan-European group of researchers have agreed to engage in a broader project using the research design that has evolved based on practitioner insights. Although a survey may be conducted and analysed in following phases, the initial research will use cognitive (causal) mapping interviews.

Required input from Technology Executives:

Each executive is asked to allow for a *single 2 hour interview*. A limited number of follow-up telephone conversations may be appropriate where clarification is necessary. Additional interviews with peers, superiors, subordinates and / or other stakeholders may be required for case study participants.

Advantages for participants:

Pilot interviews on this topic have been well received by practitioners. The process being used for data capture and initial analysis is tried and tested, and there is evidence that interviewees gain significant insights into their own practices and decision making. A recent interviewee indicated that he found the process extremely positive, challenging and thought provoking. The interviews themselves are thus considered to be developmental for the interviewees. The overall outcome is focused on surfacing implications for practice – potentially including policy, process, development interventions etc. This latter aspect is intended to benefit both individuals and the organisations they work in.

Background of the researchers:

Chris van der Hoven – Lecturer in Innovation Management at Cranfield School of Management. He is facilitating this research project as part of his PhD research at Cambridge University;

David Probert (supervisor) – Head of the Centre for Technology Management and Reader in Technology Management at Cambridge University;

Robert Phaal (advisor) – Senior Researcher based at Cambridge Centre for Technology Management.

EITIM is a collaboration of leading European universities, promoting teaching, research, and the application of technology management in Europe. The collaboration is intended to enhance the innovative and competitive performance of European technology based enterprises.

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Appendix 8. EITIM delegate survey - France 2006

Purpose

Governance of technology – i.e. how to channel money into innovation
Various people have a role in the MOT & someone needs to link technology and resource
Leading the technology development
…or identify and put in place the technology platforms
Select technology alliances
Champion the technology opportunity
Awareness of the technology future
Keep ahead of competition
Needs to be able to see technologies and make them available
Link divisional initiatives to the board
Moderate all strategic alliances
Needs to know about benchmarking of technology
A communicator who promotes technology culture
Link to universities
Technology intelligence (run the start-up watch-list)

Barriers

Too much of a bottom line orientation
Lack of decision power
Scattered view of technology
Exclusion from the board
Short-termism from board
CEO ambivalence
Lack of resources or not easily accessible
Failed manager
No CEO support

Enablers

Put processes in place (e.g. roadmapping etc.)
Balance between processes and people dynamics
Need to manage the strategy of technology and the corporate strategy
Clear top level position
Needs to have budget to promote ideas
Power to initiate
Consensus minded

Must have profile, +ve business experience in the company (credibility)

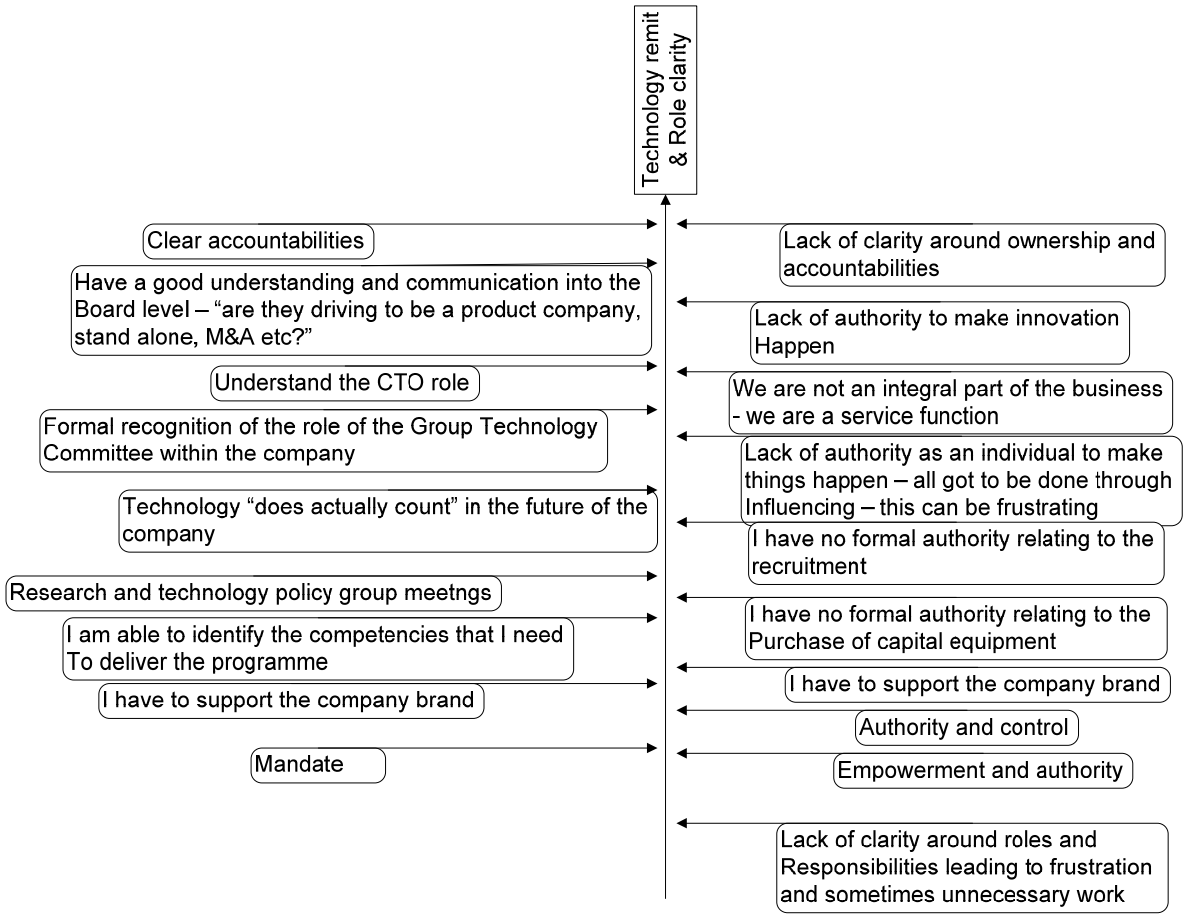
Implications

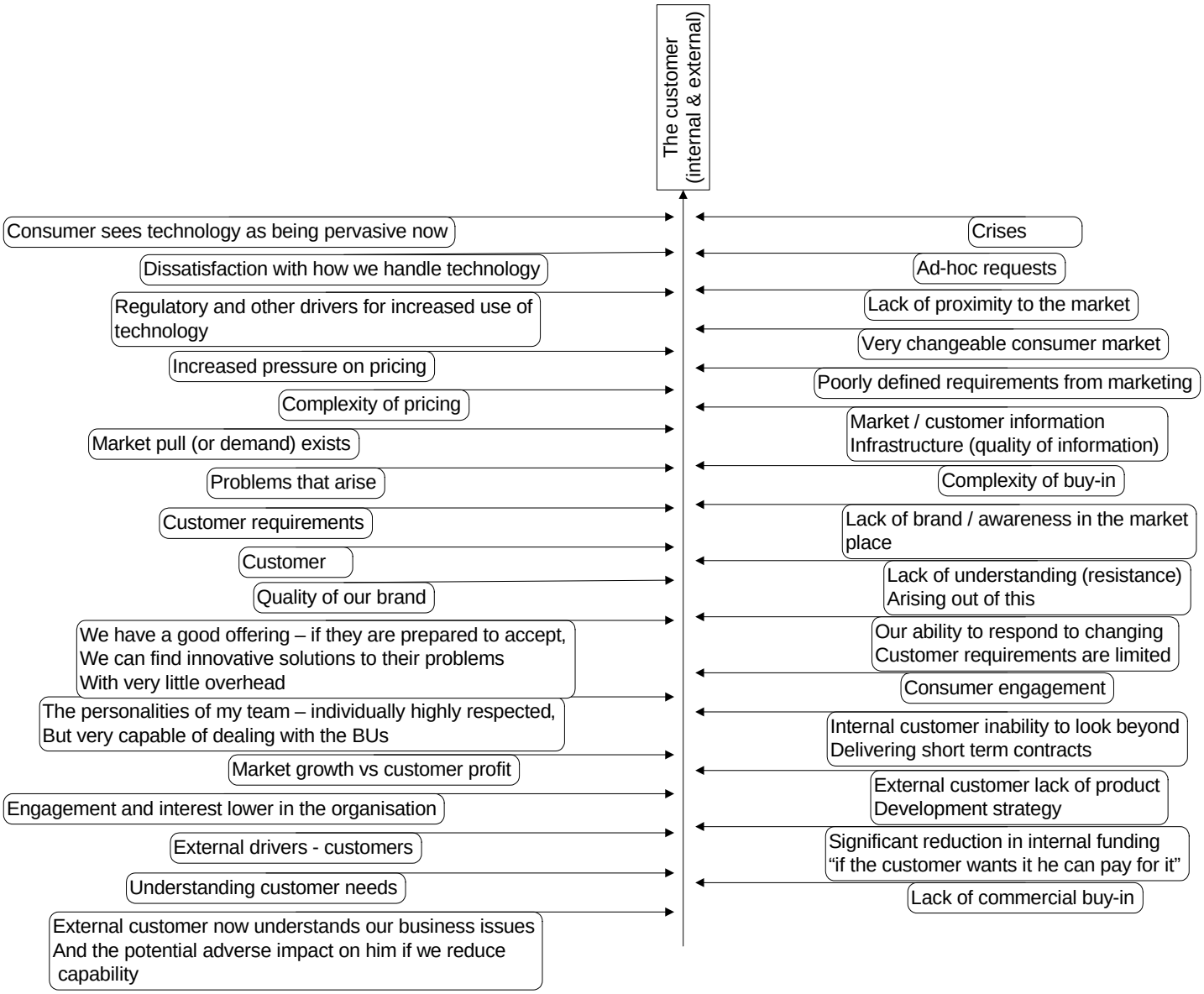
Head of R&D has resources vs … (i.e. there are polarised views of the role of the CTO)
The profile of the person: visionary, leader, social skills (connected), credibility (technical or not…)
Positioning – executive member
If in charge of R&D,most of his time will be taken managing R&D
Need to be connected to the business
Technology management – foresight – selection
Monitor technology alliances
CEO support is central

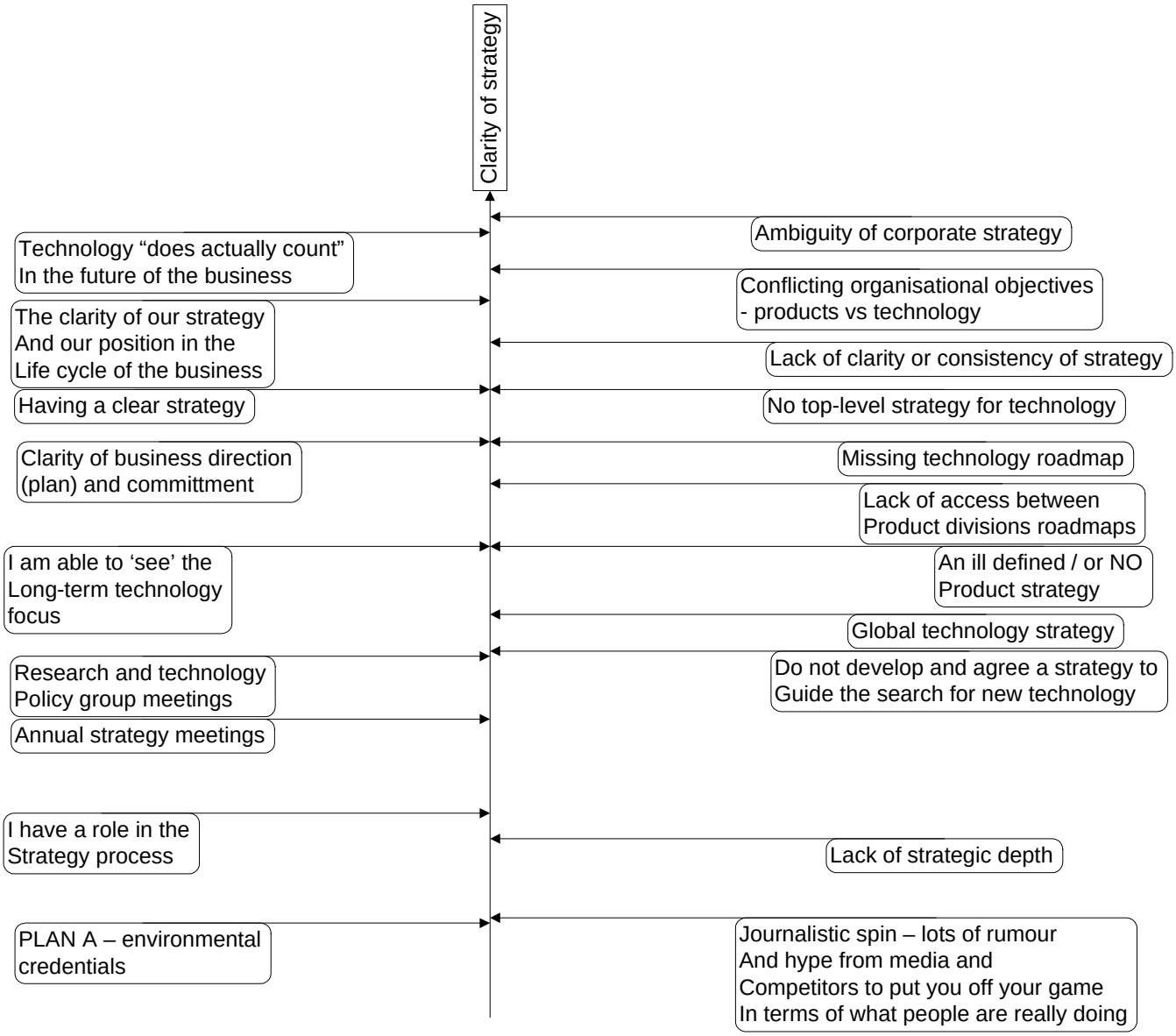
Appendix 9. Reconstituted maps

This appendix includes samples of three of the generic role maps that are based on the barriers and enablers that clustered around:

- "Technology remit and role clarity"
- "The customer (Internal & External)", and
- "Clarity of strategy".




The customer (internal & external)
Consumer sees technology as being pervasive now
Dissatisfaction with how we handle technology
Regulatory and other drivers for increased use of technology
Increased pressure on pricing
Complexity of pricing
Market pull (or demand) exists
Problems that arise
Customer requirements
Customer
Quality of our brand
We have a good offering – if they are prepared to accept, We can find innovative solutions to their problems With very little overhead
The personalities of my team – individually highly respected, But very capable of dealing with the BUs
Market growth vs customer profit
Engagement and interest lower in the organisation
External drivers - customers
Understanding customer needs
External customer now understands our business issues And the potential adverse impact on him if we reduce capability
Crises
Ad-hoc requests
Lack of proximity to the market
Very changeable consumer market
Poorly defined requirements from marketing
Market / customer information Infrastructure (quality of information)
Complexity of buy-in
Lack of brand / awareness in the market place
Lack of understanding (resistance) Arising out of this
Our ability to respond to changing Customer requirements are limited
Consumer engagement
Internal customer inability to look beyond Delivering short term contracts
External customer lack of product Development strategy
Significant reduction in internal funding “if the customer wants it he can pay for it”
Lack of commercial buy-in


Clarity of strategy
Technology “does actually count”
In the future of the business
The clarity of our strategy
And our position in the
Life cycle of the business
Having a clear strategy
Clarity of business direction
(plan) and committment
I am able to ‘see’ the
Long-term technology
focus
Research and technology
Policy group meetings
Annual strategy meetings
I have a role in the
Strategy process
PLAN A – environmental
credentials
Ambiguity of corporate strategy
Conflicting organisational objectives
- products vs technology
Lack of clarity or consistency of strategy
No top-level strategy for technology
Missing technology roadmap
Lack of access between
Product divisions roadmaps
An ill defined / or NO
Product strategy
Global technology strategy
Do not develop and agree a strategy to
Guide the search for new technology
Lack of strategic depth
Journalistic spin – lots of rumour
And hype from media and
Competitors to put you off your game
In terms of what people are really doing

Appendix 10. Case listing with associated UK or US SI Codes

Case No.	Primary Standard Industry Code	All Standard Industry Codes
1	US-6712	US-6712, 6719, 6722
2	UK-7222	UK-7222
3	UK-3210	UK-3210, 7310
4	UK-3162	UK-3162
5	UK-2442	UK-2441, 2442, 7415
6	US-3600	US-3600
7	UK-3530	UK-2960, 3320, 3511, 3530
8	UK-7487	UK-6340, 7487
9a.	UK-2872	UK-2222, 2522, 2615, 2872, 7415
9b.	UK-2872	UK-2222, 2522, 2615, 2872, 7415
10	UK-5212	UK-5212, 5242, 5243, 7412
10a.	UK-5212	UK-5212, 5242, 5243, 7412
10b.	UK-5212	UK-5212, 5242, 5243, 7412
10c.	UK-5212	UK-5212, 5242, 5243, 7412
10d.	UK-5212	UK-5212, 5242, 5243, 7412
11	UK-2121	UK-2121
12	UK-2956	UK-2225, 2924, 2956, 5190, 7310
13	UK-3530	UK-2960, 3320, 3511, 3530
14	UK-7415	UK-7415
15	UK-1533	UK-1533
16	UK-1110	UK-1110, 2320, 5151, 7415
17	US-3600	US-3600
18	US-4899	US-4899
21	UK-6420	UK-6420, 7487
22	UK-3430	UK-3410, 3430, 3663, 5186
23	UK-3410	UK-3410, 3552, 3714, 3728, 6159
24	UK-2442	UK-2441, 2442, 2452, 2466, 3310
25	US-3711	US-3711
26	US-3711	US-3711